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SURFICIAL GEOLOGIC MAP OF PART OF THE PORTLAND AND STROUDSBURG QUADRANGLES,
WARREN COUNTY, NEW JERSEY AND MONROE AND NORTHAMPTON COUNTIES, PENNSYLVANIA
OPEN-FILE MAP OFM 114
PLATE 1 OF 2

INTRODUCTION

The Portland and Stroudsburg quadrangles are located in the glaciated part of the Valley and Ridge physiographic province in Warren County, New Jersey and Monroe and Northampton Counties, Pennsylvania (fig. 1). Kittatinny Mountain forms a large southwestward-trending ridge that separates Kittatinny Valley to the south from Pennsylvania's Pocono Mountains to the north. The Delaware River flows southward, following a slightly meandering course through the Delaware Water Gap and across the Kittatinny Valley (fig. 1). It is joined by the Paulins Kill near Columbia, New Jersey, and Jacoby Creek, near Portland, Pennsylvania. The quadrangles are largely rural, a mosaic of patchwork woodlands and cultivated land in the valleys, and large tracts of forested land on Kittatinny Mountain. The highest point is on Kittatinny Mountain at Mount Tammany, elevation 1,549 feet (472 m) above sea level. The lowest point lies on the Delaware River, elevation about 250 feet (76 m) above sea level at the southern most point as it leaves the Portland quadrangle.

Surficial materials consist of till and meltwater sediment deposited during the late Wisconsinan glaciation, and postglacial deposits of alluvium, colluvium, talus, lake sediment, humus and peat. These materials may be as much as 200 feet (61 m) thick, overlie bedrock, and form the parent material on which soils form. Till typically overlies bedrock. In many places till is interspersed with numerous glacially-eroded bedrock outcrops. Thicker till forms drumlins, ground moraine, recessional moraine, and aprons on north-facing slopes. Meltwater deposits, chiefly consisting of ice-contact deltas, were laid down at and beyond the glacier's margin in the Delaware and Paulins Kill valleys. The heads (northernmost extent) of these outwash deposits delineate retreat positions of the Kittatinny Valley ice lobe. Postglacial deposits are late Pleistocene and Holocene age. They are found throughout the mapping area with the thickest deposits, consisting of alluvium, in the Delaware Valley. Surficial deposits in the Pennsylvania parts of the map area are shown on Epstein (1969) and Ridge and Braun (1997).

PREVIOUS INVESTIGATIONS

The surficial geology of Warren County, New Jersey was first described by Cook (1877, 1878, 1880) including detailed observations on the terminal moraine, recessional moraines, distribution and kinds of drift, and evidence of glacial lakes. A voluminous report by Salisbury (1902) detailed the glacial geology of New Jersey, region by region. 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." Cotter and others (1986) indicated the youngest glacial deposits in Pennsylvania and New Jersey are late Wisconsinan age, and are correlative with the Olean drift in Pennsylvania.

Epstein (1969), Ridge (1983), and Witte (1988, 1997a, 2001) detailed the late Wisconsinan deglaciation for northwestern New Jersey and a small part of northeastern Pennsylvania. In their interpretations, deglaciation was characterized by the systematic northeastward retreat of the Kittatinny Valley and Minisink Valley ice lobes (fig. 2). This interpretation was based on the distribution of ice-marginal meltwater deposits (morphosequences) and moraines, and correlative relationships between elevations of delta topset-foreset contacts, former glacial-lake-water plains, and lake spillways. The identification of ice-retreat positions by mapping morphosequences was first introduced in New England by Jahns (1941) and later refined by Koteff and Pessl (1981).

PHYSIOGRAPHY AND BEDROCK GEOLOGY

The Portland and Stroudsburg quadrangles have a pronounced northeast to southwestward topographic grain, the result of weathering folded and thrust-faulted sedimentary strata that vary in their resistance to erosion (fig. 3). Weathering and erosion over millions of years has resulted in two distinct geologic landscapes.

The first is Kittatinny Valley, which is underlain by dolomite of Cambrian and Ordovician age and slate and graywacke of Ordovician age (fig. 3). In areas underlain by carbonate bedrock, relief is as much as 200 feet (61 m). Rock outcrops are very abundant, forming in many places irregular, rocky pinnacles of moderate to steep slope. Elsewhere, the more erosion resistant beds that contain chert and minor quartzite form long, narrow, strike-parallel ridges. The lower parts of valley floors are covered by glaciodeltaic outwash, meltwater terrace deposits, and alluvium. Higher areas in Kittatinny Valley are underlain by slate and graywacke (fig. 3). These lie as much as 500 feet (152 m) above the valley's floor and have been deeply incised by the Delaware River's tributaries. Streams typically parallel the strike of the bedrock; although, cross-strike drainage is common in areas of extensive cross-jointing. Rolling hills of moderate to steep slopes and strike parallel ridges streamlined by glacial erosion make up the rural landscape. Bedrock in many places northwest of Paulins Kill is buried beneath thick till.

The second area, Kittatinny Mountain, rises as much as 1,200 feet (366 m) above Paulins Kill valley, and it is underlain by Silurian age quartz-pebble conglomerate, quartzite, red shale, and red sandstone (fig. 3). The quartz-rich rocks are very resistant to weathering and erosion and underlie the highest areas on the mountain. The red shale and sandstone typically underlie the mountain's lower ridges. The mountain's topography in most places is rugged, its southeast face forming a nearly vertical 400 foot (122 m) high escarpment. Rock outcrops are very abundant and most exhibit extensive glacial scour and plucking.

PREGLACIAL DRAINAGE

The primary drainage routes in the map area were probably well established before the Pleistocene. The Delaware Water Gap (fig. 4) and the cross-strike drainage of the Delaware River are relict features that may have formed as far back as the Neogene (Witte, 1997b). The gap and the southeast course of the river formed as a result of headward erosion and stream capture across the resistant belt of quartz-pebble conglomerate and quartzite. The cross-strike drainage is interpreted to be controlled by high-angle cross joints in the Martinsburg Formation and a flexural offset in folding through the gap (Epstein, 1966). Earlier interpretations also considered that gap location and drainage geometry may be antecedent, related to former bedrock or coastal plain cover (Johnson, 1931).

The Delaware River, through headward erosion and stream capture, has enlarged its drainage area by extending its tributaries upvalley along the strike of less resistant rock. In response to the overall lowering of sea level during the Pleistocene, drainage has further evolved by incision, which along the larger tributaries of the Delaware River has resulted in the formation of a much lower, narrower, modern river valley. Extensive headward erosion by first and second-order streams has also resulted in the dissection of the older valley floor and the surrounding uplands. The location of Illinoian glaciofluvial deposits in the Delaware Valley downstream from the late Wisconsinan terminal moraine (Ridge and others, 1990; Witte and Stanford, 1995; Stone and others, 2002) shows that the river valleys in the study area had been lowered or nearly lowered to their present levels by the time of the Illinoian glaciation (~150 ka, ka= thousand years).

GLACIAL EROSION

Erosional features of the late Wisconsinan glaciation include polished, striated, and plucked bedrock outcrops, and streamlined bedrock forms called roches moutonnées. The many unweathered and lightly weathered bedrock outcrops also show that most of the preglacial soil and weathered rock have been removed by glacial erosion. Also, based on well records in Delaware River valley (plate 2), it is estimated that as much as 150 feet (46 m) of valley-bottom glacial scour occurred during the Illinoian and late Wisconsinan glaciations.

SURFICIAL DEPOSITS

Glacial Deposits

Till

Till typically covers the bedrock surface and it is widely distributed throughout the quadrangles. It is generally less than 20 feet (6 m) thick, and its surface expression is mostly controlled by the topography of the underlying bedrock. Extending through this cover are numerous bedrock outcrops that show evidence of glacial erosion. Very thick till forms drumlins, aprons on north-facing slopes, recessional moraine, and ground moraine. It also fills narrow preglacial valleys, especially those oriented transverse to glacier flow.

Till is a compact sandy silt to silty sand containing as much as 20 percent pebbles, cobbles, and boulders. Till clasts are subangular to subrounded, faceted, and striated. In lower compact till their long axes are generally parallel to the regional direction of glacier flow. Presumably this material is lodgement till. Overlying this lower compact till is a thin, discontinuous, noncompact, poorly sorted silty sand to sand containing as much as 35 percent pebbles, cobbles and boulders, and interlayered with lenses of sorted sand, gravel, and silt. Overall, clasts are more angular, and clast fabrics lack a preferred orientation or have a weak orientation that is oblique to the regional direction of glacier flow. This material appears to be ablation till and flow till, but it has not been mapped separately due to its scant distribution and poor exposure. Also, cryoturbation and bioturbation have altered the upper few feet of till, making it less compact, reorienting stone fabrics, and sorting clasts.

Till has been divided lithologically into two types. They are informally named here Kittatinny Valley till (Qwtk) and Kittatinny Mountain till (Qwtq). Their lithology was largely dependent on the direction of ice flow over different suites of local source rocks. Qwtk is chiefly derived from slate, graywacke, dolostone, and limestone that underlie Kittatinny Valley and is only found in the valley. Qwtq is chiefly derived from quartzite, quartz-pebble conglomerate, and red sandstone and shale that underlie Kittatinny Mountain. It lies near the base of Kittatinny Mountain, especially in the vicinity of the Delaware Water Gap. Contacts between the tills are highly gradational and were interpreted from field observations, and boulder and pebble counts (Ridge,1983).

There are a few drumlins in the Portland quadrangle; their long axes parallel and crosscut the valley's southwesterly topographic grain, based on nearby bedrock outcrops, and wells (table 1 (pl. 2)).

One moraine (Qwrm) was mapped. It lies at the base of Kittatinny Mountain about one mile northwest of Mount Pleasant (pl. 1). Here knob and swale topography define a ridge about one mile in length. Based on its position along the valley wall and valley-parallel trend, it is probably a recessional moraine laid down along the lateral margin of the Kittatinny Valley lobe. Qwrm consists of unstratified to poorly stratified sand, gravel, boulders, and silt deposited at the margin of the Kittantiny Valley sublobe and is as much as 50 feet (15 m) thick.

Deposits of Glacial Meltwater Streams

Sediment carried by glacial meltwater streams was chiefly laid down at and beyond the glacier margin (fig. 5) in ice-contact deltas (Qwdv). Smaller quantities of sediment were deposited in valley-train deposits (Qwfv), meltwater-terrace deposits (Qwft), in a few kames (Qwk), and one small esker (Qwe). Most of this material was transported by meltwater through glacial tunnels to the glacier margin, and by meltwater streams draining deglaciated upland areas adjacent to the valley (Witte, 1988; Witte and Evenson, 1989). Sources of outwash sediment include till beneath the glacier and debris in its basal dirty-ice zone, and till and reworked outwash in upland areas. Debris carried to the margin of the ice sheet by direct glacial action was minor.

Glaciofluvial sediments were laid down by meltwater streams in valley train (Qwfv), outwash-fan (Qwf), and meltwater terrace deposits (Qwft), and delta topset beds (Qwdv). These sediments include cobbles, pebbles, sand, and minor boulders laid down in stream channels; and sand, silt, and pebbly sand in minor overbank deposits. Sediment laid down near the glacier's margin in valley train deposits and delta topset beds typically includes thick, planar-bedded, and imbricated coarse gravel and sand, and minor channel-fill deposits that consist largely of cross-stratified pebbly sand and sand. Downstream, the overall grain size typically decreases, sand is more abundant, and cross-bedded and graded beds are more common.

Glaciolacustrine sediments were laid down by meltwater streams in ice-contact and valley outwash deltas (Qwdv), and lake bottom deposits (Qwlb). Deltas consist of topset beds of coarse gravel and sand overlying foreset beds of fine gravel and sand. Near the meltwater feeder stream, foreset beds are generally steeply inclined (25° to 35°) and consist of thick to thin, rhythmically bedded fine gravel and sand. Farther out in the lake basin these sediments grade into less steeply dipping foreset beds of graded, ripple cross laminated, parallel laminated sand and fine gravel with minor silt drapes. These in turn grade into gently dipping bottomset beds of ripple cross laminated and parallel laminated sand and silt with clay drapes.

Typically, deltas consist of many individual lobes that prograde outward from the delta front across the lake floor, thinning and widening with distance (Gustavson, and others, 1975). Because lake basins in the Paulins Kill valley were narrow and small, they were filled with glaciodeltaic sediment that in places was covered by a thick wedge of glaciofluvial sand and gravel that extended from valley wall to valley wall.

Lake-bottom deposits include 1) glacial varves and rhythmites and 2) subaqueous-flow deposits. Glacial varves are stacked annual layers consisting of a laminated silty lower summer layer that is overlain by a thinner winter layer of clay. Most of these materials were deposited from suspension, although the summer layer may contain sand and silt carried by density currents. Each summer and winter couplet represents one year. Rhythmites have similar layering as varves, but the layer couplets are subannual; their distribution and layering related to changes in sediment transport along the delta front rather than seasonal changes that affect meltwater supply.

Kames (Qwk) and eskers (Qwe) consist of varied mixtures of stratified sand, gravel, and silt interlayered with flowtill. Kames, in most places, lie above local base-level controls. Knob and kettle topography is typical and a few deposits form isolated hills. These deposits were either laid down in an ice crevasse, ice-walled sink, or moulin on or along stagnant ice. In other places they may include very small, extensively collapsed ice-contact deltas. Eskers are short, narrow, slightly sinuous collapsed ridges that were probably deposited in glacial meltwater tunnels or large ice crevasses at the glacier's margin.

Postglacial Deposits

Slope Sediment

Thin deposits of undifferentiated colluvium (Qcu) lie in the upper parts of first-order drainage basins and along the base of a few slopes. This material is a mixture of weathered slate that was chiefly derived from frost weathering and weathered till. Undifferentiated alluvium and colluvium assemblage (Qcal) consists of mixtures of alluvium and colluvium that have accumulated in narrow valleys in the upper parts of first-order drainage basins. These deposits also include the toe slopes of small colluvial aprons. Talus (Qta) forms thick aprons of rock rubble that lie on the lower part of Kittatinny Mountain's southeast-facing escarpment and in the Delaware Water Gap. It consists of quartz-pebble conglomerate and quartzite joint-block boulders that have been dislodged from outcrops by frost weathering. These boulders, some as large as 40 feet (12 m) in diameter, accumulate on the mountain's lower slope. They further move very slowly downslope by creep. Thin deposits of shale-chip colluvium (Qcs) form aprons at the base of some cliffs in the Delaware Valley where the local bedrock is slate. Similar to talus, this material is initially broken up and dislodged by frost heave. However, water may play a greater role transporting the material downslope than the coarse talus along Kittatinny Mountain.

Organic Deposits

Swamp and bog deposits (Qs) are common. They formed in glacially scoured bedrock basins, kettles in outwash and moraine, in glacial lakes that persisted into the Holocene, in abandoned stream channels on alluvial plains, and in poorly drained areas in ground moraine. These deposits typically consist of peat, underlain by silty peat, muck and minor mineral detritus, which in turn are underlain by organic-rich clay and silt. In some places the basal section consists of postglacial deposits of laminated silt and clay. Peat is largely partially decayed organic material that originated in shallow bodies of water and accumulated on the floor of the watery basin. Muck is a mass of finely-divided organic matter, having no resemblance to the original plant remains, and in addition contains silt and clay washed in from adjacent upland soils (Waksman, 1942). In many ponds the peat is not only interbedded with marl (mixture of clay, silt and calcareous mud), but may include shell (snail) horizons. In places underlain by carbonate rock, thick deposits of calcareous marl (Waksman and others, 1943) are commonly found beneath and interbedded with organic materials.

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

Alluvium (Qal) is chiefly late Holocene in age and includes both channel (sand and gravel), and overbank (sand and silt) deposits laid down by streams. It forms narrow, sheet like deposits on the floors of modern valleys. Channels, channel scarps, and levees are commonly preserved on flood plains along the Delaware River. Stream terrace deposits (Qst, Qst3, Qst2, and Qst2a) include both channel and flood plain sediment. They lie 5 to 20 feet (2 to 6 m) above the modern flood plain and below the level of meltwater terrace deposits. Alluvial fan deposits (Qaf) are scattered throughout the quadrangle. They form fan shaped deposits that lie at the mouths of gullies and ravines, where small streams enter larger valleys. Sediment is highly variable and is derived chiefly from local surficial sediment, eroded by and laid down by streams draining adjacent uplands. Many alluvial fans are deeply entrenched by modern streams. This suggests that most are probably of late Wisconsinan age when climate, sediment supply, and amount and type of slope vegetation were more favorable for their deposition.

GLACIAL HISTORY

Glacial Advance and Changes in Direction of Regional Ice Flow

The details of the late Wisconsinan advance of the Laurentide ice sheet into the lower part of Kittatinny Valley are unclear because glacial drift and striae that record this history have been eroded or were buried by younger late Wisconsinan deposits. If the ice sheet advanced in lobes as suggested by the lobate course of its terminal moraine (fig. 2), then its initial advance was marked by lobes of ice moving down Kittatinny and Minisink Valleys. A smaller sublobe may have advanced within the inner Delaware valley, as indicated by southeasterly striations near Columbia that are oriented nearly at 90 degrees to the southwesterly striations at slightly higher elevation in Kittatinny Valley. Later as ice thickened, flow turned southward overriding the area's topography. This southward flow is evidenced by striae atop Kittatinny Mountain and the occurrence of till with reddish matrix (for example, in well 27), and of numerous Shawangunk and Bloomsburg erratics, south of the mountain (Ridge, 1983). Striae, drumlins, and erratics also show that ice flowed southward across Kittatinny Mountain into the upper part of Kittatinny Valley (Witte, 1997a). Southwestward flow occurred only along Kittatinny Mountain near the glacier's margin where ice was thinner, its flow constrained by the southwesterly topographic grain of Kittatinny Valley. During deglaciation, thinning ice near the glacier's margin resulted in more extensive southwestward ice flow in Kittatinny Valley with pronounced lobation at the glacier's margin (Witte, 1997a).

Style and Timing of Deglaciation

The late Wisconsinan recessional history of the Laurentide ice sheet is well documented for northwestern New Jersey and parts of eastern Pennsylvania. Epstein (1969), Ridge (1983), Cotter and others (1986), and Witte (1988, 1997a, 2001) showed that the margin of the Kittatinny and Minisink Valley lobes retreated systematically with minimal stagnation. However, the age of the terminal moraine, timing of the late Wisconsinan maximum, and precise chronology of deglaciation are uncertain. This is due to scant radiocarbon dates because of a lack of organic material that can be used to date deglaciation, inadequacies of dating bog bottom organic material and concretions, and use of estimated sedimentation rates to extrapolate bog bottom radiocarbon dates. Also, there are very few glacial lake bottom exposures that exhibit varves. This scarcity greatly limits their use to establish or correlate a deglaciation chronology.

The few radiocarbon dates available bracket the age of the terminal moraine and retreat of ice from New Jersey. Radiocarbon dating of pre-advanced organic material cored from Budd Lake by Harmon (1968) yielded a date of 22,890 +/- 720 yr before present (B.P.) (I 2845), and a concretion sampled from sediments of Lake Passaic by Reimer (1984) that yielded a date of 20,180 +/- 500 yr B.P. (QC 1304) suggest that the age of the terminal moraine is about 22 to 20 ka. Basal organic material cored from a bog located on the side of Jenny Jump Mountain approximately 3 miles (4.8 km) north of the terminal moraine by D. H. Cadwell (written comm., 1996) indicates a minimum age of deglaciation at about 19,340 +/- 695 yr B.P. (GX-4279) (fig. 5). Similarly, basal-organic material from Francis Lake in Kittatinny Valley, which lies approximately 8 miles (12.9 km) north of the terminal moraine, indicates a minimum age of deglaciation at about 18,570 +/- 250 yr B.P. (SI 5273) (Cotter, 1983) (fig. 5). Because the lake lies approximately 3 miles (4.8 km) southeast of the Franklin Grove moraine, this age is also probably a minimum date for that feature. Exactly when the ice margin retreated from the New Jersey part of Kittatinny Valley is also uncertain. A concretion date of 17,950 +/- 620 yr B.P. (I 4935) from sediments of Lake Hudson (cited in Stone and Borns, 1986) and an estimated age of 17,210 yr B.P. for the Wallkill moraine by Connally and Sirkin (1973) suggest that ice had retreated from New Jersey by about 18 ka.

Based on mapping of morphosequences (Koteff and Pessl, 1981), many ice recessional positions have been delineated in Kittatinny Valley (Ridge 1983; Witte 1988, 1997a). In addition, moraines, and interpretation of glacial lake histories, based on correlative relationships between elevations of delta topset-foreset contacts, former glacial lake water plains, and lake spillways, provide a firm basis for reconstruction of the ice recessional history of the Kittatinny ice lobes. Recessional deposits are discussed in reference to deposition at the margin of the Kittatinny Valley lobe in the Delaware Valley and Paulins Kill Valley.

Regional studies in Kittatinny Valley (Ridge, 1983; Witte, 1988, 1997a) have shown that the margin of the Kittatinny Valley ice lobe had a well-defined regional lobation (fig. 2). In places where the glacier crossed stream valleys, smaller sublobes, extending as much as one mile down valley, were formed. Local evidence for a lobate geometry includes arcuate trends of meltwater channels in the upland northwest of Paulins Kill. In places these channels fed glacial meltwater deltas lower in the valley and based on their course they trace a lobate geometry. The large recessional moraine located at the base of Kittatinny Mountain also shows that the glacier margin was lobate.

Delaware Valley

Meltwater deposits in the Delaware valley include outwash fans (Qwf), valley train deposits (Qwfv), and meltwater terrace deposits (Qwft). These deposits lie as much as 110 feet (34 m) above the Delaware River. The only outwash fans in the map area are at the mouths of the Dunnfield and Delawanna Creeks and Stony Brook where they enter the Delaware valley. They may have been laid down along the edge of the Delaware valley sublobe, their elevation shows they are on grade with valley-train deposits mapped on the Pennsylvania side of Delaware River by Ridge (1983).

Well records in the Delaware valley (fig. 6 and table 1 (pl. 2)) reveal silt and clay beneath sand and gravel in several places showing that short-lived small proglacial lakes formed during deglaciation. Figure 7 illustrates their formation. In panel A, the glacier margin remains in a relatively constant position, neither advancing nor retreating. Over time a thick valley-train was deposited at and well beyond the glacier's margin. In panel B, the glacier retreats to a new position up valley and a proglacial lake formed between the glacier's margin and the valley train's head-of-outwash. From this younger ice-retreat position, an ice-contact delta is laid down in the lake. Downstream, the lake's outlet waters cut a channel in the valley-train deposit. Over time, this channel deepens, lowering the level of the proglacial lake. If erosion proceeds at a high rate, the lake may be very short lived, limiting the amount of glaciolacustrine materials deposited. If the lake is longer lived, a large ice contact delta may be deposited in the valley. Because many of the valleys in New Jersey are narrow, it was not uncommon for the entire glacial lake basin to become filled with sediment. In panel C a thick wedge of glaciofluvial sand and gravel buries the glaciolacustrine materials. This deglacial sequence may repeat itself many times as the ice sheet's margin gradually retreats up the valley. The resulting sedimentation forms a complex valley-fill stratigraphy of lacustrine, fluvial and ice-contact materials.

Paulins Kill Valley

Meltwater deposits in Paulins Kill valley consist of ice-contact, and non-ice-contact deltas, and meltwater terrace deposits. These deposits lie as much as 100 feet (30 m) above the Paulins Kill. Deltaic deposits form the bulk of the stratified sediment in Paulins Kill valley. These deposits were laid down in small proglacial lakes held in the south-draining valley by older outwash deposits downvalley (fig. 5) and possibly ice from the Delaware Valley sublobe. Critical to establishing the deglacial history of the Paulins Kill valley was the reorganization of the Delaware valley and the Jacoby Creek-Paulins Kill sublobes. Deglaciation of Jacoby Creek valley in Pennsylvania resulted in the formation of several proglacial lakes that became progressively lower as the ice retreated out of the northeast-draining valley and lower lake outlets were uncovered (Ridge, 1983). Based on the topography in the vicinity of the Paulins Kill and Delaware River confluence, it appears that a small sublobe extended down the Delaware valley during the earliest stage of deglaciation in the Paulins Kill valley. Ice-contact deltas in the Paulins Kill valley delineate three ice-retreat positions. Foreset bedding and lake-bottom deposits observed by the authors, and interpretation from well records (table 1) support the former existence of glacial lakes in Paulins Kill valley. High standing outwash just north of Columbia, Knowlton Township (Qwdv1) represents the oldest meltwater deposits in the valley. Rising to an elevation of 375 feet (114 m), these materials were probably laid down in a small proglacial lake that formed between the Delaware and Paulins Kill valley sublobes. The surface of this deposit is extensively scoured, indicating that it acted as a sediment dam for younger proglacial lakes up valley. Retreat of the Paulins Kill lobe to a mile northeast of Hainesburg resulted in the expansion of a proglacial lake up the valley. A large, collapsed ice-contact delta (Qwdv2) defines a second ice-retreat position. This delta was partly made from outwash coming down Yards Creek. It reaches an elevation of 405 feet (123 m), and it appears to have had filled in the Paulins Kill valley downstream as far as deposits of Qwdv1 near Columbia. The lower Qwdv2 terrace near Columbia probably was formed on reworked and eroded Qwdv1 deposits. Ice retreat to a position just northeast of the quadrangle resulted in the deposition of Qwdv3. These deposits consist of ice-contact and non-ice-contact deltas which reach an elevation of 385 feet (117 m). Outlet channels cut through Qwdv2 down valley controlled the level of the proglacial lake that expanded up valley behind the Qwdv2 deposits.

This stepward style of deglaciation can be traced throughout Paulins Kill valley. Based on morphosequence mapping Ridge (1983) and Witte (1988) have collectively delineated 14 ice-retreatal positions in the valley. The meltwater terrace deposits that cover parts of the valley floor were formed by meltwater emanating from these up-valley positions. The broad meltwater terraces in the vicinity of Vail and Walnut Valleys lie at an elevation of 345 feet (105 m) and 325 feet (99 m), respectively. Their lower positions in the valleys reflect a lowering of local base level as older outwash down-valley became further incised by meltwater draining from younger retreat positions upstream. Meltwater as well as discharge from Lake Wallkill (Witte, 1997a, 2008) continued to flow down the Paulins Kill valley well after the valley had been deglaciated.

Summary of Deglaciation

The delineation of ice-recessional positions and the interpretation of glacial lake histories in the Paulins Kill valley show that the margin of the Kittatinny Valley lobe retreated in a systematic manner in a northeasterly direction, chiefly by melting at its margin. This style of retreat is consistent with the pattern of the late Wisconsinan deglaciation observed elsewhere in northwestern New Jersey (Ridge, 1983; Cotter and others, 1986; Witte, 1988, 1997a, 2001).

POSTGLACIAL HISTORY

The Portland and Stroudsburg quadrangles were deglaciated by approximately 18.75 ka based on the oldest Francis Lake date (Cotter, 1983). Meltwater from Lake Wallkill continued to flow down the Paulins Kill valley until a lower spillway was uncovered in the mid Wallkill Valley and the lake drained into Hudson Valley. This occurred around 17 ka., based on the estimated age of the Pellets Island moraine in Wallkill Valley (Connally and Sirkin, 1986). Meltwater continued to flow down the Delaware valley until the ice sheet retreated from the Delaware River drainage basin and into the Susquehanna River drainage basin about 15 ka. (estimated from Ozsvath and Coates, 1986).

Following deglaciation, cold and wet conditions and sparse vegetative cover enhanced erosion of hillslope material by solifluction, soil creep, and slope wash. Some of this material lies in small colluvial fills in first-order drainage basins. Mechanical disintegration of rock outcrops by frost weathering provided additional sediment, some of which now lies in aprons of talus (Qta) at the base of cliffs on Kittatinny Mountain, and in shale-chip colluvium (Qcs) in Delaware valley. In areas of less relief, boulder fields formed at the base of slopes where rocks were transported by soil creep or where fine sediment was winnowed from till by groundwater seepage. Other fields were formed where meltwater left a lag deposit consisting of the heavier stones. A few others may have been concentrated and directly deposited by the glacier. These fields, and other concentrations of boulders that were formed by glacial transport and meltwater erosion, were further modified by freeze and thaw, their stones reoriented to form crudely-shaped stone circles.

The many swamps and poorly drained areas in the quadrangles are typical of glaciated landscapes. Upon deglaciation, surface water, which had in preglacial time flowed in a well-defined network of streams, became trapped in the many depressions, glacial lakes and ponds, and other poorly drained areas created during the glaciation. Several studies on bogs and swamps in northwestern New Jersey and northeastern Pennsylvania have established a dated pollen stratigraphy that goes back nearly to the onset of deglaciation (Cotter, 1983). Pollen analysis shows an early transition from tundra with sparse vegetal cover, to open parkland of sedge and grass with scattered arboreal stands that consisted largely of spruce. From about 14 ka to 11 ka, the regional pollen sequence records a transition to a dense closed boreal forest that consisted largely of spruce and fir blanketing uplands. This was followed by a period (11 ka to 9.7 ka) when pine became the dominant forest component. These changes record the continued warming during the latter part of the Pleistocene and transition from ice age to a temperate climate. About 9.4 ka, oak and other hardwoods began to populate the landscape, eventually displacing the conifers and marking the transition from a boreal forest to a mixed-hardwoods temperate forest (Harmon, 1968). Throughout the Holocene the many shallow lakes and ponds left over from the ice age slowly filled with decayed vegetation, forming bogs and swamps. These organic-rich deposits principally consist of peat, muck, and minor rock fragments and mineral grains.

Stream-terrace deposits (Qst3 and Qst2) in the Delaware valley reflect two phases of postglacial fluvial development (Witte, 2001). Stream-terrace deposition presumably started when the ice sheet retreated from the Delaware River drainage basin about 15 ka (estimated from Ozsvath and Coates, 1986) and stream discharge diminished substantially. This promoted an interval of minor incision and extensive lateral erosion and deposition on the valley floor as the main channel of the river began to meander. The Qst3 terrace is a relic of this phase. It forms the highest flood plain deposits in the valley and it lies on elevated gravelly strath terraces that represent the former position of the Delaware River in early postglacial time. Dating the terrace is problematic due to scant organic material available for radiocarbon dating and in many places this higher terrace is covered by middle to late Holocene overbank sediment deposited during infrequent megafloods. The occurrence of eolian sand on some Qst3 terraces (Witte, 2012) also suggests that Qst3 was laid down in early postglacial time (15 to 12 ka) when conditions were highly favorable for the transport and deposition of eolian sand. Only a few Qst3 terraces have been recognized downstream from the Delaware Water Gap. One possible reason for this is the convergence of the Qst3 and Qst2 terraces downstream due to isostatic rebound. Another is that the high-standing gravel straths that Qst3 sediments rest on may have been only preserved in the wider parts of the Delaware Valley (area upstream from Wallpack Bend) (fig. 2) rather than the narrower parts of the valley downstream.

Qst2 terraces represent a renewed time of downcutting and extensive vertical and lateral accretion of overbank deposits. This interval was initiated by 1) isostatic rebound of the Earth's crust, which commenced about 14 ka (Koteff and Larsen, 1989) and 2) the onset of warmer climate toward the close of the Pleistocene, such that deeper rooted and more extensive vegetation reduced sediment load in the drainage basin. Later, throughout the Holocene, these flood-plain materials sequentially built up to heights as much as 35 feet (11 m) above the modern river. Stepped strath terraces that lie buried beneath Qst3 and Qst2 overbank deposits mark incision phases of the Delaware River from late Pleistocene (< 14 ka) to modern time. Radiocarbon dating of a log found beneath thick Qst2 sediment at Bushkill Boat Access (GX-22942, 4,105 +/- 90 ^{14}C years, collected by John Wright, National Park Service) and lying on channel gravel similar in elevation to the modern river show that the Delaware River had cut down to its modern level by at least 4.1 ka. Stewart (1991) showed that the base of the Qst2 terrace may be as old as 11 ka and Stinchcomb and others (2012) reported a date of 9.3 ka near the base of Qst2 near Buck Bar located about 15 miles (24 km) upstream from Delaware Water Gap. These dates show that the Delaware River may have cut down to or near its modern base level by the beginning of the Holocene. Mapping of postglacial terraces in Minisink Valley (Witte, 2012, 2013, and 2014; Witte and Epstein, 2004, 2012) and radiocarbon dating of charcoal collected by the author suggest that even though the Delaware River had cut down to its modern base level by the early Holocene, subsequent evolution of the valley's terrace-floodplains by lateral erosion and vertical accretion was and is still ongoing. Stinchcomb and others (2012) further divided the Delaware valley's postglacial fluvial history into 6 phases with a major climatically-driven incision event occurring during the middle Holocene (6 ka to 5 ka) followed by three additional phases of terrace and floodplain reworking. Their work further details the dynamic history of the Delaware River during the late Holocene.

The discovery of a nearly complete skeleton of *Cervalces scotti* (fig. 8) in 1885 in a marl bog near Mount Hermon, Warren County (Scott, 1885) showed the existence of Pleistocene megafauna in Kittatinny Valley at the close of the last ice age. Like the mastodon, these large mammals roamed the tundra and boreal forests of North America up to 11 ka ago when they became extinct. The cause of their extinction is not known, but it is thought that climatic warming at the close of the Pleistocene, competition from other large mammals, and hunting by nomadic groups of Paleo-Indians may have all contributed to their disappearance.

SURFICIAL ECONOMIC RESOURCES

The most important natural resource in the quadrangle, other than groundwater, is stratified sand and gravel, most of which lies in valley-train deposits (Qwfv) and ice-contact deltas (Qwdv). Sediment may be used as aggregate, subgrade fill, select fill, surface coverings, and decorative stone. Shale-chip colluvium (Qcs) and weathered slate make excellent subgrade material. The location of all sand and gravel pits and quarries is shown on plate 1. All pits are currently inactive except for occasional local use. Till can be used for fill and subgrade material, and till stones can supply building stone. Humus and marl from swamp deposits (Qs) may be used for soil conditioning.

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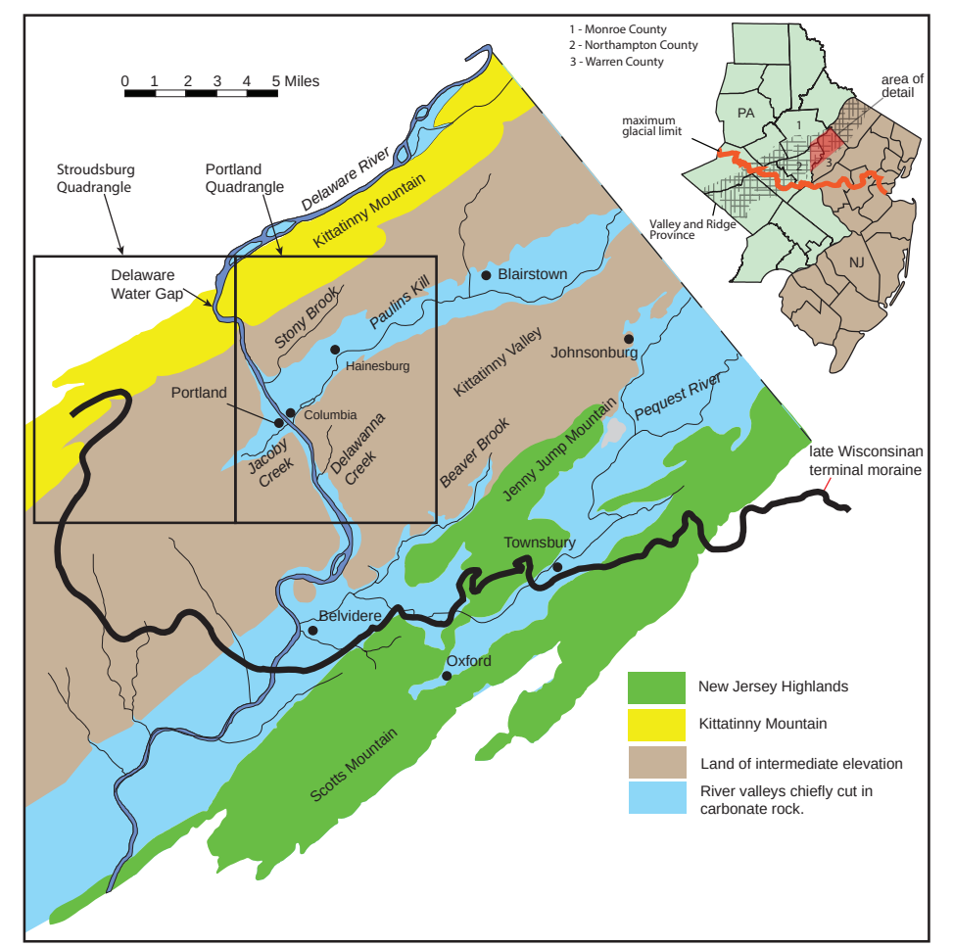


Figure 1. Location of the Portland and Stroudsburg quadrangles and physiography of the study area. Kittatinny Valley forms the broad lowland between Kittatinny Mountain to the north and the mountains of the New Jersey Highlands to the south. Valley and Ridge Physiographic Province is represented by shaded area on the inset map. Maximum glacial limit in Pennsylvania from Sevon and Braun (1997) and maximum glacial limit in New Jersey from Stone and others (2002).

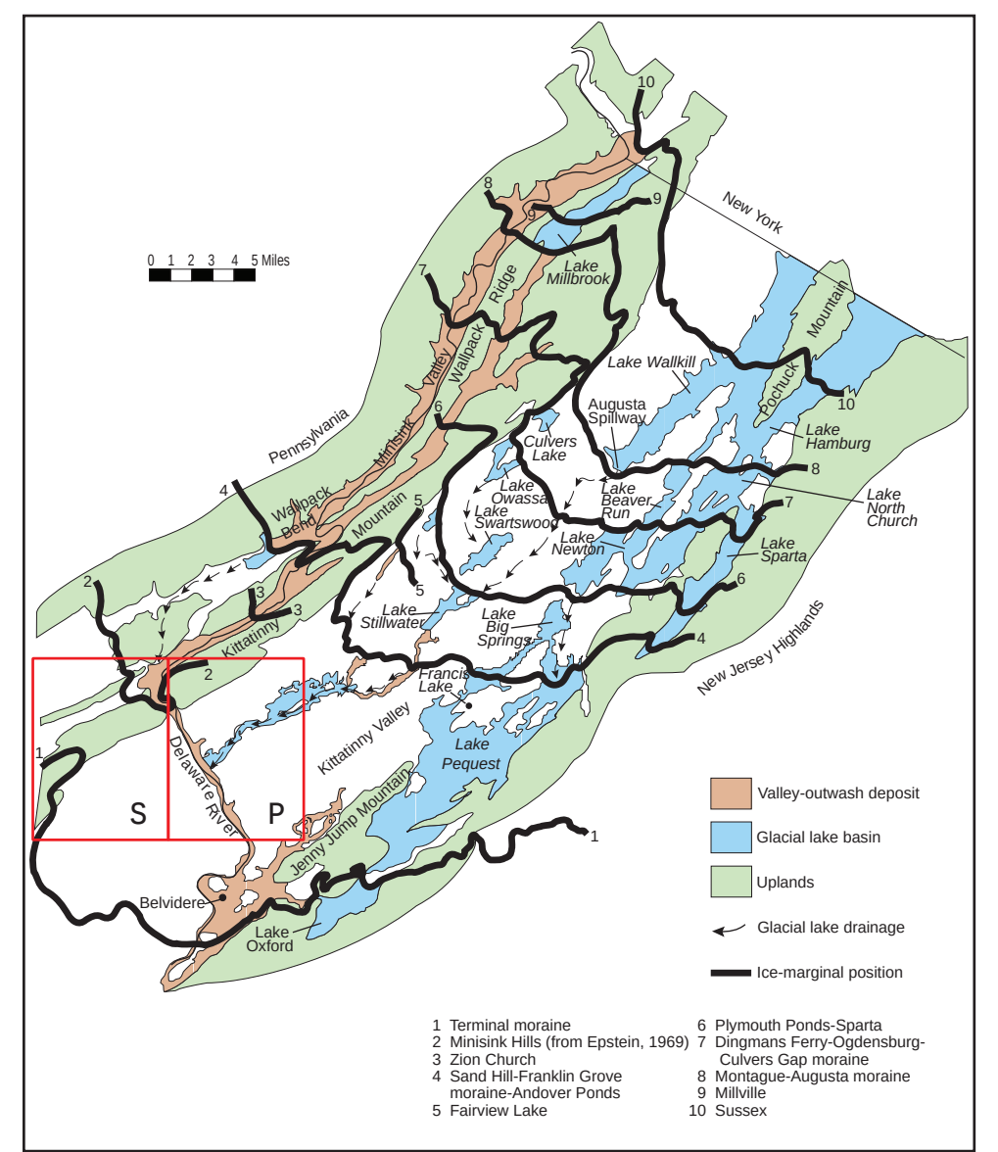


Figure 2. Late Wisconsinan ice margins of the Kittatinny and Minisink Valley ice lobes, and location of large glacial lakes, extensive valley-outwash deposits, and the Portland (P) and Stroudsburg (S) 7.5 - minute topographic quadrangles. Modified from data by Crowl (1971), Epstein (1969), Minard (1961), Ridge (1983), and Witte (1997a).

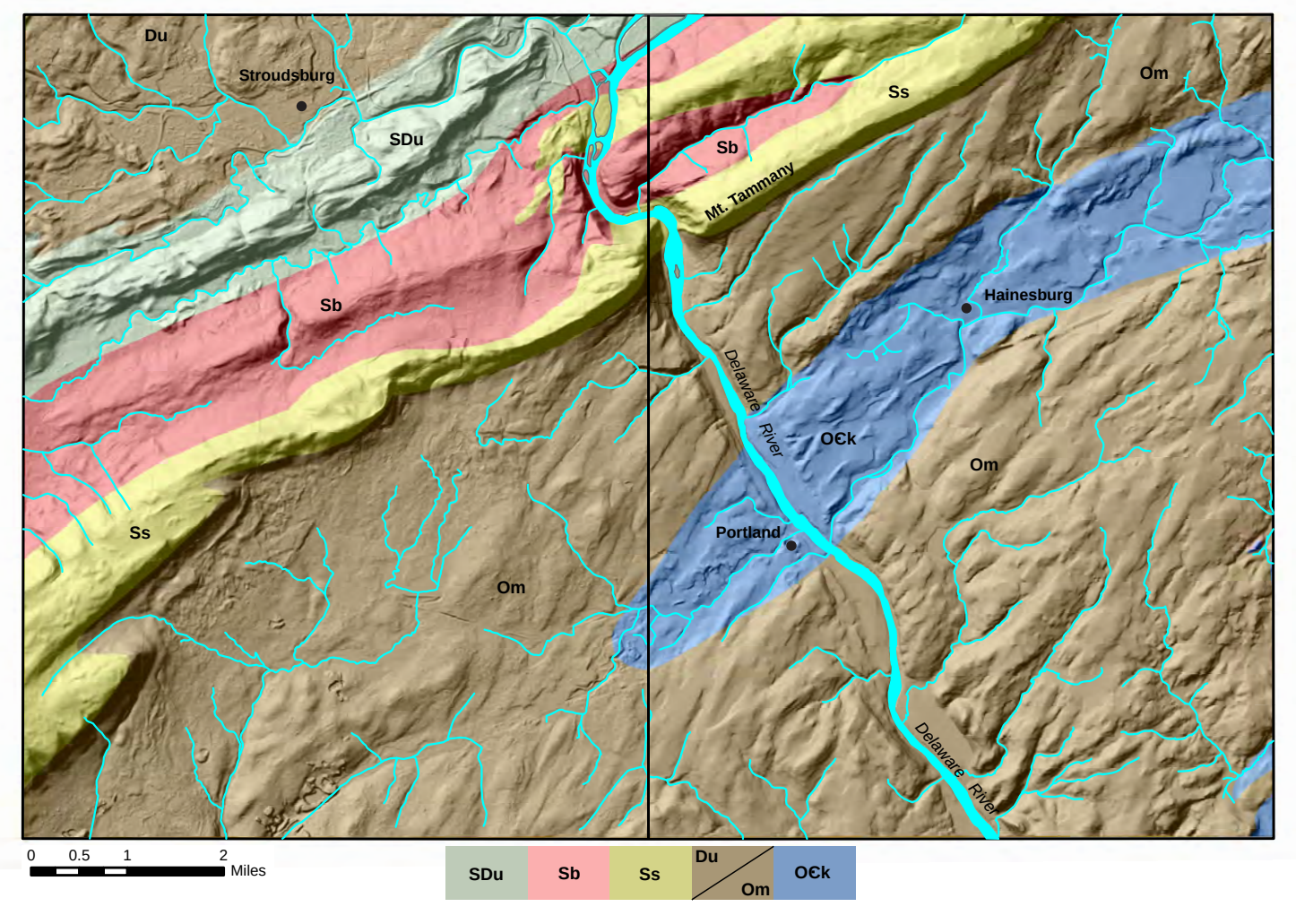


Figure 3. Simplified bedrock map of the Stroudsburg, PA and Portland, PA-NJ quadrangles (modified from Drake and others, 1996, and Epstein, 1973). List of units: OꞒk (dolomite and minor limestone) - Leithsville Fm., Allentown Dolomite, Beekmantown Fm., and Jacksonburg Limestone, Om (slate, siltstone, and graywacke sandstone) - Martinsburg Fm., Ss (quartzite and quartz-pebble conglomerate) - Shawangunk Conglomerate, Sb (red shale and sandstone) - Bloomsburg Red Beds, SDu (shale, calcareous to siliceous siltstone and sandstone, limestone, and argillaceous limestone) - Poxono Island Fm., Bossardville Limestone, Rondout and Decker Fms., Coeymans Fm., Minisink Limestone, New Scotland Fm., Port Ewen Shale, Oriskany Fm., Esopus Fm., Schoharie Fm., and Onondaga Limestone, Du (shale, siltstone, and sandstone) - Marcellus Shale, Mahantango Fm. and Trimmers Rock Fm. Base map - hillshade derived from the Bushkill 7.5 minute digital elevation model (10 m DEM) at (www.pasda.psu.edu).

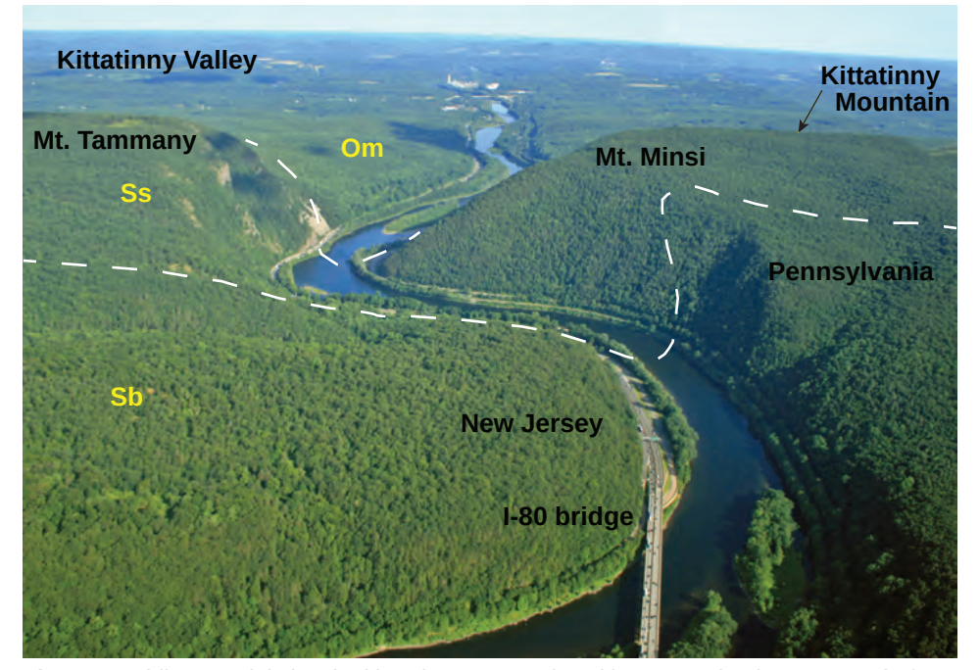


Figure 4. Oblique aerial view looking downstream (south) across Kittatinny Mountain from Delaware Water Gap. The Delaware River has deeply cut through Silurian age quartz-pebble conglomerate and quartzite of the Shawangunk Formation, (Ss) and sandstone and shale of the Bloomsburg Red Beds (Sb). Its sinuous course through the gap is controlled by small plunging folds. South of the water gap the Delaware River flows across Kittatinny Valley, initially flowing over slate and graywacke of the Ordovician age Martinsburg Formation (Om). The gap's location through the resistant Shawangunk Formation is thought to have been controlled by extensive jointing related to flexural offset along Kittatinny Mountain between Mt. Tammany and Mt. Minsi (Epstein, 1966) and not superposition as suggested by Johnson (1931).

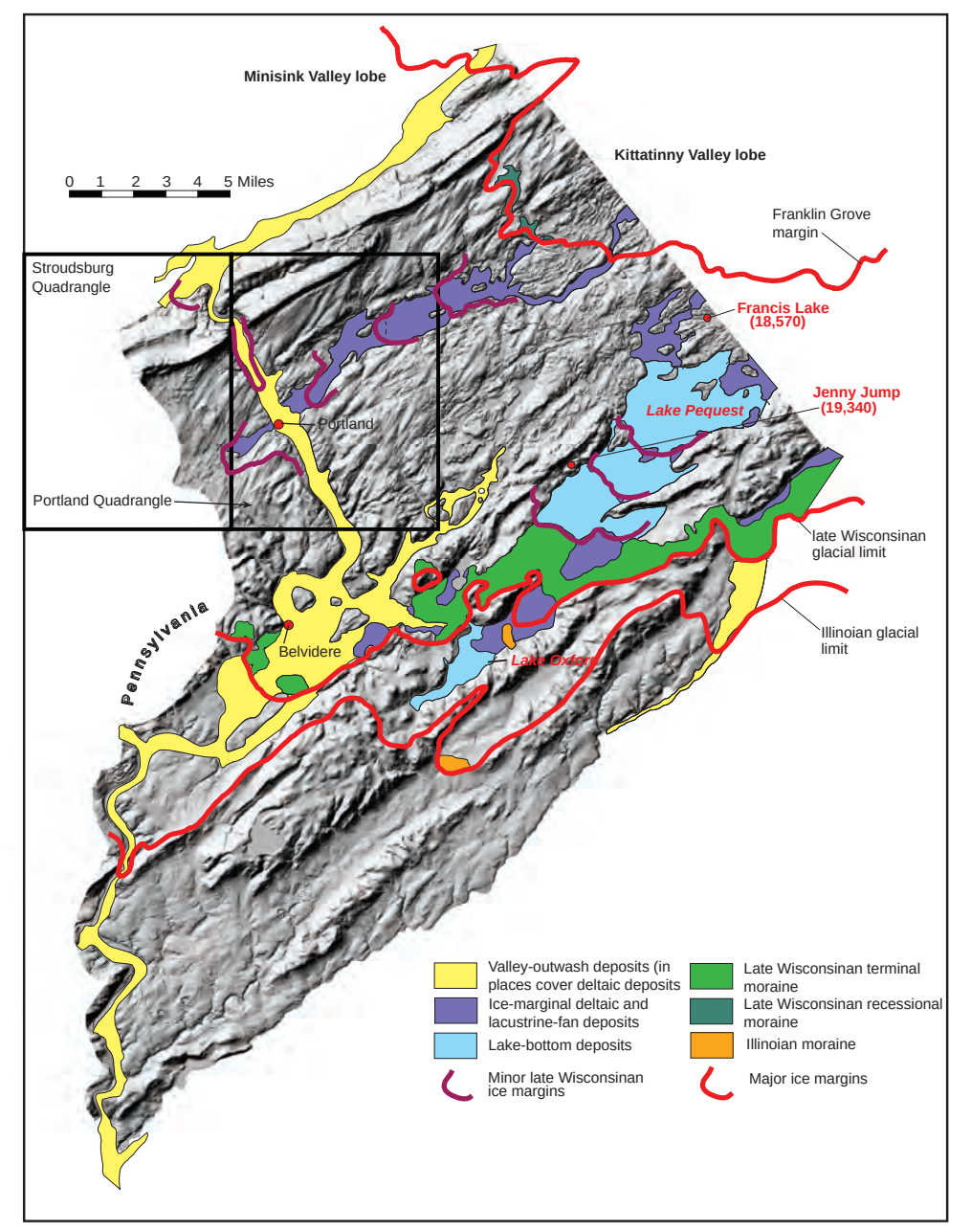


Figure 5. Extent of late Wisconsinan and Illinoian glaciations, moraines, secondary late Wisconsinan ice margins, maximum extent of late Wisconsinan meltwater deposits, and large glacial lakes in the Portland quadrangle and surrounding area. The pre-Illinoian glaciation extended southward of the area shown in this figure. Glacial data modified from Ridge (1983), Witte and Stanford (1995), and Stone and others (2002). The Francis Lake date is from Cotter (1983) and the Jenny Jump date is from D.H. Cadwell (written commun., 1996); both represent minimum dates before present for the late Wisconsinan

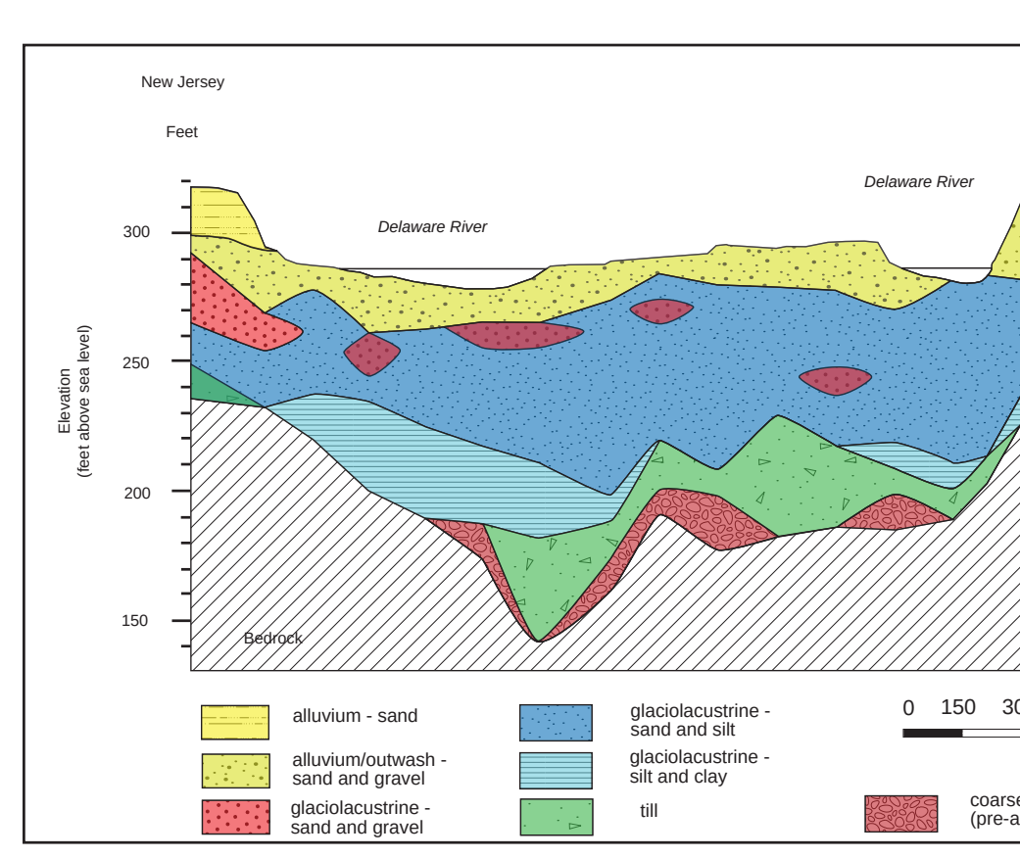
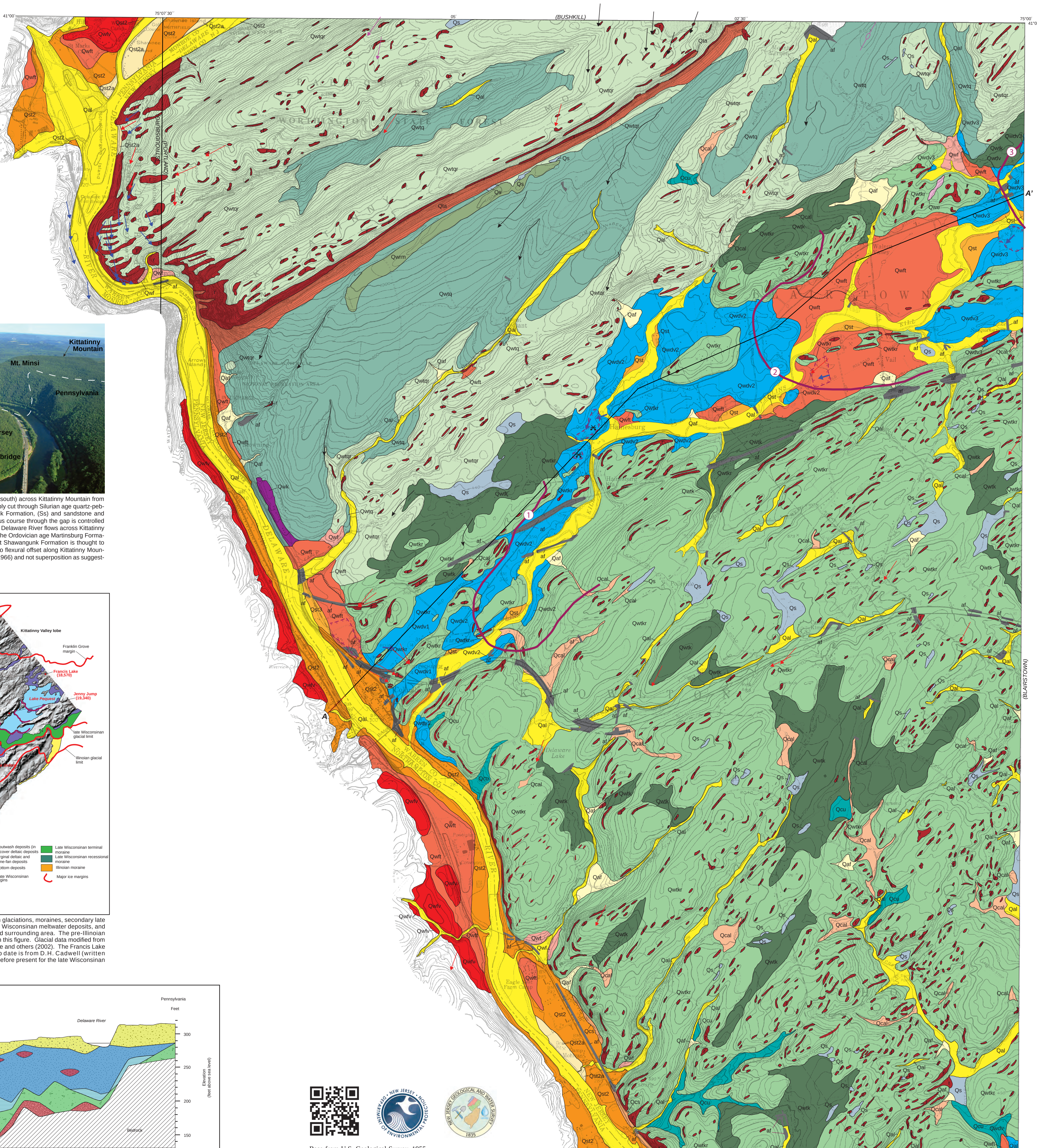


Figure 6. Interpretive cross-section of Delaware Water Gap near I-80 bridge showing depth to rock and valley-fill stratigraphy. Thick deposits of silt and clay, and sand presumed to be glaciolacustrine, are commonly encountered in the subsurface of the Delaware River valley from Belvidere, New Jersey to Port Jervis, New York. These materials were laid down in proglacial lakes that formed in the valley during late Wisconsinan deglaciation. These lakes were held in the valley by older outwash downvalley and in some places end moraine. Based on depth to rock throughout the valley (Witte and Stanford, 1995); table 1 (Plate 2), and the elevation of the river channel downstream where it flows over rock at Marble Mountain, there has been as much as 150 feet (46 m) of glacial scour over the last two glaciations. Section based on detailed logs and blow counts on file at the New Jersey Geological and Water Survey.



Base from U.S. Geological Survey, 1955.
Topography from aerial photographs by photogrammetric methods.
Photorevised 1984 from aerial photographs taken 1981.
Polyconic projection. 1927 North American Datum.

UTM Grid and 1955 Magnetic North
Declination at Center of Sheet

SCALE 1:24000
1 mile
1000 0 1000 2000 3000 4000 5000 6000 7000 feet
1 kilometer
CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

Surficial geology mapped by J. C. Ridge (1982-1983) and R.W. Witte, 1991-1993, 1998-1999. Mapping in Delaware Water Gap National Recreation Area (DEWA) was completed as part of the National Park Service Geologic Resources Inventory Program. Research supported by the U.S. Geological Survey, National Cooperative Geologic Mapping Program, under USGS award number 99HQAG0141. 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. GIS application by M. Girard, New Jersey Geological and Water Survey. Digital cartography by R.W. Witte, New Jersey Geological and Water Survey.

SURFICIAL GEOLOGIC MAP OF PART OF THE PORTLAND AND STROUDSBURG QUADRANGLES, WARREN COUNTY, NEW JERSEY AND MONROE AND NORTHAMPTON COUNTIES, PENNSYLVANIA

BY
RON W. WITTE[1] and JOHN C. RIDGE[2]
2022

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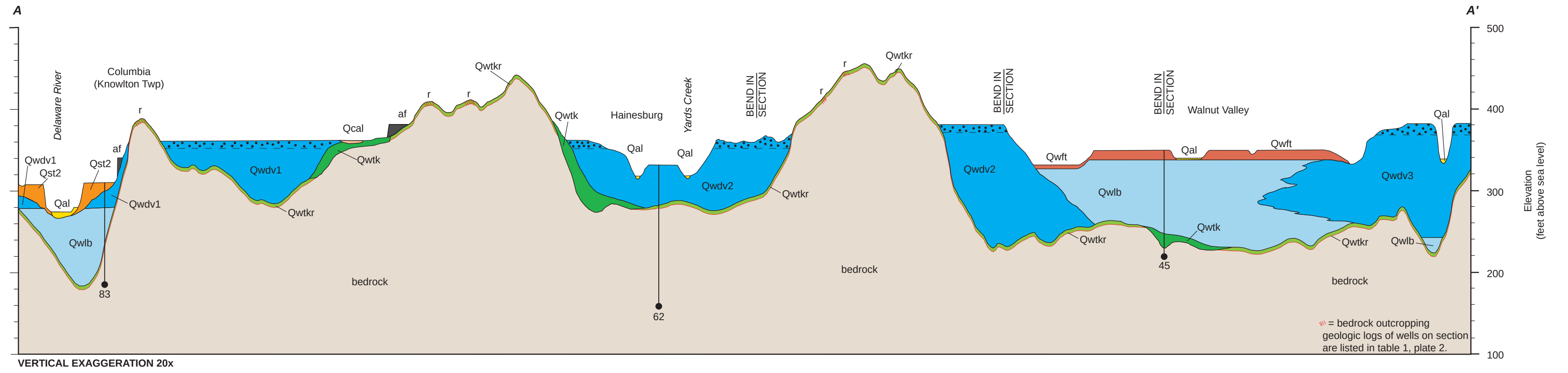


DESCRIPTION OF MAP UNITS

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

Postglacial Deposits

af **Artificial fill (Holocene)** - Rock waste, soil, gravel, sand, silt, and manufactured materials put in place by humans. As much as 90 feet thick near Vail in the large railroad fill built between 1908-1912 for the Lackawanna Railroad, generally less than 25 feet thick elsewhere. Not shown beneath roads, and railroads where it is less than 10 feet (3 m) thick. Primarily used to raise the land surface, construct earthen dams, and form a soild base for roads and railways.

Qal **Alluvium (Holocene)** - Stratified, moderately- to poorly- sorted sand, gravel, silt, and minor clay and organic material deposited by the Delaware River and its tributaries. Locally bouldery. As much as 25 feet (8 m) thick. Includes planar- to cross-bedded gravel and sand and cross-bedded and rippled sand in channel deposits, and massive and parallel-laminated fine sand and silt in flood-plain deposits.

Qcal **Alluvium and Colluvium**, undifferentiated -- Stratified, poorly to moderately sorted, brown to yellowish-brown, gray, sand, silt and minor gravel; as much as 20 feet (6 m) thick. Interlayered with or overlying massive to crudely layered, poorly sorted sand, silt, and minor gravel.

Qaf **Alluvial- fan deposits (Holocene and late Wisconsinan)** -- Stratified, moderately- to poorly- sorted sand, gravel, and silt in fan-shaped deposits. As much as 35 feet (11 m) thick. Includes massive to planar-bedded sand and gravel and minor cross-bedded channel-fill sand. Beds dip as much as 30° toward the trunk valley. Stratified sediment is locally interlayered with poorly sorted, sandy-silty to sandy gravel. Typically graded to postglacial terraces or the modern floodplain. More rarely graded to glacial outwash terraces. Most fans dissected by modern streams.

Qst
Qst2a
Qst2
Qst3
Stream-terrace deposits (Holocene and late Wisconsinan) -- Stratified, well- to moderately-sorted, massive to laminated, and minor cross-bedded fine sand, and silt in terraces flanking present and late post-glacial stream courses. As much as 20 feet (6 m) thick. Overlies glacial and postglacial fluvial, planar to cross-bedded pebbly sand and gravel; as much as 10 feet (3 m) thick. In Minisink Valley and Delaware River Valley deposits form two distinct terraces. The younger (Qst2) flanks recent and late postglacial stream courses and overlies early to late postglacial fluvial gravel and sand. It lies 20 to 35 feet (6 to 11 m) above the mean annual elevation of the Delaware River and chiefly consists of as much as 20 feet (6 m) of fine sand and silt overlying as much as 10 feet (6 m) of pebble gravel and sand. Subscript "a" indicates elevation of terrace is slightly lower than similar nearby terraces. This lower substage has not been shown to be correlative throughout Minisink Valley at map scale. The lower elevation may be due to erosion or differences in local depositional conditions. The older (Qst3) flanks late glacial and early postglacial stream courses and overlies glacial outwash and early postglacial fluvial sand and gravel. It lies 40 to 50 feet (12 to 15 m) above the river and consists of as much as 10 feet of fine sand and medium sand.

Qs **Swamp and Bog deposits (Holocene and late Wisconsinan)** -- Dark brown to black peat (partially decomposed remains of mosses, sedges, trees and other plants) and muck underlain by laminated organic-rich silt and clay. Accumulated in kettles, shallow postglacial lakes, poorly-drained areas in uplands, and hollows in ground moraine. As much as 25 feet (8 m) thick. Locally interbedded with alluvium and thin colluvium.

Qcs **Shale-chip colluvium (Holocene and late Wisconsinan)** -- Thin to thickly bedded, noncompact, poorly sorted light yellowish-brown (10YR 6/4) to brownish-yellow (10YR 7/6) or light olive-brown (2.5Y 5/2), framework supported, shale-chip gravel, containing as much as 80 percent unweathered to lightly weathered angular to subangular shale chips, and minor tabular pebbles and cobbles of siltstone, and sandstone. Interstitial material consists of silty sand. Forms aprons below cliffs and some steep slopes in the Delaware Valley; as much as 20 feet (6 m) thick. Beds dip as much as 25° toward valley. In places the distal (downslope) beds are interlayered with wind-blown sand and alluvium. Graded to glacial and postglacial stream terraces in valley.

Qta **Talus deposits (Holocene and late Wisconsinan)** -- Unsorted, nonstratified, angular boulders as much as 15 feet (4 m) long, cobbles, and smaller fragments of quartzite and quartz-pebble conglomerate forming aprons over rock and till at the base of bedrock cliffs and steep hillslopes on Kittatinny Mountain. As much as 20 feet (6 m) thick.

Qcu **Undifferentiated colluvium (Holocene and late Wisconsinan)** - Poorly sorted, brown to yellowish-brown, gray sand, silt and minor gravel derived from a mixture of weathered slate and till; as much as 10 feet (3 m) thick.

Glacial Deposits (Stratified Materials)

Qwfv **Valley-train deposits (late Wisconsinan)** -- Stratified, well- to moderately-sorted sand, boulder-cobble to pebble gravel, and minor silt deposited by meltwater streams at and extending well beyond (greater than five miles (8 km)) the glacier's margin (fig. 1). As much as 100 feet (30 m) thick. The proximal part of the deposit 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. Clasts generally are smaller downstream, sand is more abundant, and trough and planar cross-bedding, and graded beds are more common. Based on well records (table 1), may overlie glacial lake deposits previously laid down in sediment-dammed proglacial lakes. In places overlain by nonlayered, well-sorted, very fine sand and fine sand presumed to be eolian; as much as 5 feet (2 m) thick. In Minisink Valley forms shingled sets of outwash terraces.

Qwf **Outwash-fan deposits (late Wisconsinan)** -- Stratified, well- to moderately-sorted sand, cobble-pebble gravel, and minor silt deposited by meltwater streams in fan-shaped deposits at the mouth of large tributaries in Minisink Valley. As much as 60 feet (18 m) thick. Includes massive to planar-bedded sand and gravel, and minor cross-bedded and channel-fill sand. Bedding generally dips towards the trunk valley by as much as 10°. Fan deposits are graded to valley-train deposits.

Qwdv **Glacial-lake delta deposits (late Wisconsinan)** -- Stratified sand, gravel, and silt deposited by meltwater streams in proglacial lakes at and beyond the stagnant glacier margin. Includes well sorted sand and boulder-cobble to pebble gravel in planar to cross-bedded glaciofluvial topset beds that are as much as 25 feet (8 m) thick. Overlies and grades into foreset beds that dip 20° to 35° basinward and consist of well- to moderately-sorted, rhythmically-bedded cobble-pebble and pebble gravel and sand. These beds grade downward and outward into ripple cross-laminated and parallel-laminated, sand, silt and pebble gravel that dip less than 20°. Lower foreset beds grade into gently inclined prodelta bottomset beds of rhythmically-bedded, ripple cross-laminated to graded fine sand and silt with minor clay drapes. Thickness may be as much as 100 feet (30 m). Qwdv deposits were laid down in narrow sediment-dammed proglacial lakes in the Paulins Kill Valley. Deposits are extensively kettled, and in long, narrow lake basins, topset beds are extensively aggraded in their upstream sections. Qwdv1, Qwdv2 and Qwdv3, indicate deltas deposited from successive ice margins in the Paulins Kill Valley. Stippled pattern on section indicated gravelly topset beds.

Qwlb **Glacial lake-bottom deposits (late Wisconsinan)** -- Parallel-laminated, irregularly to rhythmically-bedded silt, clay, and very fine sand; and minor cross-laminated silt, fine sand, and minor clay deposited on the floor of glacial lakes chiefly by density currents and settling of fines. As much as 100 feet (30 m) thick. In subsurface only (thick deposits beneath Qs deposits and modern lakes in the Kittatinny Valley.) Thick deposits presumed to be in subsurface in Paulins Kill, Delaware River and Minisink valleys.

Qwft **Meltwater-terrace deposits (late Wisconsinan)** -- Stratified, well- to moderately-sorted sand, cobble-pebble to pebble gravel, and minor silt deposited by meltwater streams as terraces incised in valley-train, glacial lake delta deposits, and other meltwater-terrace deposits. As much as 20 feet (6 m) thick. Sediment and bedforms similar to the downstream, distal part of valley-train deposits. Includes bouldery strath terraces cut in till along meltwater stream courses in uplands. May also include the distal part of valley-train deposits where they have cut into older valley-train deposits downvalley.

Qwk **Kame (late Wisconsinan)** -- Stratified, well- to poorly-sorted sand, boulder- to pebble-gravel, silt, and interbedded flowtill in small collapsed hills and ridges overlying till. Presumed to be ice-hole and crevasse fillings. As much as 50 feet (15 m) thick. Attitude of bedding is highly variable.

Qwe **Esker (late Wisconsian)** - Stratified, well- to poorly sorted sand, boulder-cobble to pebble gravel in narrow collapsed ridge. As much as 25 feet (8 m) thick. Attitude of bedding is unknown due to lack of exposure. Interpreted as an ice-tunnel deposit near Walnut Valley.

Non-stratified Materials

Till (late Wisconsinan) -- Scattered patches of noncompact to slightly compact, bouldery "upper till" overlying a blanket-like compact "lower till" deposited chiefly on bedrock and locally some older pre-Wisconsinan surficial deposits. Includes two varieties: Kittatinny Valley till (Qwtk) and Kittatinny Mountain til (Qwtq).

Qwtk
Qwtkr
Kittatinny Valley till -- Compact, unstratified, poorly sorted yellowish-brown (10YR 5/4), light yellowish-brown (2.5Y 6/4), light olive-brown (2.5Y 5/4) to grayish-brown (2.5Y 5/2), gray (5Y 5/1) to olive-gray (5Y 5/2) noncalcareous to calcareous silt and sandy silt that typically contains 5 to 15 percent gravel. As much as 200 feet (61 m) thick. Locally overlain by thin, discontinuous, non-compact to slightly compact, poorly sorted, indistinctly layered yellow-brown (10YR 5/6-8), light yellowish-brown (10YR 6/4) sandy silt that contains as much as 30 percent gravel, and minor thin beds of well- to moderately sorted sand, gravel, and silt. Clasts chiefly consist of unweathered slate, siltstone and sandstone, dolomite, limestone, chert, minor quartzite, and quartz-pebble conglomerate. Matrix is a varied mixture of unweathered quartz, rock fragments, and silt; minor constituents include feldspar and clay. Till derived chiefly from limestone, argillaceous limestone, shale, and sandstone bedrock in Kittatinny Valley. Qwtkr denotes areas of till generally less than 10 feet (3 m) thick with few to some bedrock outcrops.

Qwtq
Qwtqr
Kittatinny Mountain till -- Slightly compact to compact, unstratified, poorly sorted yellowish-brown (10YR 5/4), brown (10YR 5/3, 7.5 YR 5/4) to light olive-brown (2.5Y 5/4) and reddish-brown (5YR 4/3) silty sand and sand containing 10 to 20 percent gravel. As much as 50 feet (15 m) thick. Locally overlain by thin, discontinuous, non-compact, poorly sorted and layered sand and minor silty sand, similar in color to lower till, that contains as much as 35 percent gravel, and minor thin beds of well- to moderately-sorted sand and pebbly sand. Clasts chiefly consist of unweathered quartz-pebble conglomerate, quartzite, red sandstone, and red shale. Matrix is a varied mixture of quartz, rock fragments, silt, minor feldspar, and clay. Till derived chiefly from quartzite, quartz-pebble conglomerate, and red sandstone bedrock on Kittatinny Mountain. Qwtqr denotes areas of till generally less than 10 feet thick (3 m) with few to some bedrock outcrops.

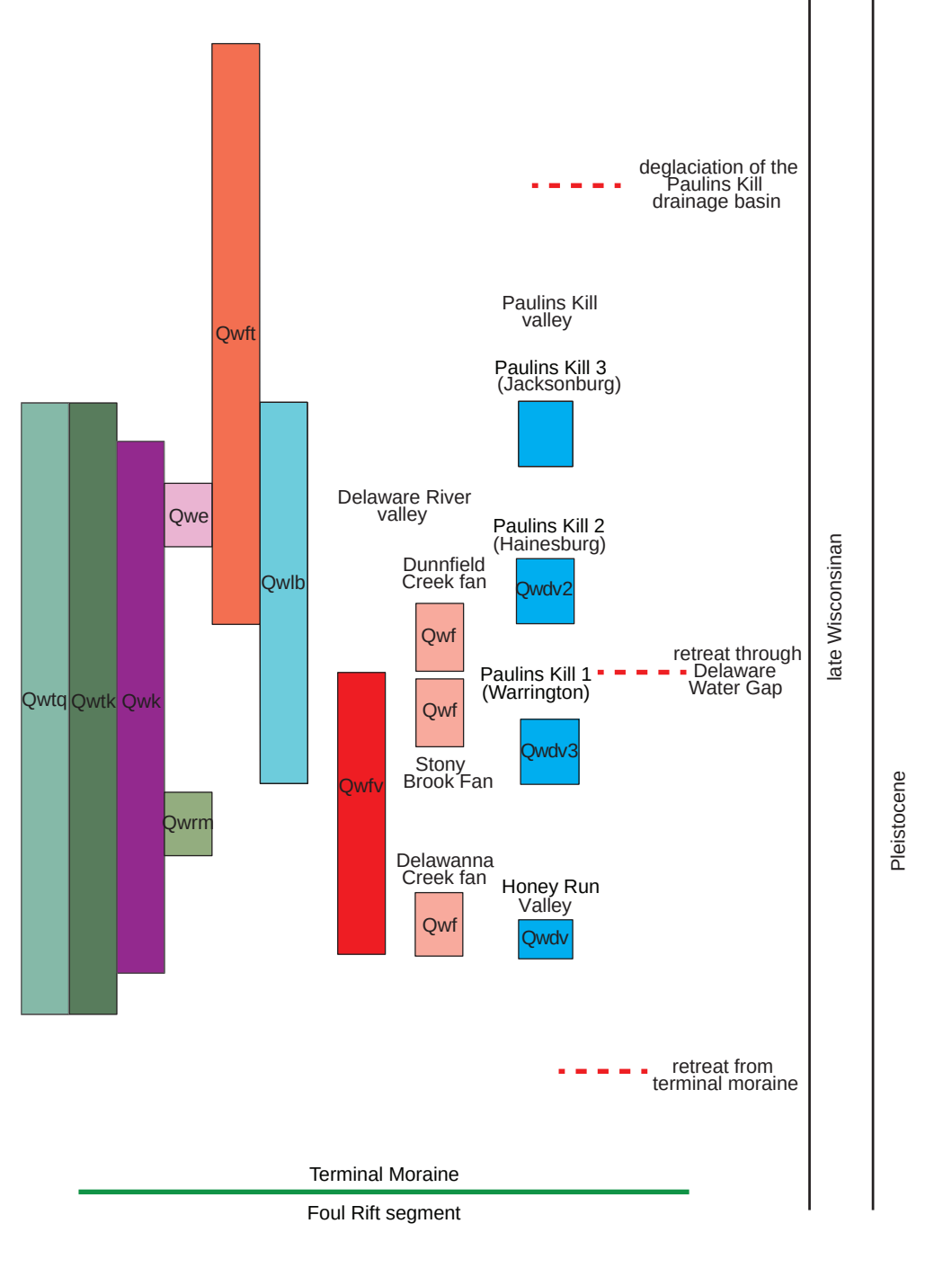
Qwrm **Recessional moraine** -- Unstratified to poorly stratified silt, sand, gravel, boulders deposited at the margin of the Kittatinny Valley sublobe. As much as 50 feet (15 m) thick, Consists of poorly compact, stony till, silty-sandy compact till, and minor lenses of water-laid sand, gravel, and silt in bouldery ridges that mark the former glacier margin.

Bedrock

r **Bedrock** -- Extensive outcroppings, minor regolith, and scattered erratics.

sr **Bedrock** -- Regolith; chiefly rock waste on steep hillslopes and ridge crests, minor talus, scattered erratics, and a few small outcrops.

CORRELATION OF MAP UNITS



EXPLANATION OF MAP SYMBOLS

Contacts.

Striation, measurement at arrow tip.

Striation, from Ridge, 1983. Measurement at arrow tip.

Striation from Epstein, 1969. Measurement at arrow tip.

Small meltwater channel.

Sand and gravel pit scarp. Tics point toward excavation.

Fluvial scarp, line lies at base of scarp. Tics point upslope.

Paleoflow determined from deltaic-foreset bedding. From Ridge, 1983.

Sand and gravel pit. Inactive in 1999

Quarry. Inactive in 1999

Inferred position of glacier margin based on meltwater heads-of-outwash and ice lobation. Numbers refer to phases of deglaciaition dicussed in text.

83 Well located on cross-section and identification number. Well information found in table 1 on plate 2.

Topset beds in deltas on cross sections.

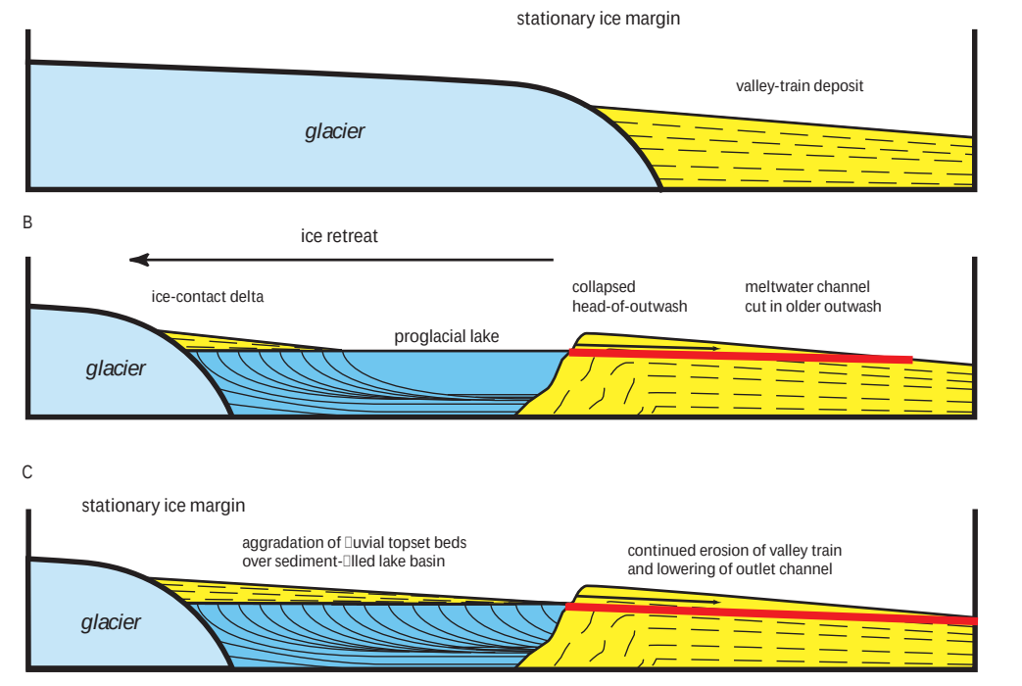


Figure 7. Typical deglaciation sequence in narrow valley draining away from the glacier. In panel A, a large valley train has been deposited at and beyond a stationary ice margin. In panel B, the glacier retreats several miles up valley to where it becomes stationary once again. During retreat from its previous position a proglacial lake has formed between the retreating glacier and the valley train's head-of-outwash. Into this lake an ice-contact delta has been deposited. Over time, the lake's outlet waters erode a channel in the underlying valley train. In panel C, continued deposition in the lake fills the lake's basin with deltaic sediment (chiefly sand and fine gravel). Over time, meltwater streams will deposit a thick wedge of coarse gravel and sand burying the ice-contact delta. Modified from Koteff and Pessl (1981).

Figure 8. *Cervalces scotti* skeleton found in 1885 in a peat bog at Mount Hermon, about four miles southeast of Hainesburg, Warren County, New Jersey. Photo from Geologic Association of New Jersey (GANJ), 2010 Calendar, (www.ganj.org/2010/GANJ_Calendar_2010.pdf).

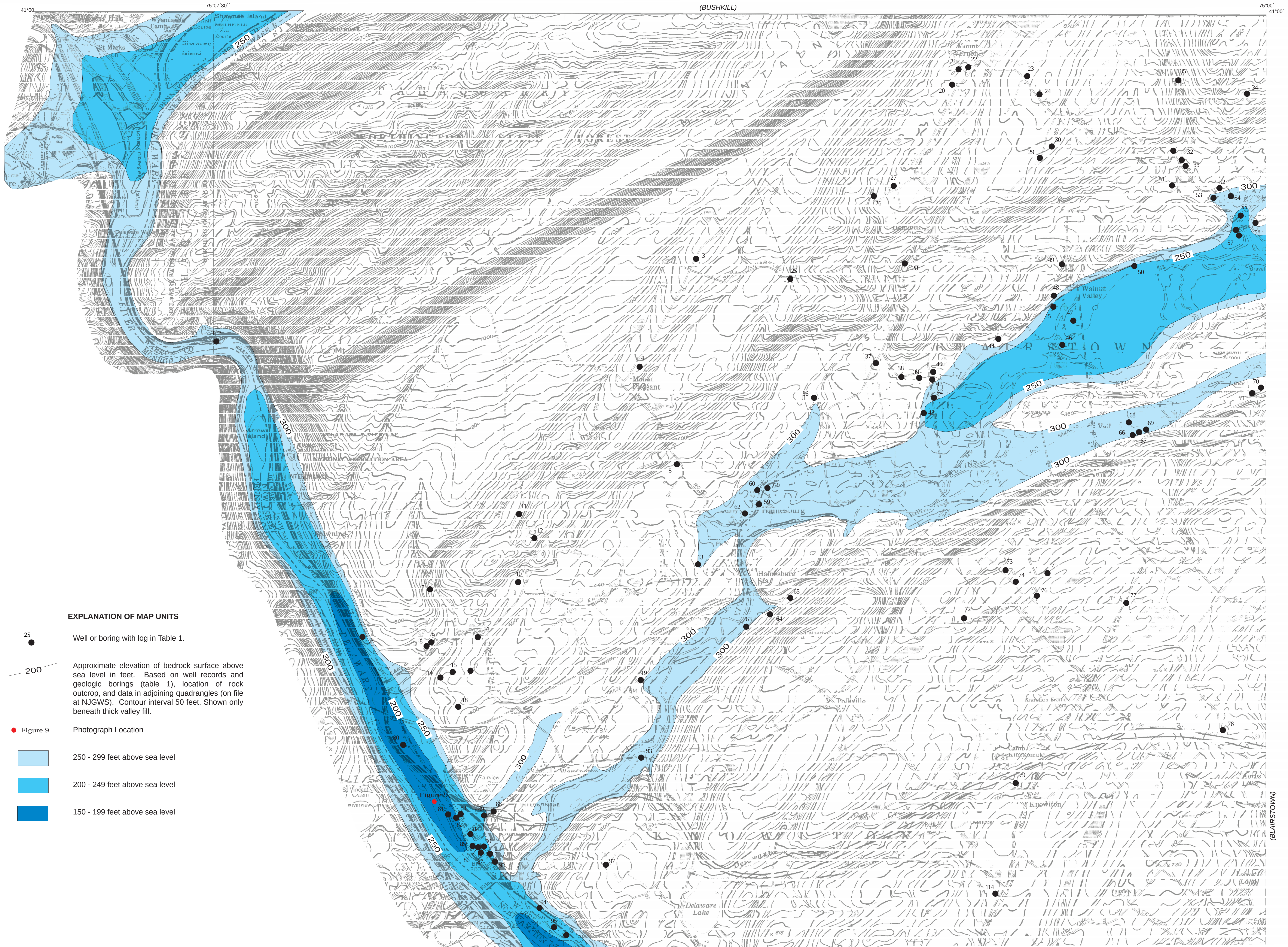
DEPARTMENT OF ENVIRONMENTAL PROTECTION
WATER RESOURCES MANAGEMENT
NEW JERSEY GEOLOGICAL AND WATER SURVEY

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

SURFICIAL GEOLOGIC MAP OF PART OF THE PORTLAND AND STROUDSBURG QUADRANGLES,
WARREN COUNTY, NEW JERSEY AND MONROE AND NORTHAMPTON COUNTIES, PENNSYLVANIA
OPEN-FILE MAP OFM 114
PLATE 2 OF 2

Table 1. Records of selected wells in the Portland quadrangle, Warren County, New Jersey. The listed wells were drilled for private and public water supply. Wells listed with a NJDEP permit number are from the files of the Bureau of Water Allocation, Division of Water Supply and Geoscience, New Jersey Department of Environmental Protection. Well locations are based on property tax maps. Bolded well numbers are depicted in cross section. Location accuracy designated by the letters "s", "f", and "t" indicate map location generally within 200 feet, 500 feet, and 1,000 feet of actual well location, respectively. Discharge listed as gallons per minute.

Well ID.	NJDEP Permit no.	Location accuracy	Discharge (gpm)	Depth (feet)	Driller's log
1	21-1927	f	20	0-30 30-60 60-67	sand sand and gravel gravel
2	21-1785	f	20	0-50 50-103	sand sand and gravel
3	21-2883	f	15	0-122 122-195	clay and gravel gray shale
4	21-1829	f	10	0-33 33-82	clay clay and gravel
5	21-5634	s-f	3	0-30 30-255	overburden granite
6	24-12674	s	7	0-100 100-161 161-170	clay and gravel gravel gravel and water
7	21-7897	s	4	0-15 15-40 40-50 50-395	sandy clay and boulders clay and gravel clay slate
8	21-1776	f	5	0-34 34-100	gravel and clay slate
9	21-1704	f	4	0-35 35-175	gravel and clay slate
10	21-7335	f	4	0-22 22-120 120-340	clay, boulders and gravel slate limestone
11	21-7595	s	2	0-20 20-490	clay and gravel limestone
12	21-7399	f	10	0-8 8-255	overburden shale
13	21-6892	s	15	0-75	gravel
14	21-8147	f	2	0-6 6-598	overburden limestone
15	21-8003	f	20	0-12 12-350	overburden limestone
16	21-7300	s	4	0-12 12-55 55-600	overburden limestone shale
17	21-7992	f	16	0-17 17-272	gravel and clay limestone
18	21-7189	f	2	0-17 17-573	overburden limestone
19	21-6524	s	15	0-3 3-20 20-42 42-50 50-60 60-61 61-66 66-75	topsoil boulders and sand limestone gravel with water limestone gravel limestone gravel with water
20	21-1675	f	15	0-29	clay and large gravel
21	21-8112	f	15	0-21 21-38 38-373	clay and large gravel fine gravel slate
22	21-7835	s	3	0-8 8-275	overburden slate
23	21-7645	s	15	0-8 8-29 29-58 58-198	clay and boulders clay and gravel rotten limestone limestone
24	21-7203	s-f	15	0-3 3-15 15-60 60-80 80-90	soil sand, gravel and clay clay and gravel clay and hardpan coarse gravel
25	21-6899	s	30	0-20 20-255	cobbles with clay shale
26	21-7303	s	4	0-15 15-550	hardpan shale
27	21-7819	s	8	0-15 15-36 36-248	clay hard red clay blue slate
28	21-3441	f	20	0-20 20-110	gravel, clay and boulders limestone
29	21-7361	s	75	0-20 20-595	clay slate
30	21-5749	s	6	0-16 16-480	overburden shale
31	21-7233	s	4	0-5 5-15 15-28 28-240	topsoil and boulders sandy clay and gravel sand and coarse gravel limestone
32	21-3375	s	12	0-134	hardpan and gravel
33	21-4058	s-f	10	0-32 32-222	overburden, boulder, and water shale
34	21-8083	s-f	12	0-10 10-755	clayey soil black shale
35	21-3634	f-t	nr	0-150 150-248	gravel, clay and boulders shale
36	21-2000	s-f	20	0-42	sand and gravel
37	21-7132	s	5	0-2 2-18 18-25 25-500	overburden gravel sand limestone
38	21-3074	f	12	0-60 60-155 155-222	boulders, clay and gravel boulders limestone
39	21-3072	f	4	0-50 50-100 100-125 125-135 135-145 145-157	boulders and large gravel boulders and sand large gravel heavy gravel gravel limestone
40	21-8047	s	20	0-42 42-503	overburden limestone
41	21-3234	f	5	0-45 45-70 70-148	boulders, sand and gravel blue shale gray limestone
42	21-2776	f	20	0-30 30-70 70-74 74-115	clay and gravel gravel clay limestone
43	21-2950	f	6	0-6 6-58 58-112 112-116 116-120 120-130	overburden limestone (erratic ?) brown clay and gravel dense gravel, clay and silt boulder clay and gravel
44	21-6440	s-f	15	0-30 30-325	sandy overburden limestone and shale
45	**21-3878**	s	60	0-11 11-101 101-117 117-120	gravel soft blue clay sand and hard gravel limestone
46	21-1460	f-t	30	0-83 83-98	hardpan, clay, fine sand gravel
47	21-2810	f-t	20	0-30 30-122 122-125	overburden gray clay sand and gravel
48	21-6782	s-f	100	0-30 30-330	sand with some gravel limestone
49	21-4016	f	10	0-26 26-30 30-33 33-81 81-135 135-155	overburden gravel limestone boulder gravel and clay clay and gravel limestone
50	21-4150	f-t	50	0-170	sand and gravel
51	21-3515	f	5	0-40 40-80 80-100	hardpan and gravel hardpan and limestone limestone
52	21-2259	f	10	0-55	hardpan and gravel
53	21-3603	s-f	6	0-75 75-173	overburden with gravel and clay limestone with clay
54	21-3638	f	3	0-112 112-173	gravel, sand, and clay limestone with clay
55	21-6020	s-f	3	0-105 105-225	sand and gravel limestone and clay
56	21-7678	s	18	0-2 2-23 23-115 115-120	clay clay and gravel sand and gravel gravel
57	21-7487	s	30	0-3 3-132 132-175	topsoil broken limestone with silt and gravel limestone
58	21-7380	s	30	0-34 34-40 40-148	sand clay and gravel limestone
59	21-8071	s	15	0-10 10-20 20-50 50-78 78-80	sand, gravel and boulders sand and gravel gravel and boulders broken limestone large gravel and sand
60	21-8095	s	20	0-25 25-75 75-87 87-95	sand, gravel and boulders sand and gravel sand and broken limestone broken limestone
61	21-7439	f	12	0-65 65-80	sand and gravel decomposed limestone
62	**21-7765**	s	20	0-50 50-175	sand and gravel limestone
63	21-1806	s	15	0-33 33-63	clay and gravel slate
64	24-15100	s	15	0-10 10-85 85-184	clay gravel slate
65	21-7989	s	25	0-25 25-54 54-70	sand and boulders sand and gravel limestone
66	21-3595	f	4	0-25 25-55 55-70 70-77 77-83	sand hard clay mixed with gravel clay and gravel gravel with boulders limestone
67	21-3596	f	20	0-20 20-40 40-50 50-70 70-90 90-148	sand sand and gravel clay and gravel hard clay gravel with clay limestone
68	21-7679	f	10	0-5 5-173	sandy clay limestone
69	21-3898	f	6	0-15 15-40 40-50 50-98	brown sand brown muck brown sand brown shale
70	21-8063	s	2	0-38 38-400	sand, clay and gravel limestone
71	21-8064	s	4	0-43 43-300	sand, clay and gravel limestone
72	21-6614	s	5	0-5 5-150	topsoil shale
73	21-7686	s	10	0-3 3-8 8-48 48-265	overburden soft broken shale broken slate slate
74	21-7522	s	10	0-6 6-150	sand, clay and gravel slate
75	21-7869	f	18	0-7 7-198	shale and clay slate
76	21-2724	f	10	0-65 65-173	gravel and clay shale
77	21-8196	s	3	0-6 6-295	dirt and shale limestone
78	21-8166	s	15	0-6 6-10 10-148	clay and cobbles brown shale slate
79	24-16057	f	12	0-36 36-175	clay and gravel slate
80	21=2072	f	20	0-25 25-35 35-45 45-50 50-84	boulders gravel and boulders fine sand gravel and boulders sand and gravel
81	24-10207	s	20	0-50 50-91	sand sand and gravel
82	24-10038	s	15	0-90 90-114	sand limestone
83	**24-13786**	s	12	0-30 30-60 60-75	sand and gravel clay clay and limestone
84	24-4649	f	20	0-83 83-90	clay and gravel gravel
85	24-14456	s	30	0-20 20-100 100-145	clay clay and sand limestone
86	24-14004	s	15	0-20 20-65 65-88	sand clay clay and limestone
87	24-24435	s	15	0-2 2-11 11-14 14-25 25-40 40-80 80-140	topsoil sandy clay and gravel boulders gravel sand and gravel gray clay limestone
88	24-1295	f	7	0-98	sand, gravel and boulders
89	24-1601	f	10	0-10 10-45 45-51 51-71	sandy clay gravel sand gravel
90	24-17555	s	10	0-26 26-64 64-125	gravel silt limestone
91	24-4682	f	10	0-78	clay and gravel
92	24-1876	f	9	0-32 32-38 38-44 44-50	clay sand and gravel gravel and slate chips slate
93	24-12765	s	5	0-20 20-125	gravel and limestone limestone
94	24-16465	s	12	0-45 45-128	sand and gravel limestone
95	24-5047	f	15	0-61 61-85	sand and gravel slate
96	24-6433	f	20	0-24 24-48	sand sand and gravel
97	24-14444	s-f	4	0-140 140-225	gravel, sand and clay blue shale
98	24-17102	s	8	0-58 58-60	sand and gravel slate
99	24-17572	f	12	0-53	sand and gravel
100	24-6477	f	10	0-53	sand and gravel
101	24-6464	f	3	0-24 24-30 30-40 40-147	sandy clay and gravel boulder gray clay and gravel slate
102	24-16997	s	2	0-64 64-128	sand, clay and gravel gray shale
103	24-6193	f	15	0-70 70-95	sand and clay clay and gravel
104	24-1556	f	12	0-100 100-350	sand and clay slate
105	24-14411	s	30	0-90 90-135	clay and gravel slate
106	24-18473	s	7	0-30 30-600	overburden shale
107	24-14442	s	20	0-30 30-98 98-105	sand and gravel clay gravel
108	24-14790	s	20	0-120 120-131	clay gravel
109	24-14005	f	12	0-50 50-90 90-95	sand and clay clay slate and clay
110	24-5889	f	15	0-35	sand and gravel
111	24-16083	f	20	0-10 10-20 20-40 40-56 56-73	overburden gravel sand fine sand and gravel blue shale
112	24-14958	s	10	0-10 10-55 55-78 78-175	sand sand and gravel gray clay slate
113	24-17472	f	5	0-25 25-150	clay and gravel shale
114	24-4131	f	20	0-40 40-60	clay and gravel slate
115	24-16280	f	16	0-30 30-125	clay and gravel slate
116	24-16510	s	10	0-27 27-175	clay and gravel slate
117	24-21965	s	nr	0-19 19-275	gravel shale
118	24-15179	s	8	0-30 30-128	clay and sand slate



EXPLANATION OF MAP UNITS

25 ●	Well or boring with log in Table 1.
200	Approximate elevation of bedrock surface above sea level in feet. Based on well records and geologic borings (table 1), location of rock outcrop, and data in adjoining quadrangles (on file at NJGWS). Contour interval 50 feet. Shown only beneath thick valley fill.
● Figure 9	Photograph Location
▨	250 - 299 feet above sea level
▨	200 - 249 feet above sea level
▨	150 - 199 feet above sea level

Figure 9. Upstream view of the Delaware Water Gap from the Portland, Pennsylvania – Columbia, New Jersey foot bridge. The arched bridge is part of the Erie Lackawanna Railroad, formerly the Delaware, Lackawanna, and Western Railroad that connected Hoboken, New Jersey with Buffalo, New York. The late Wisconsinan glaciation (24 ka) and probably the Illinoian (150 ka) glaciation have extensively scoured the floor of the Delaware River valley creating a deep trough. Depth of glacial scour is estimated at 150 feet (46 m) based on depth-to-rock determined from wells and borings drilled in the valley. The valley in the Portland and Stroudsburg quadrangles is presently filled by late Wisconsinan glacial sediment and postglacial alluvium. Detailed boring records (see table 1 and fig. 6 on Plate 1) show glaciolacustrine sediment buried beneath glaciofluvial sediment and postglacial alluvium, showing that glacial lakes occupied parts of the valley during deglaciation. Elevation contours of the buried-bedrock surface was extrapolated from well and boring records. Contours upstream from Delaware Water Gap in the Stroudsburg quadrangle were estimated by projecting data from the Bushkill and Portland quadrangles. Photo by Ron Witte.

Base from U.S. Geological Survey, 1955.
Topography from aerial phoographs by photogrammetric methods.
Photorevised 1984 from aerial photographs taken 1981.
Polyconic projection. 1927 North American Datum.

SCALE 1:24000

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

MN GN 12 1/2° 222 MILS 0° 02´ 1 MIL

Utm Grid and 1955 Magnetic North
Declination at Center of Sheet

NEW JERSEY
QUADRANGLE LOCATIONS

ELEVATION OF THE BURIED BEDROCK SURFACE OF PART OF THE PORTLAND AND STROUDSBURG QUADRANGLES, WARREN COUNTY, NEW JERSEY AND MONROE AND NORTHAMPTON COUNTIES, PENNSYLVANIA

BY

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2022

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