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SURFICIAL GEOLOGY OF THE SONESTOWN 7.5-MINUTE QUADRANGLE

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EXPLANATION OF MAP UNITS

f **FILL:**
Rock fragments and/or soil material; typically in road, railroad, dam, or mine waste embankments; up to several ten's of feet thick.

L **LAKE**

Qa **ALLUVIUM:**
Stratified silt, sand, and gravel, with some boulders; subrounded to rounded clasts; contains localized lenses of silty or sandy clay; more bouldery in upstream reaches, usually is underlain by other unconsolidated material (glacial deposits); 6 feet (2 m) thick in headward tributary valleys, 10 feet (3 m) or more thick in Muncy Creek valley.

Qat **ALLUVIAL TERRACE:**
Stratified silt, sand, and gravel with some boulders; subrounded to rounded clasts; the deposits form benches running parallel to and a few feet above the present floodplain; usually is underlain by other unconsolidated material (glacial deposits); generally 6 to 20 feet (2-6.5 m) thick.

Qaf **ALLUVIAL FAN:**
Stratified silt, sand, and gravel, with some boulders; subrounded to rounded clasts; having a fan shaped landform; usually is underlain by other unconsolidated material (glacial deposits); 6 feet (2 m) or more thick.

Qw **WETLAND:**
Area with standing water for part of each year; usually underlain by peat, clay, silt, sand, or some combination of those materials beneath which is other unconsolidated material (glacial deposits); thickness of peat usually less than 1.5 feet (0.5 m), overall thickness of unconsolidated material is usually greater than 6 feet (2 m).

Qbc **BOULDER COLLUVIUM:**
Quartz sandstone or conglomerate boulders and cobbles cover more than 50 percent of the ground surface; clasts are generally from 1 to 6 feet (25 cm to 2 m) in diameter; areas of stony colluvium with cobble-sized clasts covering more than 25 per cent of the ground surface lie within the more bouldery material but the forest cover did not

permit their delineation; the subangular to subrounded clasts are tabular to equidimensional; tabular clasts exhibit a strong downslope orientation (near parallel to slope fabric) or form crudely layered lenses oriented downslope; boulders and cobbles are concentrated at the surface of the deposit; clasts are typically sandy silt matrix-supported with lenses of clast-supported material with or without matrix; accumulates in small valleys and headwater areas of tributaries, also occurs as gently sloping, coalescent lobes at the toe-slopes of valley sides; thickness typically 6 to 15 feet (2 to 5 m); variable thicknesses of glacial deposits are often buried under the boulder colluvium.

Qwo **WISCONSINAN OUTWASH:**
Stratified sand and gravel typically forming terraces along the flank of Muncy Creek and Beaver Run valleys. The overall stratification is horizontal with individual strata showing cross-beds, ripples, clast-imbrication, or cut-fill features. Thicknesses of 6 (2 m) to more than 30 feet (10 m) occur in places.

Qwic **WISCONSINAN ICE-CONTACT STRATIFIED DRIFT:**
Stratified sand and gravel with some boulders; often chaotic stratification; some internal slump structures; gently sloping upper surfaces with a few closed depressions; generally not more than 30 feet (10 m) thick; typically deposited in valley side kames; often underlain by till.

Qwt **WISCONSINAN TILL:**
Glacial or resedimented till; texturally a diamict*; poor to multimodal sorting; unstratified to crudely stratified with a clast fabric; striated cobble and boulder clasts are common; typically occurs as a fairly smooth landform with a bouldery surface and little distinct constructional (knob and kettle) topography on hillslopes; upper 3 feet (1 m) is often colluviated, displaying a downslope-oriented fabric; thickness is greater than 6 feet (2 m), is typically 15 feet (5 m), and can be greater than 100 feet (30 m) in buried to partly in-filled valleys.

Qwtm **WISCONSINAN TILL MORAINE:**
Glacial or resedimented till; texturally a diamict; poor to multimodal sorting; unstratified to crudely stratified with a clast fabric; striated cobble and boulder clasts are common; typically occurs as an indistinct moraine [less than 10 feet (3 m) of local relief on recognizable knobs and swales or kettles] or as a distinct moraine (more than 10 feet of local relief produced by distinct knobs and swales or kettles) on hillslopes; upper 3 feet (1 m) is often colluviated, displaying a downslope-oriented fabric; thickness is greater than 6 feet (2 m), is typically 15 feet (5 m), and can be greater than 100 feet (30 m) in buried to partly in-filled valleys.

*** diamict -** a nonsorted or poorly sorted, unconsolidated deposit that contains a wide range of particle sizes, commonly from clay to cobble- or boulder-size, and rounded and/or angular fragments with a clayey, silty, or sandy matrix depending on the local source bedrock.

Qwtb **WISCONSINAN BOULDERY TILL:**
Glacial or resedimented till with a boulder-mantled surface (more than 50 per cent of ground surface boulder covered); texturally a diamict; poor to multimodal sorting; unstratified to crudely stratified with a clast fabric; striated cobble and boulder clasts are common; typically occurs in the lee of bedrock knobs as a fairly smooth landform but sometimes shows a distinct constructional (knob and kettle) topography on hillslopes; upper 3 feet (1 m) is often colluviated, displaying a downslope-oriented fabric; thickness is greater than 6 feet (2 m), is typically 15 feet (5 m), and can be greater than 100 feet (30 m) in buried to partly in-filled valleys.

Qwtf **WISCONSINAN FLOW-TILL:**
Resedimented till deposited as a series of debris flows that travel down-valley from the glacial ice front; texturally a diamict; crudely stratified with a variable clast fabric; striated cobble and boulder clasts are common; typically occurs as a bouldery surfaced terrace like landform along the sides of valleys leading away from the ice front; upper 3 feet (1 m) is often colluviated, displaying a downslope-oriented fabric; thickness is 6 feet (2 m) to more than 30 feet (10 m).

Qwil **WISCONSINAN AND ILLINOIAN LAG:**
Discontinuous cobbly mantle of subrounded sandstone clasts, some of which are erratics; the cobbles may lie directly on bedrock residuum or be underlain by less than 6 feet (2 m) of matrix-supported diamict; the diamict is a mix of residual and glacial derived material whose clasts show a downslope orientation that indicates the material is colluvium.

Qwit **WISCONSINAN AND REWORKED ILLINOIAN TILL:**
Glacial or resedimented till; matrix-supported diamict; matrix is clayey silt in areas of shaly bedrock, clayey sand in areas of sandstone bedrock; clasts are dominantly sandstone and conglomerate of cobble to boulder size; striated clasts are occasionally observed at the surface or below the surface in outcrops; poor to multimodal sorting; unstratified or with a fabric of clasts dipping gently toward the direction of ice flow; upper 0.5 to 3 feet (0.2 - 1 m) is often less weathered material underlain by more weathered material; upper 3 to 6 feet (1 - 2 m) is colluviated, displaying a downslope-oriented fabric; usually 6 to less than 30 feet (2 to 10 m) thick.

Qil **ILLINOIAN LAG:**
Discontinuous cobbly mantle of subrounded sandstone clasts, some of which are erratics; many cobbles show weathering rinds or are completely rubefied: the cobbles may lie directly on bedrock residuum or be underlain by less than 6 feet (2 m) of matrix-supported diamict; the diamict is a mix of residual and glacial derived material whose clasts show a downslope orientation that indicates the material is colluvium.

Qit **ILLINOIAN TILL:**

Glacial or resedimented till; matrix-supported diamict; matrix is clayey silt in areas of shaly bedrock, clayey sand in areas of sandstone bedrock; clasts are dominantly sandstone and conglomerate of cobble to boulder size; striated clasts are usually observed below the depth of soil development; poor to multimodal sorting; upper 3 to 6 feet (1 - 2 m) is colluviated, displaying a downslope-oriented fabric; in-situ till often has a clast fabric dipping gently toward the direction of ice flow; typically 6 to less than 30 feet (2 to 10 m) thick.

R **SANDSTONE AND SHALE BEDROCK:**

Bedrock outcrops or less than 6 feet (2 m) of clast-rich diamict of residual and colluvial material overlying bedrock of interbedded red and gray sandstone and shale; often within the late Wisconsinan limit less than 6 feet (2 m) of till overlies the bedrock on flat topped treads of the cliff and bench topography; reddish brown to yellowish brown; clayey silt to sandy silt matrix; clasts are typically matrix-supported with lenses of clast-supported material with or without matrix; tabular clasts generally exhibit a down slope directed orientation within the upper 1.5 feet (0.5 m) to 3 feet (1 m) of the material; on greater than 25 percent slopes, typically less than 3 feet (1 m) overlies bedrock.

ISOCHORES AT 30 AND 100 FEET:

An isochore is the thickness of a deposit measured in a vertical borehole or in an excavation with a vertical face. The isochores drawn on the map sometimes pass from one surficial deposit to another, like from till to ice-contact-stratified-drift. That indicates that a 30-foot thickness of till is next to a 30-foot thickness of ice-contact-stratified-drift or ice-contact-stratified-drift underlain by till, both units together being 30 feet thick.

BEDROCK LEDGE OUTCROP.

2

STRIATION:

Site number is above the arrow. Location and orientation given in Table 2. Point of the head of the arrow marks the location of the striation site.

GLACIAL MELTWATER SLUICEWAY

WISCONSINAN TERMINUS:

As mapped for this project, the long term equilibrium limit that produced morainic topography.

As mapped by Crowl (Crowl and Sevon, 1980), the short term most advanced limit that did not produce morainic topography.

DISCUSSION

Mapping Technique - Surface Distribution of Deposits

The Sonestown 1:24,000-scale detailed reconnaissance surficial geology map (map of unconsolidated materials overlying consolidated bedrock) was produced in four phases. In the first phase, a preliminary surficial deposit map was made using soil mapping (Grubb, 1986, Kohler, 1986), surficial deposit mapping (Lewis, 1884; Leverett, 1934; Denny and Lyford, 1963; Crowl and Sevon, 1980; Cenderelli, 1989; Stathl, 1990), bedrock mapping (Sevon, 1978), and landform analysis using the 1:24,000-scale topographic map and aerial photographs. In the second phase, the preliminary surficial deposit map was verified and/or corrected during twenty person-days or so of fieldwork. In the third phase, the field verified/corrected preliminary surficial geology map was finalized, drafted onto four mylar overlays (contacts, isochores, labels - rock outcrops, and glacial borders - striations - sluiceways), and had a text added. In the fourth phase, Thomas G. Whitfield of the Bureau of Topographic and Geologic Survey digitized the mylars and completed the digital map and produced nine final digital files; geologic contacts, surficial deposit isochors, bedrock outcrops, sluiceways, boulder erratics, striations, till mounds, a Wisconsinan terminus by Braun, and a Wisconsinan terminus by Crowl and Sevon.

The distribution and type of units on the preliminary surficial geology map is primarily a combined parent material and topographic position classification of the soil survey map units. The classification of all soil series by surficial deposit map unit is given in Table 1. Many soil series are common to more than one surficial deposit type. The landform of a specific area is used to decide which surficial deposit type the soil series is most likely related to at that site on the preliminary surficial geology map. The soil series boundaries are manually transferred from the 1:20,000-scale soil survey maps to the 1:24,000-scale topographic map. During the field verification and correction phase many contacts are moved to reflect conditions directly observed in the field. Positions of the boundary lines are estimated by eye using natural and human features that are identifiable on both the soil survey aerial photographs and the topographic map. At some sites a GPS unit was used to better local a contact or feature. Expectable line location error is on the order of 50 to 100 feet on the ground where there are distinct features to tie the boundaries to. Where boundaries cross large featureless areas of forest, line placement error is in the range of 100 to as much as 200 feet on the ground.

The Sonestown surficial geology map was slightly revised and re-released in February 2006. The surficial geology was revised along the northern border to edge match newer surficial mapping on the Eagles Mere quadrangle. The striation data set was changed from a line set to a point set to more accurately match the striation table (Table 2). Several cosmetic changes were also made to the map symbology.

Mapping Technique - Thickness of Deposits

The thickness of surficial deposits is divided into three thickness categories: less than 6 feet (2 m) overlying the bedrock [the contact of the bedrock (R) unit with all other surficial units], 30 feet (10 m), and 100 feet (30 m). The 30 and 100 feet thickness contours are drawn to be a conservative estimate of thickness (at least that thickness present). The thicknesses are determined from sparse water well data and outcrops of the surficial deposits. In most areas the thickness is interpreted on the basis of soil-landform associations and a reconstruction of the preglacial drainage. This reconstruction indicates that most stream valleys have segments partly to entirely filled with glacial deposits. In a few places streams have a deranged pattern where the streams turn abruptly and enter or exit valley segments that are markedly narrower or wider than adjacent segments. These changes are the result of burial of parts of the original dendritic drainage pattern (Braun, 1997).

Quaternary History

Previous Work

Sherwood (1880) noted two striation sites and a Pottsville conglomerate erratic in Penn township (south-western portion of the quadrangle).

Lewis (1884) traced what he considered to be the terminal moraine (southern limit) of glaciation (only a single age of glaciation was recognized at that time) across the area in 1881. That limit as described in the text and shown on a map on page 98, runs close to what is now mapped as the late Wisconsinan aged glacial limit in the southwestern part of the Sonestown 7.5-minute quadrangle. In the southeastern corner of the quadrangle, Lewis' limit continues eastward along the south edge of the Appalachian Plateau (North-Huckleberry Mountain) instead of turning northward around the western end of North Mountain as the limit is presently mapped. Lewis noted that south of the terminal moraine in Jordan Township (southeast Sonestown quadrangle) in the Little Muncy Creek valley there "are deposits resembling till except in the scarcity of scratched boulders". Just south of the quadrangle near Unityville he noted erratic boulders of Pocono sandstone. In Franklin township (south central part of the quadrangle) Lewis observed that the terminus was marked by distinct drift knobs in the valleys of Beaver Dam Run and Little Marsh Run (unnamed valley east of Beaver and Marsh Run valleys on the Sonestown 7.5-minute map) and that morainic topography continued north up Little March Run to the base of North Mountain. In Penn township, (southwest part of the quadrangle) Lewis remarked that the terminal "moraine is indistinct and the region immediately north of it is remarkably free from drift". He suggested that this lack of drift was caused either by the glacier retreating very quickly or only the upper and purer portions of the glacier made it over the Appalachian Plateau that lies immediately to the north of the area. Lewis also observed several striation sites in Penn township with a southwest flow direction and a site in Davidson township (northeast part of the quadrangle) on the floor of Muncy Creek valley where ice flow was almost west, parallel to the trend of the valley.

Chamberlin (1883) showed Lewis' (1884) terminal moraine across Pennsylvania on maps of the terminal moraine in the northeastern U.S. (Plate XXXIII) and the entire U.S. into Montana (Plate XXVIII). He thought that the terminal moraine in northwestern Pennsylvania was deposited during the last glacial advance (his second glacial epoch) but he gave three alternative interpretations for the age of the moraine in northeastern Pennsylvania. His preferred first interpretation was that the margin in Pennsylvania was from an earlier glacial epoch (first epoch of the two he recognized at the time), an Illinoian aged advance using present terminology. The terminal moraine of the second glacial epoch (Wisconsinan) was placed at the south end of the Finger Lakes in New York State (Valley Heads moraine). His second interpretation was that the margin in Pennsylvania was from the second glacial epoch (Wisconsinan). The third interpretation was that the second glacial epoch stopped just north of Pennsylvania, building thick glacial deposits in the Susquehanna-Chemung valleys in New York State, and that the terminus in Pennsylvania was from the earlier glacial epoch. For the next 100 years, there would be argument over whether the glacial deposits in northeastern Pennsylvania were older or the same age as those in northwestern Pennsylvania.

Leverett (1934) revised the ages of glaciation in Pennsylvania, noting that Lewis' (1884) terminal moraine marked the edge of the Wisconsinan aged advance (last advance) of the glacier and that there was a discontinuous belt of Illinoian age and older deposits south of Lewis' border. He also considerably revised Lewis' terminal moraine in the Sonestown region, mapping the terminus around the north and west sides of North Mountain rather than on the south side of North - Huckleberry Mountains as Lewis had mapped it. On the south side of the mountain in the Lungerville area Leverett described a red clayey till that he thought was of Illinoian rather than Wisconsinan age. In the south-western part of the Sonestown quadrangle, in contrast to Lewis' broadly arcuate margin across the area, Leverett mapped the Wisconsinan terminus as a series of two to three mile long elongate lobes in the south draining valleys.

MacClintock and Apfel (1944) reassessed the age of the deposits in southern New York and Pennsylvania, interpreting the three moraine belts noted by Chamberlin as different stages within the Wisconsinan glacial advance based on lithologic differences in the tills. The Olean drift of northeastern Pennsylvania was thought to be of early Wisconsinan age while the Binghamton drift of southern New York State and northwestern Pennsylvania was of early or middle Wisconsinan age. They were convinced that the Olean drift was of an earlier Wisconsinan advance than the drift in northwestern Pennsylvania. Only the Valley Heads moraine in New York State was considered to definitely be of late Wisconsinan age.

Denny and Lyford (1963) retraced the Wisconsinan terminus across the Sonestown quadrangle and produced a map (p.13) showing lobes of ice projecting only 0.5 to 0.75 miles down each of the south draining valleys. They observed the elevation of the terminus in the valleys and on the intervening hilltops to produce ice surface profiles near the terminus (p.13) in each of the south draining valleys. They show the ice profile in Beaver Run valley to be 450-500 feet per mile in the last mile to the terminus. Using their map, the ice profile was calculated in Little Indian Run to be 720 feet per mile in the last 0.5 mile to the terminus and in Big Run to be 640 feet per mile in the last 0.5 mile to the terminus. Denny and Lyford (1963) also show in the Sonestown quadrangle portion of their glacial geology map of the region (Plate 3) a striation location between the west end of North Mountain and Muncy Creek valley and a glaciofluvial gravel deposit along the south side of Muncy Creek at the west edge of the Sonestown quadrangle. On pages 25-28 they give a Parent Material - Soil Series classification table like

Table 1 in this report. With regard to the age of the deposits, they agreed with MacClintock and Apfel (1944) that the Olean glacial drift in northeastern Pennsylvania was of early Wisconsinan age.

Muller (1977) argued that the Olean drift of northeastern Pennsylvania was of middle Wisconsinan age. The Kent drift of northwestern Pennsylvania (White and others, 1969) was determined to be of late Wisconsinan age by radiocarbon dating.

Crowl and Sevon (1980) retraced the Wisconsinan terminus across the entire area of northeastern Pennsylvania. Crowl mapped the terminus across the Sonestown quadrangle and his terminus is shown on the map along with the terminal position determined from this work. Crowl's terminus is near to Leverett's in the south draining valleys and Denny and Lyford's (1963) in both the valleys and intervening hilltops. Near the eastern edge of the quadrangle, Crowl placed the terminus at Lungerville while Denny and Lyford (1963) placed the terminus about 0.5 mile west of that.

Crowl and Sevon (1980) calculated ice surface gradients along the terminus wherever the ice flow was near parallel to a mountain front (p.16). Their gradients rarely exceeded 300 feet per mile (57 m/km) and they thought the best gradient was 225 ft per mile (43 m/km), measured along the front of Allegheny Ridge in the adjacent Picture Rocks quadrangle. They note that Denny and Lyford (1963, p.13) calculated ice gradients that were often 300 feet per mile or higher. Denny and Lyford (1963, p. 13, profile HH') also gave an ice gradient along the front of Allegheny Ridge of 217 feet per mile (measured off their map rather than their profile graph). From current striation data (Table 2), the Allegheny Ridge ice gradient should more appropriately be measured along a line parallel to the terminus edge and perpendicular to the elevation contours of Denny and Lyford (1963, p.13). That yields an ice surface gradient of 257 feet per mile. These three different measurements of the ice gradient along Allegheny Ridge differ by only 25 feet per mile, probably within the error of the measurement, a degree of error also noted by Crowl and Sevon (1980). Crowl and Sevon (1980) never estimated the ice gradient in the smaller valleys.

In the Sonestown quadrangle, Crowl noted that the terminus is marked by a Kame in the Beaver Run valley. Within the terminus "scattered areas of indistinct end moraine or hummocky ground moraine occur, usually in topographic depressions" (Crowl and Sevon, 1980, p.54). (Indistinct end moraine has less than 10 feet (3 m) of local relief on recognizable knobs and swales. Hummocky ground moraine has the same landform as indistinct end moraine but lies north of the 1 to 2 mile (1.6 - 3.2 km) wide terminal moraine belt.) Along the base of the west end of North Mountain, a belt of distinct end moraine trends obliquely northwestwardly up the mountain. (Distinct end moraine has more than 10 feet of local relief produced by distinct knobs and swales or kettles.) Crowl also observed one striation location in the south-central part of the quadrangle showing southwestly ice flow around the west end of North Mountain (Table 2).

Crowl and Sevon (1980), on the basis of radiocarbon dating and degree of weathering, determined that Lewis' terminal moraine and the "Olean drift" throughout northeastern

Pennsylvania was of late Wisconsinan age.

Current Understanding of the Quaternary History and Present Work

During the Quaternary, the Sonestown 7.5-minute quadrangle area was affected by a climate that alternated between cold, glacial-periglacial conditions and warm, humid temperate interglacial conditions. About ten such alternations have affected northeastern Pennsylvania during the last one million years (Braun, 1989, 1994). There is evidence for at least three different glacial advances across the Sonestown area in that there are three glacial limits of distinctly different age to the southwest of the area (Braun, 1994). The farthest to the southwest and oldest glacial limit is considered to be of pre-Illinoian-G age (850 Ka) or older. The next distinct glacial limit is considered to be of either late Illinoian (150 Ka) or pre-Illinoian-B (450 Ka) age and is only about 10 miles (15 km) beyond the most recent, late Wisconsinan (20 Ka) aged glacial limit. Other glacial advances have approached the area and caused severe periglacial activity (Braun, 1989, 1994).

The late Wisconsinan glacier advanced and retreated across the region in a general S20 – 30°W direction (Lesley, 1884; Crowl and Sevon, 1980; Braun, 1997). Within the quadrangle, glacial striations (Table 2) indicate that ice flow radiated out as the Muncy Creek Lowland lobe (Crowl and Sevon, 1980) from the Muncy valley re-entrant in the Allegheny Plateau in the northwestern part of the quadrangle (see map). Ice flow was towards the southeast, as much as S22°E, on the eastern side of the lobe along the west end of North Mountain and south of there. In the central part of the lobe on the southwestern part of the Sonestown quadrangle the ice flow was from was about S10 to 30°W. On the west side of the lobe on the adjacent Picture Rocks quadrangle, the flow becomes almost westerly with striation orientations as much S85°W. Individual valleys also strongly influenced basal ice flow, an example of that is in the northeastern part of the quadrangle where a striation near the floor of the west trending Muncy Creek valley runs S80°W.

The earlier glacial advances across the Sonestown area should have accomplished some erosional work. The trend of the glacial limits and glacial striations of the older glaciations is similar to that of the late Wisconsinan glacier (Braun, 1994). This indicates that the older glaciers moved across the region in about the same direction as the late Wisconsinan ice and the older glaciers should have eroded and deposited in a pattern generally like that of the late Wisconsinan. Preglacial valleys oriented parallel to ice flow would tend to be significantly scoured. Valleys oriented perpendicular to ice flow would have the least scour and be the most back-filled, sometimes becoming completely buried (Braun, 1997). An example of the variable amount of scour in the Sonestown quadrangle occurs in the Beaver Run drainage at Beaver Lake. There, two tributaries on the east side of the Beaver Run valley are hanging 40 to 60 feet above the main valley and descend into the main valley in a series of waterfalls. The tributaries trend east or northeast, transverse to ice flow and were therefore little deepened by scour. The main Beaver Run valley runs north to south, parallel to ice flow, and has been deepened considerably by glacial scour.

In the Sonestown quadrangle the overall deposit pattern is one of bedrock ridges separated by valleys partly filled with 30 to more than 100 feet of glacial till (as delineated by the thickness contours on the map). The original dendritic drainage pattern has been little modified by glacial erosion but has been somewhat modified by glacial deposition. Masses of till, often in excess of 100 feet in thickness, partly to entirely block some segments of individual valleys. This is what occurred on the north-central edge of the quadrangle at Wenonan Falls. There, just south of the falls, is the preglacial valley of Bully Run buried by 100 feet of till capped by 50 feet of sand and gravel. When the glacier melted from the area, Bully Run cut down on the north side of this mass of glacier deposited material and incised into the bedrock side of the valley, forming the present day waterfall. In the headwaters of the West Branch Fishing Creek there is another buried valley just west of the word west in the name of the creek. The fill is about 100 feet thick, between 2100 to 2200 feet in elevation, and is exposed in gullies on the north flank of the valley. The State Gamelands wild game food plots lie on top of the buried valley. A bedrock gorge and waterfall lie immediately south of the buried valley. The same situation also occurs in the next valley to the north, Swanks Run, where 60 feet or so of fill probably underlies another set of State Gamelands food plots there. Both of those valleys have an Illinoian or older aged fill. To the east in Hemlock Run, right at the late Wisconsinan terminus, there are two buried valleys to either side of the present bedrock gorge and waterfall reach of Hemlock Run. One buried valley runs northward along the west side of Hemlock Run while the second buried valley runs northeasterly toward the hollow south of the Roundtop knob. One last bedrock gorge containing waterfall cascades suggesting the presence of a buried valley occurs in the headwaters of the West Branch of Little Muncy Creek where the stream runs just east of Route 42. There the buried valley would lie just east of the present valley. This gorge though also carried meltwater from the edge of the glacier descending the west slope of North Mountain and may simply have been incised by that discharge.

Glacial meltwater also scoured a number of saddles or cols in ridgelines throughout the area. These meltwater sluiceways (double line arrows on the map) develop where ice marginal drainage of the Muncy Valley Lowland lobe spilled over pre-existing saddles in ridges just uncovered by the receding ice. The sluiceways are often bare bedrock with some scoured out plunge pool like depressions though intense post-glacial periglacial activity has shattered and displaced the scoured bedrock features.

In general in the Sonestown quadrangle glacial deposits are relatively thin with extensive areas that are essentially bare bedrock once one moves more than 0.5 to 1.0 mile north or inside of the late Wisconsinan terminus. Lewis (1884, p.130) noted that “Immediately north of the moraine there is a remarkable scarcity of boulders and till, as though either the glacier had retreated very quickly for several miles after beginning to recede from the terminal moraine; or else, as though the ice was so free from transported material as to leave but scanty marks of its passage. The latter explanation is supported by the fact that the Allegheny Mountain lies immediately to the north, which only the upper and purer portions of the ice would flow. Lewis’ explanations of the scarcity of glacial deposits are essentially correct except that the mountains to the north would tend to cause ice stagnation in their lee as the glacier thinned during recession rather than blocking the flow of basal ice. The preferred explanation for the scarcity of deposits at this point is rapid retreat of the glacier with localized stagnation in the northern part of the quadrangle.

At the late Wisconsinan terminus in the southeastern part of the quadrangle, the ice surface gradient, as noted by Denny and Lyford, was exceptionally steep. The terminus mapped in this project (see map) produces gradients of about 300 to 400 feet in first 0.5 mile up-ice from the edge of the glacier (600 to 800 feet per mile) for the valleys of Big Run, Beaver Run, and Little Beaver Run (just east of Beaver Run). These gradients are essentially the same as those determined by Denny and Lyford (p. 9, above). In the central part of the quadrangle where the Muncy Creek Lowland ice lobe wrapped around the west end of North Mountain, the ice was found to be thicker on the north side of the mountain and have a steeper gradient around the west end of the mountain than that mapped by Crowl (Crowl and Sevon, 1980). How the terminus is now mapped around the western end of North Mountain yields, where there is distinct morainal topography to follow, yields a gradient of 550 feet in 1.2 miles or 460 feet per mile. That gradient is almost twice that measured by both Denny and Lyford (1963) and Crowl and Sevon (1980) for the western edge of the Muncy Valley ice lobe along the southern flank of Allegheny Ridge.

This mapping project delineated an almost continuous belt of morainic features along the late Wisconsinan terminus as marked by the Quaternary Wisconsinan till moraine unit (Qwtm) on the Sonestown map. Others, as noted above in previous work, had described the distinct moraine at the western end of North Mountain, kames in the south draining valleys, and patches of morainic topography elsewhere along the terminus. Walking the areas between roads along the terminus showed that indistinct end moraine was almost continuous across the area and often several “push moraine” ridges were present running obliquely down the hillsides, distinctly marking the glacial limit. On the north side of North Mountain several distinct arcuate till ridges were mapped in the Hemlock Run valley and Ship Run valley (see map). To the west of Ship Run valley, conglomerate erratics (see map) mark the glacial limit at the 2420 feet elevation, where the glacier starts descending and wrapping around the west end of North Mountain.

The glacial margin marked by the morainic topography belt on the southern part of the Sonestown map for the most part lies inside the margin mapped by Crowl (Crowl and Sevon, 1980). What Crowl had marked as the outer edge of the late Wisconsinan terminus is a 0.25 to 1.25 mile (0.5 - 1.5 km) wide belt of thin glacial till and till-residuum colluvial lag (Qwil and Qwit map units) that had an abundance of erratics, was draped over much of the hilly landscape, and did not generally show the degree of weathering of the older Illinoian aged glacial deposits farther to the south. This belt may represent a short-lived late Wisconsinan advance of the terminus that added and mixed material into the upper part of pre-existing Illinoian aged deposits. The long-term equilibrium position of the late Wisconsinan terminus is the morainic belt just to the north.

The widest difference between the terminus marked by morainic topography and the erratic rich fringe mapped by Crowl occurs along the south flank of North-Huckleberry Mountain at Lungerville. This is the same place that Lewis originally though the terminus continued eastward along the base of the mountain. This study agrees with Leverett (1934, p.15) that the till at Lungerville is Illinoian in age but further notes that the material is not so deeply oxidized as Illinoian material in the heads of hollows another mile to the south. The edge of a short lived late Wisconsinan advance is probably best placed where Denny and Lyford (1963) put it, about 0.5 mile west of Lungerville (the eastern edge of Qwil area as presently mapped).

On the southern edge and southeast corner of the Sonestown quadrangle, Illinoian or older till deposits remain in the hollows and the toeslope of Huckleberry Mountain, as originally noted by Leverett (1934). The surface of the material is marked by common to abundant sandstone erratics from North-Huckleberry Mountain. The material is intensely oxidized at well-drained sites and many clasts are weathered throughout in both well-drained and poorly drained sites. As noted under the descriptions of the map units Illinoian lag and Illinoian till, the upper part to the entire thickness of the material shows a well-developed downslope fabric. This indicates the upper material has been transported from upslope and is colluvium. Only in the floors of the hollows just above bedrock does the material look liked in situ glacial till with fabric related to basal ice deposition with flow from the north or northwest (northwest because this is the eastern side of the Muncy valley lobe).

As the glacier receded north of the Sonestown area, cold periglacial climate conditions prevailed in the area for several thousand years. At that time exposed sandstone ledges were frost shattered and the blocks transported downslope by various processes collectively known as gelifluction (Braun, 1997). This activity produced the mantle of bouldery colluvium on the toe-slopes and hollows of North-Huckleberry Mountain. In a few areas on the mountain where plant cover was sparse, patterned ground features indicative of periglacial frost activity such as stone rings and stone stripes where observed. The late Wisconsinan glacial till deposits themselves have been "mobilized" on the slopes by gelifluction. On the upper to middle parts of the slopes, the upper 1.5 to 3 feet (0.5 to 1 m) of material is a till-derived colluvium material (Braun, 1994 and map units descriptions above). That material often shows a well-developed downslope fabric (tabular clasts near parallel to the surface slope). On the lower parts of the hillslopes the till derived colluvium often reaches a 3 to 6 feet (1 - 2 m) thickness (Braun, 1994). In the latest Pleistocene, after 13,000 BP (Dalton and others, 1997) and throughout the Holocene, vegetation became well established and organic matter started accumulating in wetlands and lakes in the region. All the natural wetlands in the region are depressions dammed on one or two sides by glacial deposits.

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Table 1. Classification of soil series by surficial geology map unit		
Surficial geology unit	**Sullivan Co. Soil Series**	**Lycoming Co. Soil Series**
FILL (f)	Udorthents (Uo)	Udorthents (Uo)
ALLUVIUM (Qa, Qat, Qaf)	Braceville (Ba), Canadice (Ca), Holly (Ho), Linden (Ln), Pope (Po), Udifluvents (Ud), Unadilla (Un)	Barbour (Ba), Basher (Bc), Holly (Hm, Ho), Linden (Lm, Ln), Tunkhannock (Tu), Udifluvents (Ud), Wheeling (Ws)
WETLAND (Qw)	Aquepts (Ao), Canadice (Ca), Medisaprists Md), Norwich (No),	Nolo (No), Norwich (Nr, Nx),
BOULDER COLLUVIUM (Qbc)	Dystrochrepts (Dy), Ochrepts-rock outcrop (Oc),	Buchanan (Bu), Laidig (Ld, Lb)
ILLINOIAN TILL OR LAG (Qit, Qil); WISCONSINAN & ILLINOIAN TILL OR LAG (Qwit, Qwil)		Albrights (Ab), Allenwood (Al), Alvira (Av, Ax), Hartleton (Hh), Leck Kill (Lk), Shelmadine (Sh), Watson (Wb),
WISCONSINAN OUTWASH (Qwo) & WISCONSINAN ICE CONTACT STRATIFIED DRIFT (Qwic)	Alton (Ag), Braceville (Ba), Chenango (Cn), Rexford (Re), Wyoming (Wm, Wo)	Chenango (Cn), Rexford (Re), Tunkhannock (Tu), Wyoming (Wy)
WISCONSINAN TILL (Qwt, Qwtb, Qwtf, Qwtm)	Chippewa (Cp), Mardin, (Ma, Mb), Morris (Mo, Ms), Norwich (No), Volusia (Vo, Vs), Wellsboro (Wb, Wg)	Bath (Be, Bf, Bs), Lackawanna (La, Lb), Morris (Mo, Mr), Nolo (No), Norwich (Nr, Nx), Swartswood (Sv, Sx), Wellsboro (Wl, Wm), Wurtsboro (Wx)
RED AND GRAY SANDSTONE AND SHALE BEDROCK (R)	Arnot (Ar), Arnot-Rock outcrop (As), Lordstown (Lo, Lp), Ochrepts-rock outcrop (Oc), Oquaga (Og, Os)	Albrights (Ab), Berks (Be), Clymer (Cm, Cn), Cookport (Co, Cx), Hartleton (Hh), Klinesville (KI), Lackawanna (Lb), Leck Kill (Lk), Oquaga (Og), Oquaga and Lordstown (Ox), Rubble land (Ru), Weikert (We, Wk)

Table 2. Sonestown quadrangle glacial striations					
Site	Location		Direction	Topographic Position	Source of data other than this map
	Latitude	Longitude			
1	41° 22' 09"	76° 36' 55"	S 23° W	Hill-top	
2	41° 22' 00"	76° 37' 04"	S 27° W cut S 18° W	Hill-top	
3	41° 22' 08"	76° 30' 21"	S 80° W	Southwest Valley floor	Lewis, 1884
4	41° 21' 48"	76° 34' 35"	S 43° W	North slope	
5	41° 20' 16"	76° 36' 21"	S 56° W	South slope*	
6	41° 20' 16"	76° 34' 31"	S 42° W	Saddle in ridge	
7	41° 19' 46"	76° 36' 20"	S 30° W	East slope*	
8	41° 19' 42"	76° 34' 45"	S 22° W	North slope*	Denny & Lyford, 1963
9	41° 18' 57"	76° 34' 40"	S 08° E	Hill-top	
10	41° 18' 52"	76° 35' 43"	N - S	Hill-top	Sherwood, 1880
11	41° 18' 51"	76° 34' 05"	S 10° W	West slope*	
12	41° 18' 47"	76° 35' 03"	S 11° E	Hill-top	
13	41° 18' 15"	76° 36' 13"	S 09° W	Hill-top	Lewis, 1884
14	41° 18' 08"	76° 34' 43"	S 08° W	Southeast slope*	
15	41° 18' 08"	76° 34' 15"	S 22° E	West slope*	
16	41° 18' 00"	76° 36' 25"	S 17° W	Hill-top	Also Lewis, 1884; Sherwood, 1880
17	41° 17' 42"	75° 37' 01	S 22° W	Hill-top	
18	41° 17' 20"	76° 34' 45"	S 20° E	Hill-top	Also Crowl & Sevon, 1980 but at S 10° W

* Direction slope faces

Sites from other sources of striation data were estimated from verbal descriptions and/or map positions of striation arrows.

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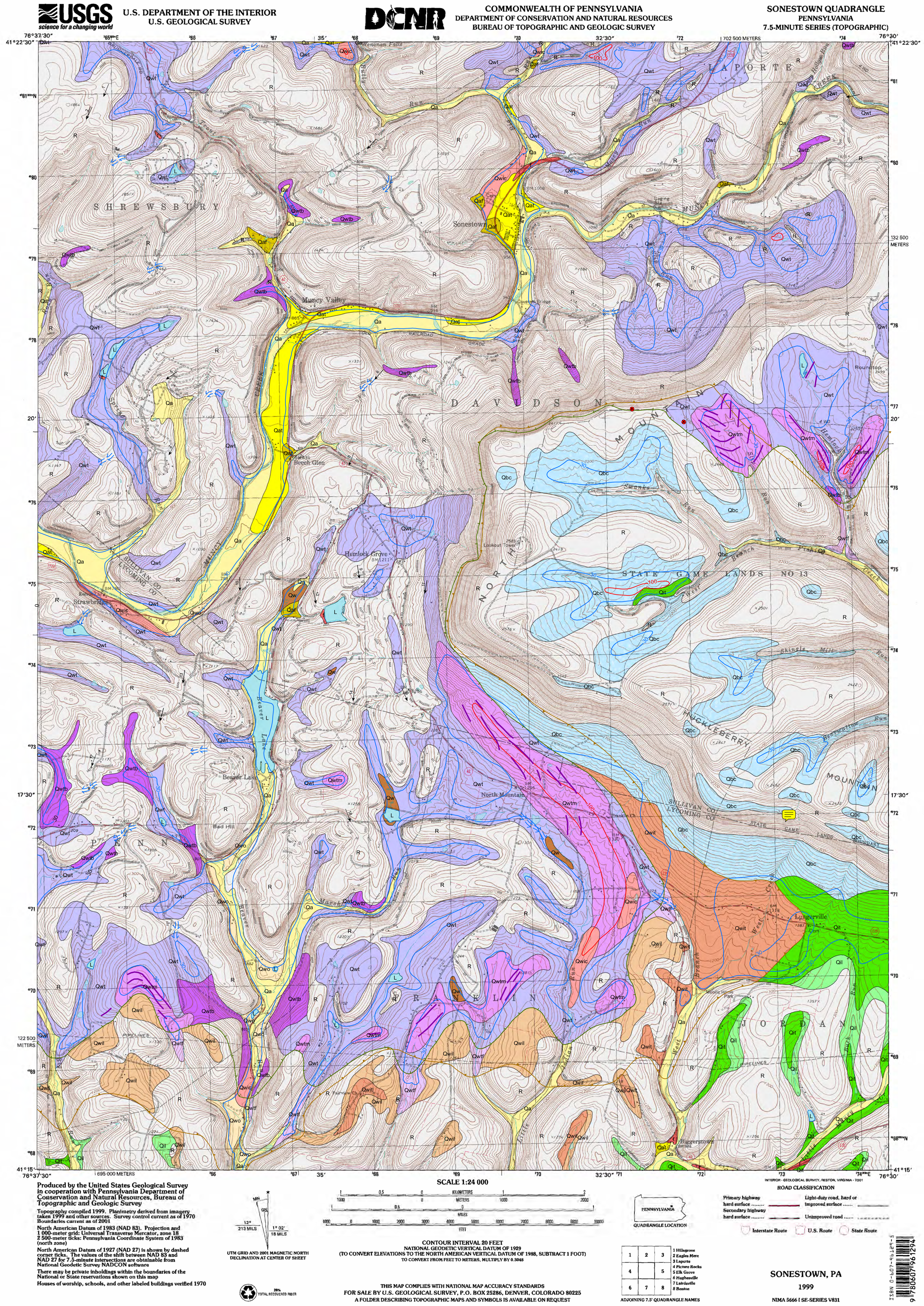


Description of Map Units

f — **fill**
Rock fragments and/or soil material; typically in road, railroad, dam, or mine waste embankments; up to several ten's of feet thick.

L — **Lake**

Qa — **Alluvium**
Stratified silt, sand, and gravel, with some boulders; subrounded to rounded clasts; contains localized lenses of silty or sandy clay; more bouldery in upstream reaches, usually is underlain by other unconsolidated material (glacial deposits); 6 feet (2 m) thick in headward tributary valleys, 10 feet (3 m) or more thick in Muncy Creek valley.

Qat — **Alluvial Terrace**
Stratified silt, sand, and gravel with some boulders; subrounded to rounded clasts; the deposits form benches running parallel to and a few feet above the present floodplain; usually is underlain by other unconsolidated material (glacial deposits); generally 6 to 20 feet (2-6.5 m) thick.

Qaf — **Alluvial Fan**
Stratified silt, sand, and gravel, with some boulders; subrounded to rounded clasts; having a fan shaped landform; usually is underlain by other unconsolidated material (glacial deposits); 6 feet (2 m) or more thick.

Qw — **Wetland**
Area with standing water for part of each year; usually underlain by peat, clay, silt, sand, or some combination of those materials beneath which is other unconsolidated material (glacial deposits); thickness of peat usually less than 1.5 feet (0.5 m), overall thickness of unconsolidated material is usually greater than 6 feet (2 m).

Qbc — **Boulder Colluvium**
Quartz sandstone or conglomerate boulders and cobbles cover more than 50 percent of the ground surface; clasts are generally from 1 to 6 feet (25 cm to 2 m) in diameter; areas of stony colluvium with cobble-sized clasts covering more than 25 per cent of the ground surface lie within the more bouldery material but the forest cover did not permit their delineation; the subangular to subrounded clasts are tabular to equidimensional; tabular clasts exhibit a strong downslope orientation (near parallel to slope fabric) or form crudely layered lenses oriented downslope; boulders and cobbles are concentrated at the surface of the deposit; clasts are typically sandy silt matrix-supported with lenses of clast-supported material with or without matrix; accumulates in small valleys and headwater areas of tributaries, also occurs as gently sloping, coalescent lobes at the toe-

Qwo — **Wisconsinan Outwash**
Stratified sand and gravel typically forming terraces along the flank of Muncy Creek valley. The overall stratification is horizontal with individual strata showing cross-beds, ripples, clast-imbrication, or cut-fill features. Thickness 6 (2 m) to more than 30 feet (10 m) in places.

Qwic — **Wisconsinan Ice-Conract Stratified Drift**
Stratified sand and gravel with some boulders; often chaotic stratification; some internal slump structures; gently sloping upper surfaces with a few closed depressions; generally not more than 30 feet (10 m) thick; typically deposited in valley side kames; often underlain by till.

Qwt — **Wisconsinan Till**
Glacial or resedimented till; texturally a diamict, a nonsorted or poorly sorted, unconsolidated deposit that contains a wide range of particle sizes, commonly from clay to cobble- or boulder-size, and rounded and/or angular fragments with a clayey, silty, or sandy matrix depending on the local source bedrock; poor to multimodal sorting; unstratified to crudely stratified with a clast fabric; striated cobble and boulder clasts are common; typically occurs as a fairly smooth landform with a bouldery surface and little distinct constructional (knob and kettle) topography on hillslopes; upper 3 feet (1 m) is often colluviated, displaying a downslope-oriented fabric; thickness is greater than 6 feet (2 m), is typically 15 feet (5 m), and can be greater than 100 feet (30 m) in buried to partly in-filled valleys.

Qwtm — **Wisconsinan Till Moraine**
Glacial or resedimented till; texturally a diamict; poor to multimodal sorting; unstratified to crudely stratified with a clast fabric; striated cobble and boulder clasts are common; typically occurs as an indistinct moraine [less than 10 feet (3 m) of local relief on recognizable knobs and swales or kettles] or as a distinct moraine (more than 10 feet of local relief produced by distinct knobs and swales or kettles) on hillslopes; upper 3 feet (1 m) is often colluviated, displaying a downslope-oriented fabric; thickness is greater than 6 feet (2 m), is typically 15 feet (5 m), and can be greater than 100 feet (30 m) in buried to partly in-filled valleys.

Qwtb — **Wisconsinan Bouldery Till**
Glacial or resedimented till with a boulder-mantled surface (more than 50 per cent of ground surface boulder covered); texturally a diamict; poor to multimodal sorting; unstratified to crudely stratified with a clast fabric; striated cobble and boulder clasts are common; typically occurs in the lee of bedrock knobs as a fairly smooth landform but sometimes shows a distinct constructional (knob and kettle) topography on hillslopes; upper 3 feet (1 m) is often colluviated, displaying a downslope-oriented fabric; thickness is greater than 6 feet (2 m), is typically 15 feet (5 m), and can be greater than 100 feet (30 m) in buried to partly in-filled valleys.

Qwtf — **Wisconsinan Flow-Till**
Resedimented till deposited as a series of debris flows that travel down-valley from the glacial ice front; texturally a diamict; crudely stratified with a variable clast fabric; striated cobble and boulder clasts are common; typically occurs as a bouldery surfaced terrace like landform along the sides of valleys leading away from the ice front; upper 3 feet (1 m) is often colluviated, displaying a downslope-oriented fabric; thickness is 6 feet (2 m) to more than 30 feet (10 m).

Qwil — **Wisconsinan and Illinoian Lag**
Discontinuous cobbly mantle of subrounded sandstone clasts, some of which are erratics; the cobbles may lie directly on bedrock residuum or be underlain by less than 6 feet (2 m) of matrix-supported diamict; the diamict is a mix of residual and glacial derived material whose clasts show a downslope orientation that indicates the material is colluvium.

Qwit — **Wisconsinan and Reworked Illinoian Till**
Glacial or resedimented till; matrix-supported diamict; matrix is clayey silt in areas of shaly bedrock, clayey sand in areas of sandstone bedrock; clasts are dominantly sandstone and conglomerate of cobble to boulder size; striated clasts are occasionally observed at the surface or below the surface in outcrops; poor to multimodal sorting; unstratified or with a fabric of clasts dipping gently toward the direction of ice flow; upper 0.5 to 3 feet (0.2 - 1 m) is often less weathered material underlain by more weathered material; upper 3 to 6 feet (1 - 2 m) is colluviated, displaying a downslope-oriented fabric; usually 6 to less than 30 feet (2 to 10 m) thick.

Qil — **Illinoian Lag**
Discontinuous cobbly mantle of subrounded sandstone clasts, some of which are erratics; many cobbles show weathering rinds or are completely rubefied: the cobbles may lie directly on bedrock residuum or be underlain by less than 6 feet (2 m) of matrix-supported diamict; the diamict is a mix of residual and glacial derived material whose clasts show a downslope orientation that indicates the material is colluvium.

Qit — **Illinoian Till**
Glacial or resedimented till; matrix-supported diamict; matrix is clayey silt in areas of shaly bedrock, clayey sand in areas of sandstone bedrock; clasts are dominantly sandstone and conglomerate of cobble to boulder size; striated clasts are usually observed below the depth of soil development; poor to multimodal sorting; upper 3 to 6 feet (1 - 2 m) is colluviated, displaying a downslope-oriented fabric; in-situ till often has a clast fabric dipping gently toward the direction of ice flow; typically 6 to less than 30 feet (2 to 10 m) thick.

R — **Sandstone and Shale Bedrock**
Bedrock outcrops or less than 6 feet (2 m) of clast-rich diamict of residual and colluvial material overlying bedrock of interbedded red and gray sandstone and shale; often within the late Wisconsinan limit less than 6 feet (2 m) of till overlies the bedrock on flat topped treads of the cliff and bench topography; reddish brown to yellowish brown; clayey silt to sandy silt matrix; clasts are typically matrix-supported with lenses of clast-supported material with or without matrix; tabular clasts generally exhibit a down slope directed orientation within the upper 1.5 feet (0.5 m) to 3 feet (1 m) of the material; on greater than 25 percent slopes, typically less than 3 feet (1 m) overlies bedrock.

Symbols

30
100

Contours of Total Thickness of Surficial Deposits in Feet
Isochore lines sometimes pass over more than one surficial deposit, indicating total thickness of all deposits encountered.

Bedrock Ledge Outcrops

Boulder Erratics

Braun 2004
Crowl and Sevon 1980

Wisconsinan Terminus
Mapping by Braun shows long term equilibrium limit that produced morainic topography. Mapping by Crowl (Crowl and Sevon 1980) shows short term, most advanced limit that did not produce morainic topography. Tic marks point toward ice.

2

Striations
Site number above arrow. Location and striation orientation in Table 2, listed by site number. Arrow point marks site location.

Glacial Meltwater Sluiceway

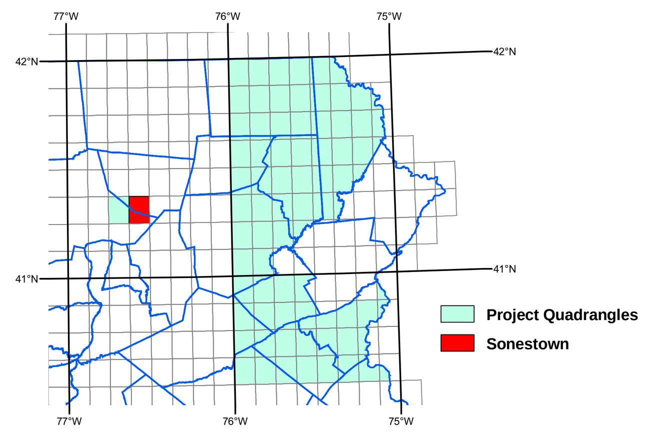
Till Mounds

Surficial Geology of the Sonestown 7.5-minute Quadrangle
Lycoming and Sullivan Counties, Pennsylvania

Geologic Mapping by
Duane D. Braun, Bloomsburg University, 2004

Digital Map Production by
Thomas G. Whitfield, Bureau of Topographic and Geologic Survey, 2004

Surficial Geology Mapping Project Area



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(rev. 02/2006)

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