

The Belvidere quadrangle lies entirely in the Delaware River drainage basin. The elaware River enters the quadrangle flowing southward through a narrow trough underlain by thick deposits of glacial meltwater and alluvial sediment. Outcrops of slate and siltstone sburg Formation) form steep valley walls that confine the valley to a narrow width (3,500 ft. (1,067 m)). South of Macks Bar, the river valley broadens considerably where the underlying rock changes to Cambro-Ordovician dolomite and limestone. The river's course mostly follows bedrock strike except for a large bend northwest of Belvidere where its ourse has been changed during an earlier glaciation. At Foul Rift, large ledges of dolomite form rapids and mark the first place downstream from Port Jervis, New York--a distance of about 38 miles--where the river flows over rock. The Pequest River flows westward through a narrow gap in the New Jersey Highlands before entering the Delaware Valley and flowing ward Belvidere. Just north of the town it is joined by Beaver Brook. These streams also flow over thick deposits of glacial sediment. The only exception is just north of Belvidere where the course of the river, after having been joined by Beaver Brook, lies over bedrock. ohatcong Creek, in the southeastern part of the quadrangle, flows southwestward through a broad strike valley underlain by dolomite, slate, and siltstone, chiefly following the less resistant carbonate bedrock. The quadrangle's physiography is largely the result of differential weathering on chiefly uthwest-trending fold and thrust belts of Lower Paleozoic dolomite, slate and siltstone, and Proterozoic gneiss and granite (fig. 2). Areas of higher elevation are generally underlain by gneiss and granite of Proterozoic age. These uplands rise as much as 1,000 feet (305 m) above the floor of the Delaware River Valley. Topography here is rugged and the landscape is deeply dissected. Ridge lines chiefly follow layering in the bedrock; although, discordant

elationships between elevations of delta topset-foreset contacts, former glacial-lake

morphosequences was first introduced in New England by Jahns (1941) and later refined

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water levels, and lake spillways. The identification of ice-retreatal positions by mapping

by Koteff and Pessl (1981).

trends are common. In such places deep gaps, such as Pequest Gap and the many smaller gaps on Jenny Jump and Scotts Mountains, cut across the regional southwest-trending opographic grain. Areas underlain by slate and siltstone (Martinsburg Formation) are typically of intermediate elevation, consisting of rolling topography of moderate to steep slope hat's deeply dissected in places. Hills and ridges here rise as much as 400 feet (122 m) above the valleys. Valleys are underlain by dolomite and minor limestone and relief is less than 200 feet (61 m). The Delaware Valley in many places contains thick deposits of late Wisconsinan outwash whereas the Pohatcong Valley is underlain by thin deposits of deeply weathered pre-Illinoinan glacial drift (till and stratified drift). Pohatcong Creek is incised as much as 80 feet (24 m) below the older valley floor following a very narrow rock-cut course. he rock surface of the older valley floor is deeply weathered in most places. North of the late Wisconsinan glacial limit, rock outcrops are very abundant because in many places the preglacial cover of loose rock and soil has been removed by the erosive action of the last ice sheet. South of the limit, rock outcrops are fewer and the topography is not as rugged because in many places the rock surface is covered by weathered bedrock and colluvium. PREGLACIAL DRAINAGE

The primary drainage routes in the guadrangle and surrounding area were probably

established well before the Pleistocene. The transverse gaps in the Highlands are possibly relicts of an earlier drainage system that may have flowed in a southeasterly direction. The Delaware River, through headward erosion and stream capture, has enlarged its drainage chiefly by extending its tributaries upstream along the strike of less resistant rock (Witte 997c). In response to the overall lowering of sea level during the Pleistocene, the 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, river valley. Extensive headward erosion by first- and second-order streams has also resulted in the dissection of the older valley floor, and surrounding highlands. The location of Illinoian glaciofluvial deposits in the Delaware Valley (Ridge and others, 1990; Stone and others, 2002) show 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. QUATERNARY GEOLOGY New Jersey's terrestrial glacial record shows that the Laurentide ice sheet reached New Jersey at least three times (Stone and others, 2002) over the last two million years. hese glaciations (fig. 3), following the terminology of Richmond and Fullerton (1986). are rom youngest to oldest the late Wisconsinan (Marine Isotope Stage (MIS) 2), late Illinoian IIS 6), and pre-Illinoian G (MIS 22) or older and possibly more than one glaciation. Braun (2004) cited evidence of four glaciations in Pennsylvania: late Wisconsinan, late Illinoian pr pre-Illinoian B (MIS 12), pre-Illinoian D (MIS 16), and pre-Illinoian G (MIS 22). Similar to New Jersey's oldest glacial deposits, those 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 either side of the Delaware River. The youngest glacial deposits laid down during the late Wisconsinan substage provide the clearest record of glaciation. he glacial record indicated by the Illinoian and especially the pre-Illinoian deposits is nuch less clear due to an extensive and complex periglacial and weathering history. Multiple glacial cycles have greatly modified New Jersey and Pennsylvania. Valleys were deeply scoured, and bedrock ridges, hills, and slopes were worn down by glacial erosion. In places, valleys were dammed by ice and glacial deposits, rerouting streams

in valleys dammed by moraine, ice-contact deltaic deposits and ice. These lakes and their associated deposits, and recessional moraines provide a detailed record of deglaciation. e many unweathered and lightly weathered bedrock outcrops north of the terminal moraine show that most of the pre-existing weathered bedrock and surficial material had been removed by glacial erosion. This area lies in stark contrast to that south of the late isconsinan glacial maximum (LGM) where outcrops are far fewer. The LGM also divides the largely glacial landscape to the north and the largely colluvial landscape to the south. Although the effects of glaciation in modifying the landscape are pronounced, these modifications in the older glacial landscapes have been largely masked or removed by periglacial weathering. Based on the sawtooth record of the marine isotope record, Braun 989) indicated that there may have been as many as ten glaciations of a magnitude sufficient to glaciate or introduce a periglacial climate to New Jersey and Pennsylvania. lacial/periglacial periods in New Jersey were short-lived and marked by intense physical weathering. Colluvium, a major weathering product of periglacial climate, 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. Braun (2004) suggested that sub-till dissolution of carbonate bedrock in the Great Valley has been sufficient to overprint the primary glacial topography, particularly on the oldest till (\geq 850,000 yr BP). Constructional knob and kettle lacial topography, subsequently altered by periglacial processes and bedrock dissolution produced a composite topography that Braun (2004) refered to as "pseudo-moraine". The oldest glaciation, named the Jerseyan in Chamberlin and Salisbury (1906) and now

represented by the pre-Illinoian Port Murray Formation (Stone and others, 2002) covered the

quadrangle. The Port Murray drift appears to be chiefly till. It is highly and deeply weathered,

lies a minimum of 60 feet (18 m) above modern valley floors in areas that are protected from

and it lies on weathered bedrock. Constructional topography is not preserved, and the drift

hillslope and fluvial erosion.

and establishing new drainage directions. Most of the eroded debris entrained by the ice

sheets was deposited as till and meltwater sediment. Numerous ice-marginal lakes formed

The second ice sheet reached the study area during the Illinoian stage (150 ka, ka = ousand years ago) and it covered about seventy-five percent of the quadrangle (fig. his glaciation is represented by the Lamington and Flanders Formations (Stone ar others, 2002). These deposits are moderately weathered, and the underlying bedrock is not as weathered as it is beneath the Port Murray deposits. The deposits lie in moder valleys and constructional topography is preserved, although it's subdued, and the drift in many places has not been colluviated off hillslopes. The difference in the distribution of Illinoian and pre-Illinoian glacial drift suggests that uplift and/or a drop in sea level after the pre-Illinoian glaciation had lowered base level. The Delaware River and its tributaries adjusted by downcutting as much as 100 feet (30 m). The position of Illinoian glaciofluvial deposits in the Delaware River valley suggests that most of the erosion may have taken place well before the onset of the Illinoian glaciation. The narrow, rock-walled valleys of the Delaware River, Musconetcong River, and Pohatcong Creek support the above hypothesis. The youngest ice sheet reached the quadrangle during the late Wisconsinan substage of the Wisconsinan stage; approximately 22 to 19 ka (Cotter and others, 1986) (dates for te Wisconsinan and Holocene events are stated in uncalibrated radiocarbon years). Its urthest advance (fig. 3) is generally marked by the terminal moraine (Salisbury, 1902). he deposits of this glaciation are represented by the Kittatinny Mountain and Netcong tills,

and stratified drift of the Rockaway Formation (Stone and others, 2002). They are lightly weathered, generally lie on non-weathered rock, and lie in the modern drainage. During deglaciation the outer part of the ice sheet thinned and its flow became more constrained the northeast-to-southwest orientation of Kittatinny Valley. The lobation of the Kittatinny /alley ice lobe also became much more pronounced (fig. 3). During glacial retreat, meltwater sediment was chiefly laid down in glacial lakes (fig. 3) that occupied parts of the Pequest River valley, and to a lesser extent in small upland basins and valleys (Ridge, 1983; Witte 1997a). These former lake basins were dammed either by stratified drift, moraine, and stagnant ice, or by the margin of the ice lobe. The Belvidere quadrangle was uncovered by e approximately 20 ka to 19 ka based on radiocarbon dates on postglacial sediment in a bog at the base of Jenny Jump Mountain (Cadwell, personal communication) and in Francis Lake (Cotter, 1983) (fig. 3). Meltwater continued to flow down Pequest Valley until the glacier margin retreated out of the Pequest River drainage basin and into the Paulins Kill drainage basin sometime about 18 ka (Witte, 1997a). Following the late Wisconsinan glaciation, cold and wet conditions, and sparse vegetative

nechanical disintegration of rock outcrops by freeze and thaw provided additional sediment. some of which forms aprons of talus at the base of large cliffs in the New Jersey Highlands and shale-chip colluvium along the flanks of the Delaware River Valley. A few small boulder fields were formed where boulders, transported downslope by creep, accumulated at the pase of hillslopes and in first-order drainage basins. These fields, and other concentration boulders formed by glacial transport and meltwater erosion, were further modified by freeze and thaw, their stones reoriented to form crudely shaped stone circles. Gradually as climatic conditions warmed, vegetation spread and was succeeded by types that further imited erosion. Between 14.3 ka and 11.3 ka (Cotter, 1983) lacustrine sedimentation, which had been dominated by clastic material, became enriched in organic material. This transition epresents a warming of the climate such that subaguatic vegetation could be sustained and it also marked a change in terrestrial vegetation from herb (tundra) to spruce and hemlock parkland, and eventually to a closed forest of spruce and hemlock. Forests of oak and mixed hardwoods started to populate the landscape around 9.7 ka (Cotter, 1983). SURFICIAL DEPOSITS

cover enhanced erosion of hillslope material by solifluction, soil creep, and slope wash. The

Non-Glacial Deposits 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 typically forms narrow, sheet like deposits on the floors of modern valleys. Channels, channel scarps, and ow levees are commonly preserved on flood plains along the larger rivers. In the Delaware Valley, the modern floodplain is typically a narrow terrace that lies as much as 12 feet (4 m) above the mean-annual elevation of the Delaware River. This terrace also forms all or parts of the lowest islands in the river's channel. Stream terrace deposits (Qstl, Qstu) include both channel and flood plain sediment, and they lie 15 to 45 feet (5 to 14 m) above the modern flood plain and below meltwater-terrace

deposits. They form two distinct sets (Witte, 1997b) in the Delaware Valley. The lower and younger (Qstl) terrace lies between 20 and 35 feet (6 to 11 m) above the river (measured at height above base flow) and consists of as much as 30 feet (9 m) of overbank fine sand and silt overlying cobble pebble gravel and sand. The underlying gravel and sand are channel-bar and point-bar deposits, and in places, strath terraces of a postglacial river. The Qstl deposits typically form broad terraces that cover large parts of the valley's floor and ank the present course of the Delaware River. The highest parts of the terrace lie next to he Delaware River, on a levee. The levee in a few places is a low ridge that is as much as 6 feet (2 m) high. Mostly, the levee is represented by the highest point on a gently inclined surface that slopes away from the river to the valley wall. At the base of the valley wall, the errace is cut by a shallow channel that typically contains organic deposits. Alluvial-channel scrolls are preserved in many places, especially where the terrace lies on the inside of a large river bend. The 15 foot (5 m) range in elevation of the terrace throughout the valley is due to: 1) as much as 8 feet (2 m) of constructional relief on the terrace, and 2) parts of the terrace may have been lowered by erosion. The differing levels may also be related to local riparian conditions and channel morphology of the postglacial Delaware River. The oldest stream-terrace deposits in the Delaware Valley (Qstu) lie 40 to 48 feet (12 to

15 m) above the modern river and typically consist of as much as 10 feet (3 m) of overbank ne sand and medium sand overlying glacial outwash. This material is eroded in places, exposing the underlying sand and gravel. The Qstu terraces are typically small and flank he younger Qstl deposits. In places, they lie surrounded by Qstl deposits. No dates are available for the Qstu terrace, but based on the age of the Qstl terrace, it is late Wisconsinan in age, and it may mark a transition from glaciofluvial to a postglacial fluvial environment. Alluvial fan deposits (Qaf) are fan shaped deposits that lie at the base of hillslopes at the mouths of gullies, ravines, and tributary valleys. Their sediment is highly variable and is derived chiefly from local surficial materials eroded and laid down by streams draining adjacent uplands. Most of the alluvial fans in the quadrangle are deeply entrenched by odern streams, suggesting that they are probably of late Wisconsinan and early Holocene age when climate, sediment supply, and amount and type of hillslope vegetation were more favorable for their deposition. Organic deposit

glaciation. They formed in glacially scoured bedrock basins and kettles in outwash and oraine that previously contained shallow lakes, in glacial lakes that persisted into the Holocene, in abandoned stream channels on alluvial plains, and in poorly drained areas n ground moraine. These deposits typically consist of peat, underlain by silty peat, muck, nd 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 lacustrine silt and clay. Pe s largely the decayed remains of organic material that had originated in shallow bodies of vater and upon their expiration 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. n addition, muck contains silt and clay washed in from adjacent upland soils (Waksman, Hillslope sediment

Swamp and bog deposits (Qs) are common north of the limit of the late Wisconsinal

Hillslope deposits include colluvium (Qcg, Qcs, Qcu), and undifferentiated alluvium and colluvium (Qac). These deposits are derived from underlying and upslope materia ransported downslope by soil creep, solifluction, earth and debris flows, and rock fall. Colluvium south of the LGM is very widespread and is chiefly derived from weathered bedrock. It mantles most hillslopes and forms thick aprons of material on their lower parts. It also collects in small first-order drainage basins in upland areas. In places colluvium includes thin beds and lenses of sorted. stratified sheet- and rill-wash sand and gravel. Undifferentiated alluvium and colluvium assemblage (Qac) consists of a mixture of alluvium and colluvium that has accumulated in narrow valleys in the upper parts of drainage basins. These deposits in places also include the toe slopes of small colluvial aprons. In Pohatcong Valley, colluvium of Wisconsinan age overlies weathered colluviu presumably pre-Wisconsinan age, and a truncated red soil marks the contact between the two. This stratigraphy supports the hypothesis that the formation of colluvium is cyclic, produced during repeated periods of periglacial climate throughout the Pleistocene.

Glacial Materials Till is a poorly sorted, nonstratified to very poorly stratified mixture of clay- to boulder-sized material deposited directly by or from a glacier. It typically covers the bedrock surface and it is distributed widely throughout the quadrangle. It is generally less than 20 feet (6 m) ick, and its surface expression is mostly controlled by the shape of the bedrock surface. Extending through this cover are numerous bedrock outcrops that show evidence of glacial erosion. Thicker, more continuous till smooths bedrock irregularities and may completely mask them. Very thick till forms drumlins, aprons on north facing hillslopes, recessional moraine, and ground moraine. It also fills narrow preglacial valleys, especially those oriented transverse to glacier flow. Late Wisconsinan till is widely distributed throughout the quadrangle, consisting of compact sandy silt to silty sand containing as much as 20 percent pebbles, cobbles, and boulders. Clasts are subangular to subrounded, faceted, and striated, and clast fabrics indicate a preferred long-axis orientation that is generally parallel to the regional direction of glacier flow. Presumably this material is lodgement till. Overlying this lower compact till is thin, discontinuous, noncompact, poorly sorted silty-sand to sand containing as much as 35 percent pebbles, cobbles, boulders, and interlayered with lenses of sorted sand, gravel, and silt. Overall, clasts are more angular, and clast fabrics lack a preferred orientation or ave a weak orientation that is obligue to the regional direction of glacier flow. This material

appears to be ablation till and flowtill, 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. Presumably the Illinoian and pre-Illinoian tills also consisted of two facies that are recognizable in the youngest till. However, long and complex histories of weathering and erosion, and poor exposures have made it impossible to differentiate the two based on field observations. Late Wisconsinan till has been divided into two types. They are named Kittatinny Mountain (Qwtk) and Netcong (Qwtn) till (Stone and others, 2002), and their lithology was largely dependent on the direction of ice flow over different suites of local source rocks. In some places the composition of till is unlike that of the underlying rock, because glacial flow vas southward across different types of bedrock. Kittatinny Mountain till (Qwtk) is chiefly derived from slate, graywacke, dolomite, and limestone that underlie Kittatinny Valley with secondary amounts of quartzite, quartz-pebble conglomerate, and red sandstone derived om Kittatinny Mountain. Netcong till (Qwtn) is chiefly made up of materials derived from gneiss and granite that underlie Jenny Jump Mountain and the New Jersey Highlands. contacts between the two tills are highly gradational and were interpreted from field observations, and boulder and pebble counts. Qwtk lies in Kittatinny Valley and on the northwest flank of Jenny Jump Mountain and Scotts Mountain where it is mixed with gneiss and granite. Qwtn lies on Jenny Jump Mountain.

Based on their extensive modification by weathering, and overall limited distribution, older tills are not differentiated based on their lithology. Illinoian till (Qit), equivalent to the Flanders Till of Stone and others (2002), is moderately weathered, and lies on weathered bedrock. It is preserved on many hillslopes, and it lies in the modern river valleys. In place its surface is marked by a truncated red soil of presumably Sangamon age. Elsewhere, the soil has been stripped by colluviation. Generally clasts and matrix material are moderately weathered, and dolostone and limestone clasts are leached to depths of at least 12 feet (4). Illinoian deposits in the Delaware Valley appear significantly more weathered due to bification of matrix material and staining of clasts than deposits farther east in the New Jersey Highlands, which look younger. These differences result from differences in parent material with the more carbonate rich drift in the Delaware Valley appearing to be more weathered than the crystalline rich (gneiss and granite) drift found in the Highlands. Also, in situ weathering of drift in the Highlands was attenuated due to colluviation in areas of higher relief and slopes compared to the moderately flat valley floors. Till of pre-Illinoian age (Qpt) is known as the Port Murray Formation, till facies (Stone and others, 2002). It is deeply weathered, thin and patchy, and lies on deeply weathered bedrock. Rubification is extensive. Deposits are generally only preserved in valleys in areas of low relief 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 (Stone and others, 2002). The drift is not found in the

Moraines include the late Wisconsinan terminal moraine, and several smaller recessional moraines. The terminal moraine consists of discontinuous, bouldery transverse ridges that are chiefly made of compact silty sandy to poorly compact sandy till and minor lenses of glaciotectonized substrate (weathered bedrock and older till, colluvium), and water-laid sand, gravel, and silt. It follows a discontinuous looping course through the quadrangle. Its segments have been locally named the Foul Rift, Bridgeville, Jenny Jump Mountain, and Mountain Lake moraines. These features define sublobe and nterlobate geometries of the Kittatinny Valley lobe. R.D. Salisbury and H.B. Kummel (Salisbury, 1902) described in detail the course of the moraine across New Jersey. Their excellent description of its trace through the southern part of Kittatinny Valley and across the Jenny Jump outlier stands today, except for a few areas in the Pequest and Delaware /alleys where outwash was mapped as part of the moraine. The terminal moraine's topography in most places is distinct and easily recognizable to its well-formed ridge and swale or knob-and-swale topography with the ridge and swale opography much more pronounced along the outer margin of the moraine. However, in a places where steep topography constrained its formation, the moraine is very difficult to discern from slightly hummocky ground moraine. Morainal ridges are as much as 500 feet 152 m) in length and typically parallel the moraine's course. Relief is generally less than 25 feet (8 m), although in places it may be as much as 60 feet (18 m). Many depressions

are wet and contain swamp or bog deposits. Other depressions are dry or only contain

and orientation suggest they were formed at the glacier's margin at successive ice-retreatal

positions. The outer edge of the terminal moraine marks the LGM in most places.

seasonal water. In places the moraine is cut by small meltwater channels, whose location

nodern valleys, more often lying as much as 100 feet (31 m) above modern valley floors in

areas that are protected from mass wasting and fluvial erosion.

Belvidere, New Jersey. The pit is named after a nearby section of class-two rapids on the Delaware River formed over dolomite ledge and glacial boulders. The Foul Rift pit provides an exceptional opportunity to study, in three dimensions, glacial valley fill laid down at the ont of the Kittatinny Valley ice lobe, and view a cross section of an end moraine. Figure 4 is a photo composite that summarizes the Foul Rift stratigraphy. Unfortunately, this section is now covered by a very large stockpile of cobbles and small boulders. Because this pit is active, most of the outcrops viewed earlier by the authors (Ridge, 1985) are no longer available for inspection. However, the overall stratigraphy of the pit and character of aterials exposed there have remained consistent. The lower gravel and sand (fig. 4) is glacial outwash laid down in front of the advancing ice sheet (fig. 5). This unit makes up more than half the stratigraphic section at the Foul F t. Based on the distribution of nearby bedrock outcrops and a reconstruction of the buried ock topography (sheet 2; Witte and Stanford, 1995) bedrock beneath the pit floor is about 200 feet (61 m) above sea level, rising upward to the east. Based on this estimate there may be an additional 50 to 75 feet (15 to 23 m) of material beneath the lowest part of the pit por. These stratified materials consist chiefly of matrix-supported planar to cross-stratified cobble-pebble gravel, pebble gravel, pebbly sand, and minor lenses of sand. The provenance of the outwash has a decidedly Delaware Valley lithology. Clasts consist chiefly of dolostone, slate, gravwacke, guartzite, with secondary amounts of red sandstone, Gneiss and granite (Highlands source) account for less than 5 percent of the gravel. These fluvial materials were laid down by meltwater streams that formed a braided

beyond the terminal moraine

Elsewhere, a narrow belt of late Wisconsinan till extends as much as 3,000 feet (914 m) out

The Foul Rift pit lies in the Delaware Valley about two miles south of the village of

pattern of channels and bars across the valley floor. Most of the gravelly beds are bar

Foul Rift Segment of the Terminal Moraine (a view from the inside)

while most of the sandy lenses are channel-fill deposits. Individual beds may be as much as five feet thick, although most are less than two feet thick. Both normal and reverse grading may be observed and grain size changes rapidly in both vertical and horizontal directions. This suggests that these materials were deposited under highly fluctuating water discharges, the result of daily and seasonal meltwater production. In a nearby pit about one mile downstream in the Buckhorn Creek Valley, boulders, some as large as 3 feet (1 m) in diameter, form coarse beds. These features may have been deposited during a meltwater flood related either to an outburst of subglacially trapped meltwater or glacial-lake drainage. In places the stratified materials are cemented with calcium carbonate. The location of the cemented gravel probably represents the former water table where calcium carbonate was precipitated during cycles of wetting and drying. The cementing agent was probably derived from weathered clasts of carbonate rock. Lying above the proglacial outwash is a compact, fissile, sandy-silty till that contains many striated and rounded clasts (as much as 15 percent by volume). Lithology of the clast

fraction is similar to that of the underlying outwash. In places the till contains thin beds, small lenses, and clots of sand, pebbly sand, and pebbly gravel. These intra-unit materials exhibit horizontal to subhorizontal attitudes, typically have pinch and swell boundaries, and have the overall appearance of having been sheared. The lower till contact is typically abrupt and there is very little mixing across boundaries, other than a few clasts that straddle the contact. Elongated clasts show a preferred long axis orientation downvalley (fig. 6) This material appears to be a basal till laid down at the base of the ice sheet when it advanced to its most southern position about 2,500 feet downvalley from the pit. A large part of the till is reworked glacial outwash. The preservation of some primary sedimentary bedding structures within these intra-unit beds suggest that some parts of the outwash were rozen before their incorporation within the glacier's bed. Based on the location of the lower till and that it was deposited during glacial advance, it nay be part of the same till sheet that covers the rock ridge south of the Foul Rift moraine. In places, a thin layer of laminated silt and clay caps the till. This unit has been observed

hundreds of feet southward. The silt and clay bed might be lacustrine, although its depositional setting is unclear. Its location atop the basal till suggests that the glacier had retreated north of the pit location at the time the fine-grained material was deposited. Possibly residual ice downvalley may have temporarily dammed a lake in front of the ice sheet. These materials may have also been deposited in shallow depressions formed on e surface of the till sheet by glacial scour. Lying above the till is a complex section of stratified gravel, sand, and silt. This unit has been the most difficult to decipher in terms of its history because its composition, bedding, and geometry vary throughout the pit. Previous exposures showed that materials ranged from cobble-pebble gravel to clayey silt. Bedding contacts typically exhibit pinch-and-swell traces across the outcrop face, and are sharply truncated in places. Texture ar sedimentary structures show that these materials were laid down by meltwater streams in both fluvial and lacustrine settings. However, the complex geometric relationships between the various layers and lenses of material cannot be explained as a product of deposition but a product of postdepositional deformation. Given that these materials were laid down

elsewhere in the pit. Previous exposures did show that this material extended several

shown by the lower till, deformation was probably caused by ice shove during a readvance of the Delaware Valley sublobe. Exposures dug in 1999, located northeast of those described above, showed large scale ecumbent folds and imbricate thrusts that further support the contention that this material has been ice shoved and probably overridden by ice. Near the upper center of figure 4 and below a moraine parallel ridge, there are several stacked ramp-like structures that decreas n attitude going upwards. Beds of darker-colored material highlight these features. They consist of deformed clavev-silt (fig. 4) similar to the fine-grained materials previously described. In other places the dark-colored beds are till. Most of the deformation is best preserved in the finer-grained materials rather than in the coarser gravels. Apparently the gravelly material was largely deformed by intergranular rotation and sliding whereas the finer material, because of its higher moisture content, and competence, deformed more he ramp-like structures may be a sequence of stacked thrusts that consist of ice-shoved outwash and glacial pond sediment. The stacking may represent several advance and retreat cycles, or the thrusts may have developed during a single readvance. Based on the amount of deformation observed (fig. 4) it appears that deformation attenuates down valley

ductilel

at the margin of an ice lobe and that active ice was present in the Delaware Valley, as

with the highest degree of deformation occurring beneath a moraine-parallel ridge. Based on the composition and morphology of the terminal moraine it is a polygenetic deposit that was formed by the melting out of and release of sediment from the glacier terminus, and the pushing of debris and debris-rich ice at an active glacier margin. Its norphology and its composition were further modified by contemporaneous and postglacial esedimentation due to the melting of buried ice. Recessional moraines in the quadrangle consist of small hummocky deposits near Bridgeville in the Pequest River Valley, and in the Beaver Brook Valley. They form low relief knob-and-swale topography and they consist of a mix of till and stratified materials. Deposits of glacial meltwater streams

Sediment carried by glacial meltwater streams was laid down in the Delaware Valley and its tributaries at and beyond the glacier margin in valley-train deposits (Qwfv), neltwater-terrace deposits (Qwft), and ice-contact deltas (Qwde, Qwdv). Most of this material was transported to the glacier's margin through glacial tunnels and by meltwater streams draining ice free upland areas adjacent to the valleys (Witte, 1988; Nitte and Evenson, 1989). Sediment presumably was eroded from till beneath the glacier and debris in its basal "dirty ice" zone and till and reworked drift 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), meltwater-terrace deposits (Qwft), and delta topset beds (Qwde, 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 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 crossbedded and graded beds are more common Glaciolacustrine sediments were laid down by meltwater streams in ice-contact deltas (Qwde, Qwdv), and lake bottom deposits (Qwlb); all deposited in glacial lakes. Typica deltas consist of many individual lobes that prograded outward from the delta front across the lake floor, thinning and widening with distance (Gustavson and others, 1975). However, in many places the glacial lake basins were small and narrow and individual delta lobes merged and filled the lacustrine basin. If these deposits filled in a sediment-dammed river alley at some distance from their source, they are mapped as Qwdv deposits rather than Qwde deposits. Deltas consist of topset beds of coarse gravel and sand overlying foreset eds 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,

parallel laminated sand and silt with clay drapes. Lake bottom deposits (Qwlb) consist of laminated, rhythmically bedded silt, clay, and very fine sand that has progressively settled out from suspension, and coarser sand and silt carried by turbidity currents in the lake basin. These deposits grade laterally into bottomset beds of deltas and lacustrine fan deposits. In smaller lake basins Owlb deposits may be very sandy due to high rates of deposition from density currents that emanate off the delta Weathered bedroc Weathered bedrock consists of saprolite, decomposition and solution residuum, and rock rubble. It was formed during the Pleistocene throughout a long and complex history of veathering and erosion where the climate varied between boreal conditions during glacial periods to temperate and subtropical conditions during interglacial periods. Weathered bedrock materials in the guadrangle were chiefly derived from gneiss and foliated granite (Qwg), and dolomite. They have only been mapped south of the late Wisconsinan border. North of the late Wisconsinan border, the bedrock is fresh to lightly weathered. Weathered bedrock in this area has largely been removed by the erosive action of the last glaciation. However, in a few places it lies beneath late Wisconsinan drift near the terminal morain

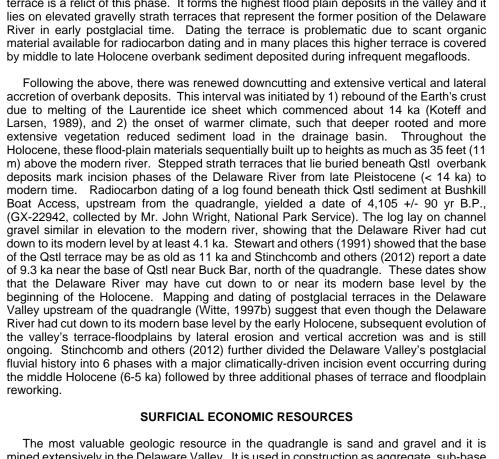
Wisconsinan till. The large number of bedrock outcrops north of the late Wisconsinan acial border highlight the difference between the most recently glaciated landscape and the older colluviated landscape that lies to the south. Weathered gneiss and foliated granite consist chiefly of saprolite, grus, and rock rubble. 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 border, bedrock outcrops are few and generally lie only along ridge crests and the upper parts of very steep hillslopes. Outcrops form tors, subtors, and mounds of irregularly-spaced joint-block boulders that denote areas of subcrop. The surface of most outcrops is granular, and deeply etched. Weathered carbonate rock underlies glacial deposits in the Delaware and Pequest valleys. It 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 veathered bedrock alternates in the subsurface with nonweathered bedrock.

and on Jenny Jump Mountain a nunatak of weathered gneiss is surrounded by late

VALLEY-FILL STRATIGRAPHY The geologic framework of the late Wisconsinan stratified valley-fill deposits shows that meltwater deposits were laid down in two depositional settings. The first includes deposits laid down in vallevs that drained away from the ice sheet. These areas include the Delaware River and Buckhorn Creek Vallevs south of the terminal moraine. Outwash materials here consist of as much as 100 feet (30 m) of glaciofluvial cobble-pebble gravel, pebble gravel and sand. Near Foul Rift, thick deposits of proglacial outwash are consecutively overlain by basal till, outwash, and the terminal moraine (fig. 4). The lower stratified materials here were laid down in front of the advancing Kittatinny Valley lobe. The second setting includes deposits in lake basins that are nearly or completely filled with glaciolacustrine sediment (fig. 5). Typically these basins are small and/or narrow, and opset beds may have been extensively aggraded as deposition in the basin became largely dominated by glaciofluvial sedimentation. Deltas and lacustrine-fan deposits commonly coalesce, and delta plains commonly cover the floor of the entire lake basin, extending far downvalley. Lacustrine-fan deposits may also lie beneath younger deltaic and lake-bottom deposits. Typically these fans lie on till or bedrock at the bottom of the former lake basin and well records show that they do not form continuous sheets across the basin floor. The Delaware Valley north of the Foul Rift moraine and the Pequest River Valley illustrate this

STYLE AND TIMING OF DEGLACIATION Pre-Illinoian Due to the scant distribution and poor preservation of the pre-Illinoinan deposits, and lack of recognizable recessional deposits, the history of the pre-Illinoian deglaciation is problematic. If deglaciation proceeded as it did in the late Wisconsinan, then ice-recessional positions may have been marked by the heads-of-outwash of glaciofluvial deposits laid down in the Pohatcong and Delaware River valleys, and ice-contact deltas laid down in sediment-dammed glacial lakes in the Pequest and Beaver Brook valleys. Except for a few high-standing remnants in the lower parts of the Musconetcong and Pohatcong valleys (Witte and Stanford, 1995), all pre-Illinoian stratified deposits have been removed by erosion.





mined extensively in the Delaware Valley. It is used in construction as aggregate, sub-base material, select fill, surface coverings, and decorative stone. A large part of the local groundwater supply (table 1) also lies in the thick stratified deposits that underlie parts of he Delaware and Pequest valleys. Humus, which is primarily used as a soil conditioner, is found in the many bogs and swamps that generally lie north of the late Wisconsinan border. Most of the peat is of reed and sedge type with organic content varying between 60 and 96 percent (Waksman, 1943). In the Belvidere quadrangle it is of limited extent, found only in a few kettles. Other surficial materials that are of limited economic importance include clay for ceramic materials and bricks. Clay is chiefly derived from lake-bottom deposits, deeply weathered older till, and saprolite.

designations are based on Munsell Soil Color Charts (1975), and were determined from naturally moist samples. HOLOCENE Postglacial Deposits **ARTIFICIAL FILL** -- Rock waste, soil, gravel, sand, silt, and manufactured materials put in place by man. As much as 25 feet (8 m) thick. Not shown

DESCRIPTION OF MAP UNITS

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 solid base for roads and railways. ALLUVIUM -- Stratified, moderately to poorly sorted sand, gravel, silt, and minor clay and organic material. Locally bouldery. As much as 25 feet (8 m) 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 sand, and silt in flood plain deposits.

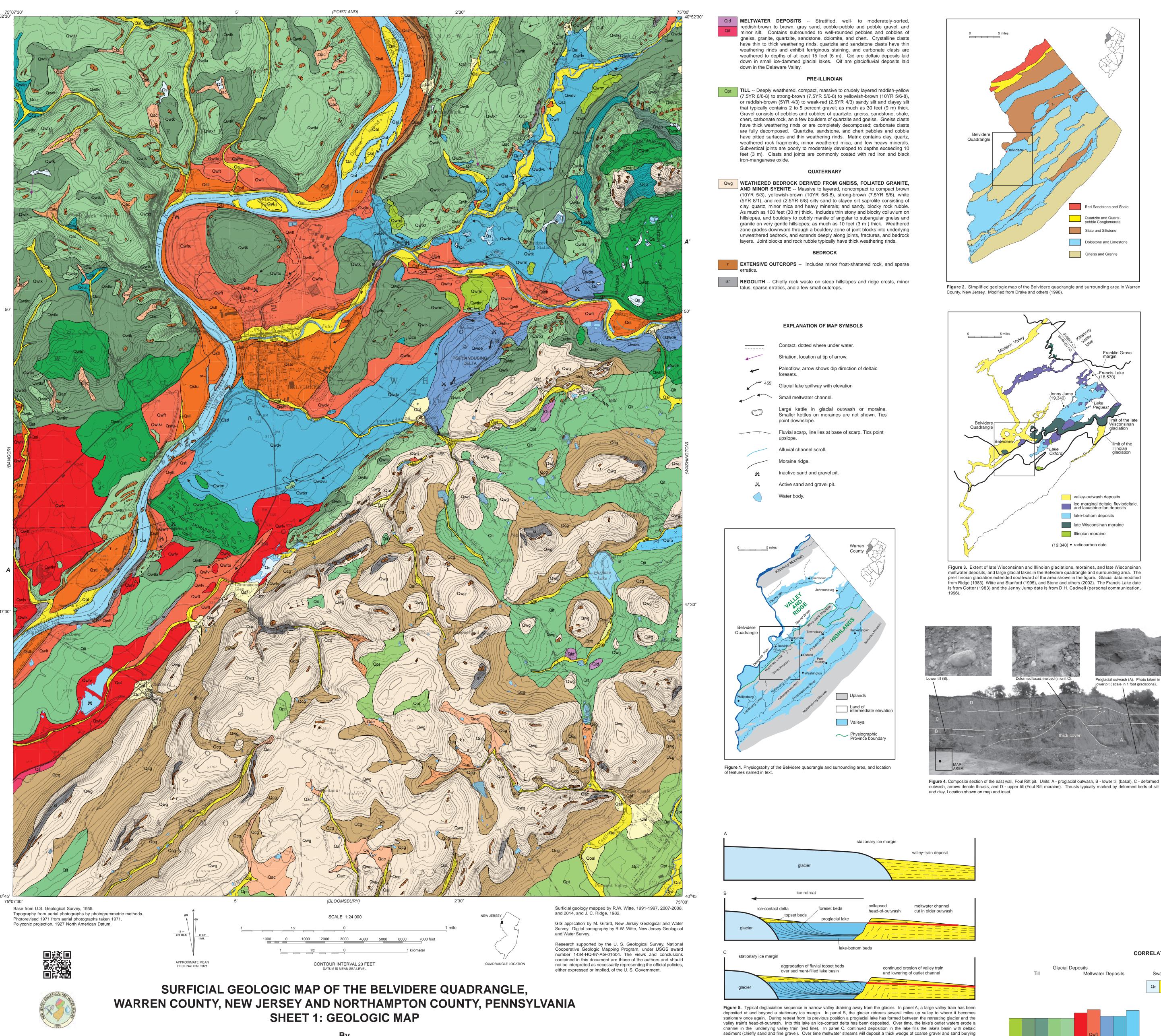
HOLOCENE AND LATE WISCONSINAN Postglacial Deposits

- STREAM TERRACE DEPOSITS -- Stratified, well- to moderately-sorted, massive to laminated, and minor cross-bedded fine sand, and silt in terraces flanking present and late postglacial 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 the Delaware River valley deposits form two distinct terraces. The younger (Qstl) 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. The older (Qstu) 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
- SWAMP AND BOG DEPOSITS -- Peat of reed, sedge, and woody origin, and $^{\perp}$ muck underlain by laminated organic rich silt and clay. As much as 25 feet (8 m) thick. Locally interbedded with alluvium and thin colluvium. In areas underlain by carbonate rock, marl as much as 20 feet (6 m) thick typically underlies the peat and muck. SHALE-CHIP COLLUVIUM -- 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 (3 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.

LATE WISCONSINAN Glacial Meltwater Deposits

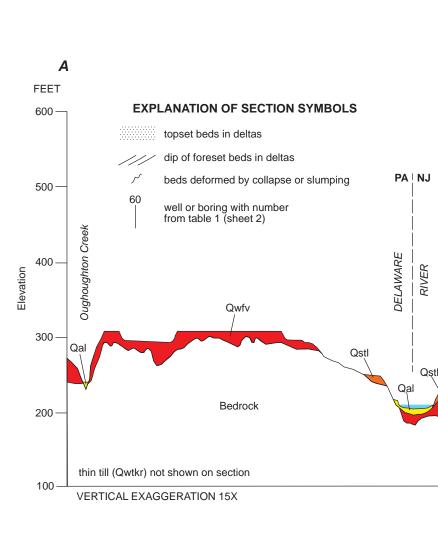
- **VALLEY TRAIN DEPOSITS** -- Stratified, well- to moderately-sorted sand, boulder-cobble to pebble gravel, and minor silt deposited by meltwater streams in Delaware Valley from ice-recessional positions at and extending well beyond (more than five miles (8 km)) the stagnant glacier margin. As much 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.
- GLACIAL LAKE DELTA DEPOSITS -- Stratified, sand, gravel, and silt deposited by meltwater streams in proglacial lakes at and beyond the glacier margin. Includes well sorted sand and boulder cobble to pebble gravel in glaciofluvial topset beds that are as much as 25 feet (8 m) thick. Topsets overlie and grade 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 similar to Qwde but fluvial topset beds may be as much as 65 feet (20 m) thick and deposit may have once filled the valley from wall to wall in a similar way as valley-train deposits. "Qwdvu" indicates older, higher deltas.
- GLACIAL LAKE BOTTOM DEPOSITS -- Parallel laminated, irregularly to rhythmically bedded silt, fine sand, and clay; and minor cross laminated silt, fine sand, and minor clay deposited on the floor of glacial lake basins chiefly by density flows and settling of fines. As much as 100 feet (30 m) thick. **MELTWATER TERRACE DEPOSITS** -- 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. Includes bouldery lag
- **NETCONG TILL** -- Compact, unstratified, poorly sorted yellowish-brown (10YR 5/4), light yellowish-brown (2.5Y 6/4), pale-brown (10YR 6/3) to brown (10YR 5/3) noncalcareous sand and silty sand that typically contains 10 to 20 percent gravel; as much as 80 feet (24 m) thick. Locally overlain by thin, discontinuous, noncompact to slightly compact, poorly sorted, indistinctly layered yellowish-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; as much as 10 feet (3 m) thick. Clast consist of unweathered to lightly weathered gneiss and granite with minor marble, quartzite, sandstone, and carbonate rock. Matrix is a varied mixture of gneiss and granite fragments, quartz, feldspar, mica, heavy minerals, and silt; minor constituents may include fragments of sandstone, siltstone, quartzite, carbonate rock, and clay. Near the limit of the late Wisconsinan glaciation weathered materials derived from preglacial surficial deposits and weathered rock are mixed with the lesser weathered sediment. "Qwtnr" denotes areas of
- KITTATINNY MOUNTAIN TILL -- Compact, unstratified, poorly sorted light olive-brown (2.5Y 5/4) to grayish-brown (2.5Y 5/2), gray (5Y 5/1) to olive-gray ^{Kr} (5Y 5/2) calcareous sandy silt and silty sand that typically contains 5 to 15 percent gravel; as much as 70 feet (21 m) thick. Locally overlain by thin, discontinuous, non compact to slightly compact, poorly sorted, indistinctly layered yellowish-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; as much as 10 feet (3 m) thick. Clasts chiefly are unweathered to lightly weathered slate, silstone, sandstone, dolostone with minor limestone, chert, guartzite, and guartz-pebble conglomerate. Matrix is a varied mixture of nonweathered to lightly weathered quartz, rock fragments, and silt; minor constituents include feldspar and clay. On the northwest flank of Jenny Jump Mountain and the New Jersey Highlands, additional minor constituents include clasts of gneiss, and granite, and mica and heavy minerals in matrix. "Qwtkr" denotes areas of till generally less than 10 feet (3 m) thick, with few to some bedrock outcrops, regolith, and thin colluvium.
- **TERMINAL MORAINE TILL** -- Unsorted, poorly compact sandy-gravelly till with minor layers of very poorly stratified sand, gravel, and silt deposited in hummocky, bouldery, segmented ridges at the margin of the Kittatinny Valley lobe near or at its terminal position. As much as 150 feet (46 m) thick. Locally named the Foul Rift, Bridgeville, and Mountain Lake moraines. **RECESSIONAL MORAINE TILL** -- Unsorted, poorly compact sandy-gravel till with minor layers of very poorly stratified sand, gravel, and silt deposited in low
- relief hummocky knolls at the margin of the Kittatinny Valley lobe. EARLY WISCONSINAN OLDER ALLUVIUM -- Stratified, weathered, moderately- to poorly-sorted sand, gravel and minor silt; as much as 30 feet thick.
- HOLOCENE AND WISCONSINAN ALLUVIUM AND COLLUVIUM, UNDIFFERENTIATED -- Stratified, poorly- to ¹ 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.
- ALLUVIAL-FAN DEPOSITS -- 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. MIDDLE PLEISTOCENE TO HOLOCENE
- **GNEISSIC AND GRANITIC COLLUVIUM** -- Massive to crudely layered, slightly compact, poorly sorted yellowish-brown (10YR /4-8) to dark yellowish-brown (10YR 4/4), brown (10YR 5/3), strong-brown (7.5YR 5/6) 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; as much as 50 feet (15 m) thick. Matrix consists of a varied mixture of quartz sand, weathered feldspar, mica, amphibole, heavy minerals, silt, and clay.
- SLATE, SILTSTONE, AND SANDSTONE COLLUVIUM -- Crudely to moderately layered, noncompact, poorly sorted light yellowish-brown (10YR 6/4) to brownish-yellow (10YR 6/6) or light olive-brown (2.5Y 5/4) silty sand and clayey silt, containing as much as 80 percent lightly to moderately weathered angular to subangular slate chips, tabular pebbles and cobbles of siltstone and sandstone, as much as 30 feet (9 m) thick. Matrix consists of a varied mixture of rock fragments, quartz sand, silt, and clay.
- **UNDIFFERENTIATED COLLUVIUM** -- Poorly sorted, brown to yellowish-brown, ray sand, silt, and minor gravel derived from a mixture of weathered bedrock and till; as much as 10 feet (3 m) thick.
- **TILL** -- Massive, compact, poorly sorted strong-brown (7.5YR 5.6), pale-brown (10YR 6/3), yellow (10YR 7/6) to yellowish-brown (10YR 5/4-6) clayey silt and sandy silt that typically contains 5 to 15 percent gravel as much as 60 feet (18 m) thick. Locally reddish in till rich in weathered carbonate rock. Clasts consist of gneiss, foliated granite, quartzite, quartz-pebble conglomerate, slate, sandstone, chert, and carbonate rock. Crystalline clasts have thick to thin weathering rinds (0.5 in.); carbonate clasts are generally decomposed to depths exceeding 10 feet (3 m). Other clasts have thin weathering rinds (0.1 in.), and pitted surfaces. Matrix is a varied mixture of quartz, rock fragments, silt, clay, weathered feldspar, minor mica, and heavy minerals. Subvertical joints moderately developed to depths of at least 10 feet (3 m).. Iron and iron-manganese stain the surface of clasts, sand grains, and joints to depths of at least 10 feet (3 m). In the Delaware Valley some clasts are reddish due to a

thin coating of iron oxide.





FOUL RIFT MORAINE

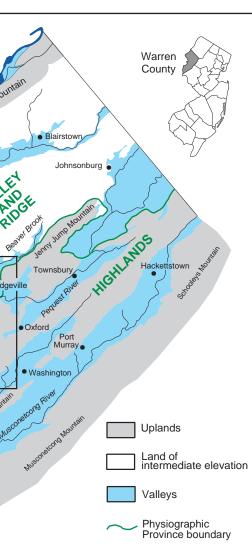


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Bedrock

SURFICIAL GEOLOGIC MAP OF THE BELVIDERE QUADRANGLE. WARREN COUNTY. NEW JERSEY AND NORTHAMPTON COUNTY. PENNSYLVANIA **OPEN-FILE MAP OFM 135**



the ice-contact delta.

MOUNTAIN LAKE

MORAINE

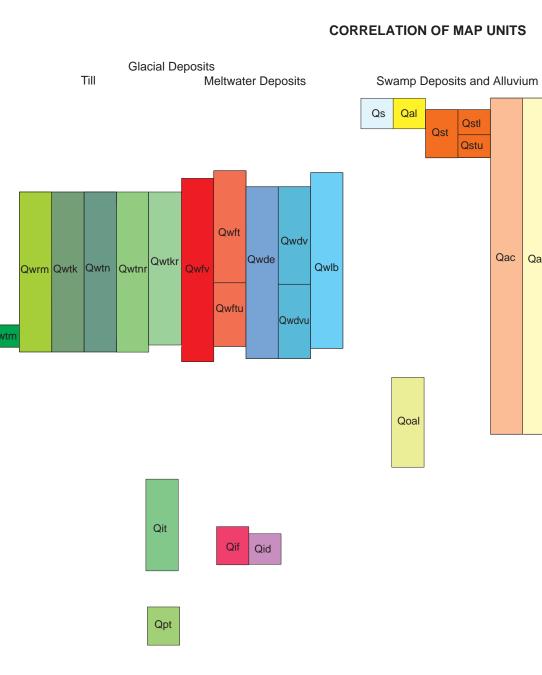
BRIDGEVILLE

Bedrock

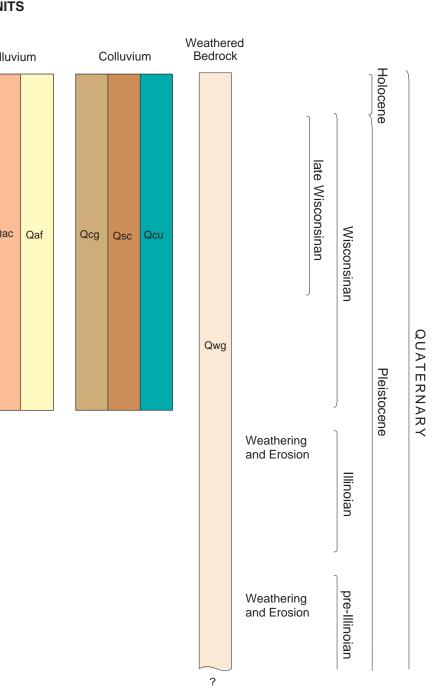
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CORRELATION OF MAP UNITS



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

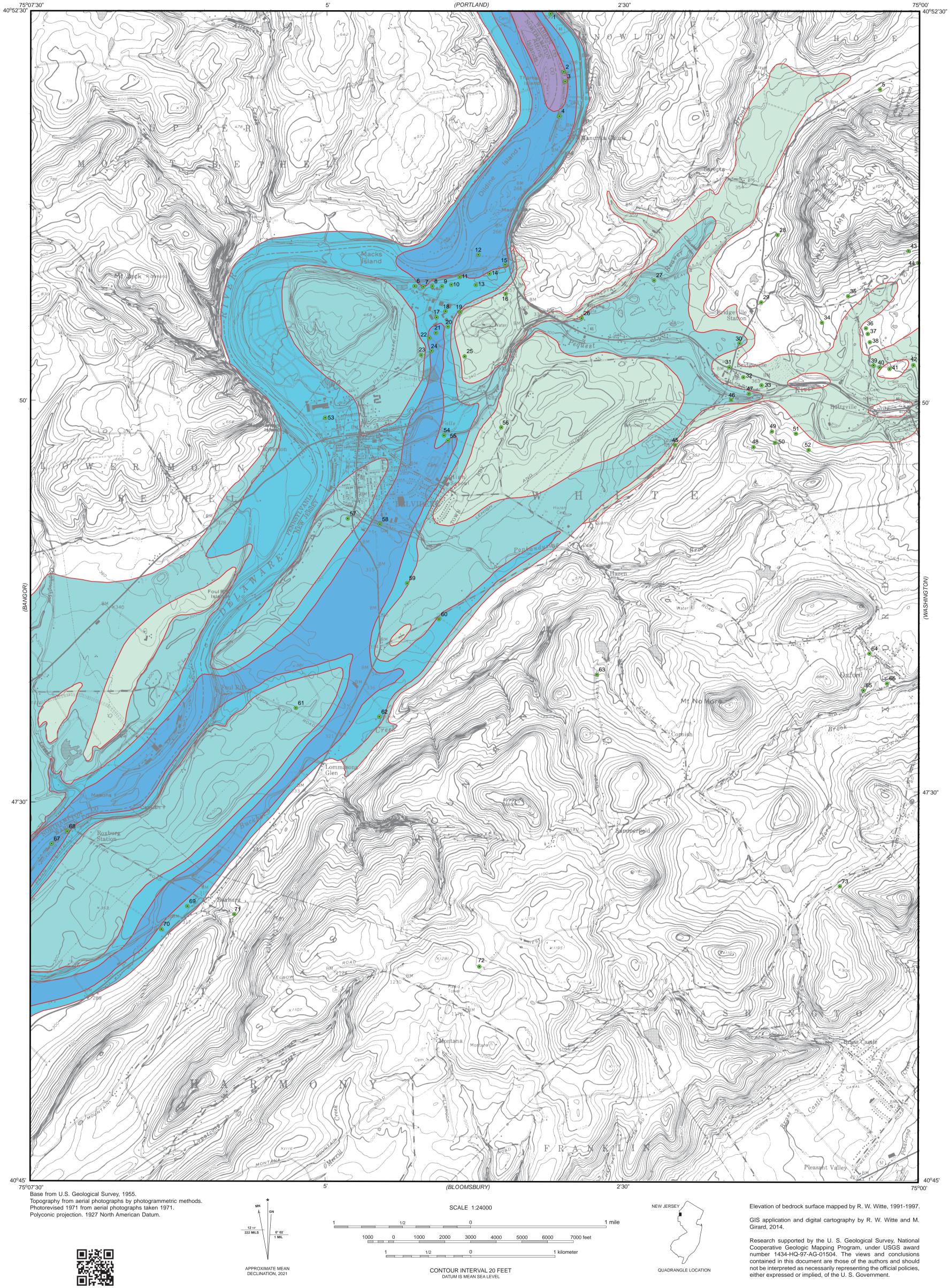
Prepared in cooperation with the U.S. GEOLOGICAL SURVEY NATIONAL GEOLOGIC MAPPING PROGRAM

SURFICIAL GEOLOGIC MAP OF THE BELVIDERE QUADRANGLE WARREN COUNTY, NEW JERSEY AND NORTHAMPTON COUNTY, PENNSYLVANIA **OPEN-FILE MAP OFM 135** SHEET 2 OF 2

 Table 1. Records of selected wells in the New Jersey part of the Belvidere quadrangle.
The listed wells were drilled for private and public water supply, and exploration. Wells listed with a NJDEP permit number are from the files of the Bureau of Water Allocation and Well Permitting, Division of Water Supply and Geoscience, New Jersey Department of Environmental Protection. All other records are from exploratory borings that are on file at the New Jersey Geological and Water Survey. The location of wells listed with NJDEP numbers are based on tax maps, and they are generally accurate to 500 feet of the actual location. The location of exploratory borings (EB) are based on detailed site maps, and they are generally accurate to 100 feet of the actual location.

Well No.	NJDEP permit number	Discharge reported by driller in gallons per minute	Depth in feet below land surface	Driller's Log
1	24-24085	30	0-114 114-348	sand, gravel, clay, and silt slate
2	24-22928	30	0-55 55-100 100-134 134-150	sand and gravel gray clay clay shale
3	24-23978	19	0-22 22-40 40-130 130-144 144-165	clay and gravel gravel soft silt and clay broken slate slate
4	24-4078	none reported	0-47 47-103 103-113	sand and cobbles blue clay gravel
5	24-13378	8	0-90 90-180 180-200 200-248	gray clay and gravel granite brown granite soft sandstone with layers of hardpan
6	EB	none reported	0-91	depth to rock
7	EB	none reported	0-118	depth to rock
8	EB	none reported	0-117	depth to rock
9	EB	none reported	0-112	depth to rock
10	EB	none reported	0-128	depth to rock
11	EB	none reported	0-90	gravel
12	EB	none reported	0-38 38-39 39-72	brown fine to medium sand clay fine to medium sand, and some gravel
13	EB	none reported	0-109	depth to rock
14	EB	none reported	0-84	depth to rock
15	EB	none reported	0-115	gravel
16	EB	none reported	0-37 >37	gravel rock
17	EB	none reported	0-124	depth to rock
18	EB	none reported	0-125	depth to rock
19	EB	none reported	0-147	sand and gravel
20	EB	none reported	0-151	depth to rock
21	EB	none reported	0-147	depth to rock
22	EB	none reported	0-145	depth to rock
23	EB	none reported	0-145	depth to rock
24	EB	none reported	0-118	gravel
25	EB	none reported	0-140	sand and gravel
26	24-850	40	0-35	sand and gravel
27 28	24-1154 24-14655	8	0-93 0-22 22-68 68-160 160-198 198-300	sand and gravel brown soil and rock mix sand and gravel brown clay brown sand and gravel limestone
29	24-13691	20	0-20 20-73	sand and gravel limestone
30	24-15502	12	0-82 82-104 104-175	sand and gravel brown clay and rock mix limestone
31	24-1153	10	0-20 20-57	gravel and boulders hard limestone
32	24-5476	20	0-20 20-50	overburden with boulders sand and gravel
33	24-15097	25	0-2 2-20 20-30 30-73	overburden sand and gravel heavy gravel granite
34	24-17094	18	0-38 38-220	sand, clay, and gravel soft yellow and gray limestone
			-	

36	24-19526	none reported	0-138 >138	sand, brown clay, and gravel rock
37	24-17188	none	0-100	clay and gravel
38	24-15789	12	0-15 15-82 82-162	brown soil sand and gravel limestone
39	24-21579	15	0-20 20-120 120-160	topsoil and boulders silt and clay gravel
40	24-16030	8	0-25 25-90 90-165 165-178 178-200	brown soil and rock sand and gravel brown clay brown soil and rock limestone
41	24-16962	10	0-68 68-144	sand and gravel limestone
42	24-6082	10	0-155	hardpan and gravel
43	24-21434	2	0-25 25-60 60-200 200-275 275-297 297-568	clay and boulders silt and gravel silt, granite ledges, and sand silt broken granite granite
44	24-18073	5	0-1 1-80 80-270 270-300	topsoil sand and gravel bouldery clay rotten shale
45	24-14170	6	0-3 3-30 30-40 40-45 45-50 50-448	overburden sand and gravel large gravel sand and gravel large gravel gneiss
46	24-15471	30	0-15 15-51	clay gravel
47	24-6083	20	0-28 28-48	sand and gravel gravel
48	EB	none reported	0-6 6-25 25-40 40-57	soil brown fine sand, some silt, trace of clay decomposed bedrock gneiss
49	EB	none reported	0-1 1-18 18-34 34-38 38-43	topsoil brown fine sand and some silt gray silt and clay decomposed bedrock amphibolite
50	EB	none	0-2	soil
51	EB	none reported	0-2 2-8 8-13 13-27 27-35	soil clay and silt, some gravel same as above but with increasing cobbles grayish brown to light brown dense, massive cla gravel and some clay, occasional boulder
52	EB	none reported	0-2 2-17 17-45 45-52	topsoil brown fine gravel and fine to coarse sand, some silt brown fine sand, trace to some silt with cobbles and boulders brown and gray silty clay with trace very thin
53	EB	none reported	0-90 >90	sand seams sand and gravel rock
54	24-18692	20	0-75 75-100	gravel broken limestone
55	24-17395	12	0-3 3-103	clay gravel
56	24-24346	25	0-15 15-28 28-190	sand, clay, and boulders sand and gravel limestone
57	24-14207	25	0-10 10-30 30-36 36-252	sand, gravel, and cobblestones sand and cobblestones stones and large rocks limestone
58	24-17521	40	0-110	gravel
59	24-15329	200	0-80 80-350 350-375	overburden limestone void
60	24-16865	25	0-65 65-90 90-102	sand and gravel clay limestone
61	24-17573	9	0-41 41-100	overburden limestone
62	24-9303	60	0-100	sand and gravel
63	24-16275	6	0-85 85-188	sand and clay sandstone
64	24-17032	12	0-70 70-132	clay and sand sandstone
65	24-13830	none reported	0-30 30-85	clay and sand granite
66	24-17112	15	0-75 75-100	clay limestone
67	24-9902	24	0-74 74-94 94-105	sand and gravel white clay and gray rock limestone
68	24-9901	22	0-34	sand and gravel
69	EB	none reported	0-99	sand and gravel
70	EB	none reported	0-95	sand and gravel
71	24-13013	13	0-60 60-275	sand and loose rock granite
70	24-14955	50	0-20 20-35	clay sandstone
72			35-78	gray granite





EXPLANATION OF MAP SYMBOLS

²⁵ • Well or boring with log in Table 1.

Approximate elevation of bedrock surface beneath thick valley fill. Based on records of wells and boring (Table 1), location of rock outcrop and thin till areas, and data in adjoining quadrangles (Witte and Stanford, 1995), Elevation of bedrock surface at wells is determined by

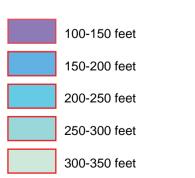


scale = 4 feet

Β NE Rose plot of the azimuth of elongated clasts (> 3 in.), measured in the upper till that makes up the Foul Rift moraine. 20 30 40 30 20 = 30 sector size = 10 degrees vector mean = $S 39^{\circ} W$ SW

Figure 6. Upper till exposed along the north rim of the Foul Rift pit (A), and rose plot showing alignment of long axes of elongate clasts in the till (B). The till has a compact, fissile, sandy-silty matrix containing by volume 7 to 10 percent subangular to subrounded stones. Many stones are striated and elongated clasts have a pronounced downvalley fabric. Although the till forms part of the Foul Rift moraine, it has characteristics of a basal till. It may represent a subglacial till facies associated with a push moraine.

subtracting the depth to bedrock reported in well and boring logs from the ground surface elevation of the well or boring. Contour interval 50 feet.







SURFICIAL GEOLOGIC MAP OF THE BELVIDERE QUADRANGLE, WARREN COUNTY, NEW JERSEY AND NORTHAMPTON COUNTY, PENNSYLVANIA SHEET 2: ELEVATION OF BEDROCK SURFACE

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