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SURFICIAL GEOLOGY OF THE ELK GROVE 7.5-MINUTE QUADRANGLE SULLIVAN, COLUMBIA, AND LYCOMING COUNTIES, PENNSYLVANIA

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SURFICIAL GEOLOGY OF THE ELK GROVE 7.5-MINUTE QUADRANGLE

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EXPLANATION OF MAP UNITS

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

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 meters) thick in headward tributary valleys, 10 feet (3 meters) or more thick in the Fishing Creek and West Branch Fishing Creek valleys.

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); 6 feet (2 meters) or more thick. Terraces were mapped only along the Fishing Creek and West Branch Fishing Creek valleys.

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 meters) or more thick. Some fans have a series of levels with younger, lower, less steeply sloped segments inset in older, higher, steeper segments.

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 meter), overall thickness of unconsolidated material is usually greater than 6 feet (2 meters).

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 centimeters to 2 meters) in diameter; 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 headwater areas of tributaries and as a blanket of material on the toe-slopes of valley sides; colluvium thickness typically 6 to 15 feet (2 to 5 meters). Glacial till is often under the boulder colluvium. It was only mapped as a separate unit in hollows and on benches on North Mountain and Huckleberry Mountain southwest of the late Wisconsinan limit.

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 meters) thick; typically deposited in valley side kames; often underlain by till.

Qwicl **WISCONSINAN ICE-CONTACT STRATIFIED DRIFT UNDERLAIN BY GLACIAL LAKE CLAYS:**
Ice-contact stratified drift as described above in Qwic underlain by clay rich proglacial lake sediments. The lake deposits are mostly varves as described below under unit Qwtl. Typically the stratified drift is tens of feet or more (10+ meters) thick and is underlain by a few feet to few tens of feet (1 to 10 meters) of varves. The unit was only mapped at one site in the West Branch Fishing Creek valley upstream of the junction with Painter Run.

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, 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; 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 meter) is often colluviated, displaying a downslope-oriented fabric; thickness is 6 feet (2 meters) to more than 30 feet (10 meters). Only mapped in the valley of Laurel Run.

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 meter) is often colluviated, displaying a downslope-oriented fabric; thickness is greater than 6 feet (2 meters), is typically 15 feet (5 meters), and can be greater than 100 feet (30 meters) in buried to partly in-filled valleys. Locally areas mapped as till may have a thickness of less than 6 feet (2 meters) on hilltops or where there are cliff

top edges in the till mantled cliff and bench bedrock topography. It is expected that in more than 90 percent of the area mapped as till, the till has a thickness of more than 6 feet (2 meters). Large areas of the mountain slopes are covered by boulder colluvium derived from rock ledges high on the mountain side that extends down over till lower on the slopes. Generally the till is considerably thicker than the boulder colluvium and those areas have been mapped as till.

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 meter) is often colluviated, displaying a downslope-oriented fabric; thickness is greater than 6 feet (2 meters), is typically 15 feet (5 meters), and can be greater than 100 feet (30 meters) in buried to partly in-filled valleys.

Qwtm **WISCONSINAN TILL MORAINE:**
Till as described above in Qwt with a well developed knob and kettle land surface topography. Kettles typically have 1 to 10 feet (0.3 to 3 meters) of closure and contain vernal pools.

Qwtl **WISCONSINAN TILL UNDERLAIN BY GLACIAL LAKE CLAYS**
Till as described above in Qwt underlain by clay rich proglacial lake sediments (varves), alternating thin layers of silt and clay. Each layer is usually less than an inch (2.5 cm) thick. A pair of silt and clay layers is called a couplet and represents a single year’s summer (silt) and winter (clay) deposition in a proglacial lake. Clay is usually one quarter or less of the volume of the deposit. At some sites the lake deposits are dominated by sands and silts and represent places where melt-water issued from tunnels in the ice. The lake sediment thickness typically ranges from a few feet to a few tens of feet (1 to 10+ meters). Hill-slopes underlain by varves typically show a stepped appearance due to slope failure in a series of slumps. Such slopes are hazardous to build upon and failure can be aggravated by cut and fill excavations when such slopes are built upon. Typically the overlying till is tens of feet or more (10+ meters) thick. Only present along the sides of the West Branch Fishing Creek valley upstream of the junction with Painter Run.

Qwtbl **WISCONSINAN BOULDERY TILL UNDERLAIN BY GLACIAL LAKE CLAYS:**
Bouldery till as described above in Qwtb underlain by clay rich proglacial lake sediments. The lake deposits are mostly varves as described above under unit Qwtl. Typically the till is tens of feet or more (10+ meters) thick and is underlain by a few feet to few tens of feet (1 to 10 meters) of varves. The unit was mapped only along the

south flank of West Branch Fishing Creek where slumping was prominent south of the village of Elk Grove.

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 meters) of matrix-supported diamict that is a mix of residual and glacial derived material whose clasts show a downslope orientation that indicates the material is colluvium. Mapped only in the southeastern part of the quadrangle.

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 to 2 meters) 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 meters) thick. Mapped only in the southeastern part of the quadrangle.

R **SANDSTONE AND SHALE BEDROCK:**

Bedrock outcrops or clast-rich diamict of glacial, residual and/or colluvial material overlying bedrock of interbedded red and gray sandstone and shale; often forming a cliff and bench topography. The diamict is reddish brown to yellowish brown and has 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 to 3 feet (0.5 to 1 meter) of the diamict. On greater than 25 percent slopes, typically less than 3 feet (1 meter) of diamict overlies bedrock. Locally on broad hilltops and benches the diamict is thicker than 6 feet (2 meters).

SLUMP HEAD-WALL:
Slump scarp, dot on down-dropped side indicates the direction of movement.

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
An abandoned glacial meltwater channel cut into bedrock and/or glacial deposits.

MORAINE RIDGES:
Arcuate to irregular ridges of till a few tens of feet high and a few hundred feet long, probably representing seasonal re-advance of the glacier producing a "push moraine".

WISCONSINAN TERMINUS:
As mapped by Braun for this project, the long term equilibrium limit that produced morainic topography.

As mapped by Crowl (Crowl and Sevon, 1980) and shown where it differs from the limit mapped for this project. Those differences are discussed in the text.

V

VARVES
Clay rich sediments composed of alternating layers of silt and clay deposited in a proglacial lake. Each pair or couplet of layers represents one year of deposition, with the silt layer representing summer deposition and the clay layer representing winter deposition. Each couplet is typically from 1 to 3 inches thick (2 to 8 cm). Close to where meltwater enters the lake, the summer layer becomes thicker and coarser. There, individual varve couplets may be several feet thick with rippled silts and sands of the summer layer overlain by a one inch or so clay drape of the winter layer. In the West Branch Fishing Creek valley, the total thickness of the varve sequences is on the order of tens of feet (see text).

100
30

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 with underlying till, both together 30 feet thick.

DISCUSSION

Mapping Technique - Surface Distribution of Deposits

The Elk Grove 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; Parrish, 1967), surficial deposit mapping (Lewis, 1884; Leverett, 1934; Denny and Lyford, 1963), bedrock mapping (Sherwood and Platt, 1880; White, 1883; Sevon, 1977), 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 field work. An undergraduate geologic field assistant, Stephanie Jones was responsible for the field mapping on the northwest corner of the quadrangle in the Muncy Creek drainage. Another undergraduate geologic field assistant, Chris Guise, was responsible for the ridge on the north side of Painter Run and the south side of Huckleberry Mountain west of the Late Wisconsinan limit. Geologic assistant Ruth Braun mapped the southeastern part of the quadrangle between West Creek and Fishing Creek. Duane Braun, surficial geology mapper, spot checked the work of the field assistants and mapped the rest of the quadrangle. In the third phase, the field verified/corrected preliminary surficial geology map was finalized, drafted onto three mylar overlays (contacts, isochores, and labels - rock outcrops), and had a text added by Duane Braun. In the fourth phase, the mylar overlays were scanned, digitized, and produced in Adobe PDF and ArcGIS formats by Pennsylvania Geological Survey personnel.

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 guide line placement. Where boundaries cross large featureless areas of forest, line placement error is in the range of 100 feet and occasionally as much as 200 feet on the ground.

Mapping Technique - Thickness of Deposits

The thickness of surficial deposits is divided into four thickness categories: less than 6 feet (2 meters) overlying the bedrock (the contact of the bedrock (R) unit with all other surficial units), 30 feet (10 meters), and 100 feet (30 meters). 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 (Lohman, 1937; Taylor and others, 1983) 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 drainage reconstruction indicates that most stream valleys have segments partially filled with glacial deposits.

Quaternary History

Previous Work

Platt mapped the Elk Grove 7.5-minute quadrangle area and did not mention any glacial features, even striations (Sherwood and Platt, 1880). Sherwood noted two striation sites in the Sonestown 7.5-minute quadrangle immediately southwest of the Elk Grove 7.5-minute 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, shown on a sketch map on page 98 and the accompanying map of Pennsylvania, runs close to what is now mapped as the late Wisconsinan-aged glacial limit at the south edge of the Elk Grove quadrangle. Lewis' limit continues westward along the south edge of the Appalachian Plateau (North-Huckleberry Mountain) across an area now mapped as older glacial deposits and colluvium. He noted that "Till is nearly absent both upon the (North) mountain and in the valley of Muncy Creek to the north" (p.125). He recorded a S 09°W striation at the head of Painter Run where the road to Nordmont crosses the crest of North Mountain. Just southwest of the quadrangle near Unityville he noted erratic boulders of Pocono sandstone.

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. On his map of Pennsylvania showing Glacial Deposits, he also considerably revised Lewis' terminal moraine in the Elk Grove area, mapping the terminus around the north of North Mountain rather than on the south side of North - Huckleberry Mountains as Lewis had mapped it. Leverett showed the Late Wisconsinan ice over-topping North Mountain to the east of the Elk Grove quadrangle, flowing down the East Branch Fishing Creek valley, and flowing southwest onto the southeast corner of the Elk Grove quadrangle. The glacier flowed around both sides of Huckleberry Mountain to about the middle of the quadrangle and did not over-top that mountain. On the south side of the mountain in the Lungerville area just west of the Elk Grove quadrangle, Leverett described a red clayey till that he thought was of Illinoian rather than Wisconsinan age.

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) on their reconnaissance glacial geology map of the region (Plate 3) mapped the late Wisconsinan glacial terminus on the north side of North Mountain from the west edge of the Elk Grove quadrangle to the head of Elk Run. There, they had a tongue of ice descend Elk Run and merge with a tongue of ice flowing up the Fishing Creek valley at the present site of the village of Elk Grove. From there they projected narrow, elongate tongues of ice westward up the West Branch Fishing Creek valley and northwest up the Painter Run valley. On pages 25-28 of their report, 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 Elk Grove 7.5-minute quadrangle and his terminus is shown on the map along with the terminal position determined from this work. Crowl's terminus in the southeastern part of the quadrangle is essentially where Leverett (1934) and Denny and Lyford (1963) placed it. On the northwest part of the quadrangle, Crowl placed the terminus on top of the north side of North Mountain, extended it southeasterly down the south flank of Painter Run, and a short distance westward up the West Branch Fishing Creek valley. He left the noses of two ridges and an intervening hollow as an ice free Nunatak just northeast of the Painter Run and West Branch Fishing Creek junction. Huckleberry Mountain projected out of the glacier all the way to its eastern end at the eastern edge of the quadrangle.

In the center of the Elk Grove quadrangle, Crowl noted several small masses of ice-contact stratified drift in the valleys of Elk Run and West Branch Fishing Creek. In the southeast corner of the quadrangle, Crowl mapped scattered areas of indistinct end moraine. Indistinct end moraine has less than 10 feet (3 meters) of local relief on recognizable knobs and swales. Crowl also observed striations at a location in the southeast corner of the quadrangle, striation site 5 in this report (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. As noted by Braun (1994, 2003), dating of the glacial deposits in adjacent states has amply confirmed a late Wisconsinan age for the glacial deposits in this area.

Lohman's regional groundwater reports (1937, 1939) list a single well in the Elk Grove quadrangle. That well is in the southeast corner of the quadrangle at a road intersection called Laubach. The well is at the edge of the Fishing Creek valley and is cased through 30 feet of sand and gravel (Lohman, 1937, well 919), confirming the thickness of glacial deposits in the creek valley. Taylor, Werkheiser, and Kriz (1983) list three wells (632, 633, 636) in the southwestern corner of the quadrangle in Lycoming County. Those wells, with casing lengths of 40 to 84 feet, confirm the thickness of the older glacial deposits at the base of Huckleberry Mountain and in the hollows south of that. Taylor (1984) listed no wells for the Columbia County portion of the quadrangle.

Current understanding of the Quaternary History and Present work

During the Quaternary, the Elk Grove 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, 2003). There is evidence for at least three different glacial advances across the Elk Grove area in that there are three glacial limits of distinctly different ages to the southwest of the area (Braun, 1994, 2003). The farthest to the southwest and oldest glacial limit is considered to be of pre-Illinoian-G or Oxygen Isotope Stage (OIS) 22 age (850 Ka) or older. The next distinct glacial limit is considered to be of either late Illinoian or OIS 6 age (150 Ka) or pre-Illinoian-B or OIS 12 (450 Ka) age and is only about 10 miles (15 km) beyond the most recent, late Wisconsinan (20 Ka C_{14} , 25 Ka Calendar (Ridge, 2003)) age glacial limit. All Pleistocene glacial advances should have at least reached the Great Lakes region and should have caused severe periglacial activity in northern Pennsylvania (Braun, 1989, 1994).

The earlier glacial advances across the Elk Grove 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, 2003, 2006a, 2006b).

The late Wisconsinan glacier advanced and retreated across the northeastern Pennsylvania region in a general S 20 – 30°W direction (Lesley, 1884; Crowl and Sevon, 1980; Braun, 1997, 2003). In the northern part of the quadrangle along the crest of North Mountain, the glacial striation sites (see the map and Table 2) indicate that ice flow was similar to the overall regional pattern, with striation values in the S 17 – 23°W range. In other places on the crest of North Mountain the ice flow was directly to the south, funneling into the heads of south draining Elk Run and Painter Run. In the northwestern corner of the quadrangle, the southwest trending Muncy Valley funneled ice in a more southwesterly direction (S 46°W). In the southeastern part of the quadrangle, ice flow at the late Wisconsinan terminus was split to either side of the long, narrow nose of Huckleberry Mountain. Ice on the north side of the mountain was directed to the northwest (N 62°W) up the valley of the West Branch Fishing Creek valley. Ice on the south side of the mountain flowed in a strongly southwesterly direction (S 76°W).

The northern three-fourths of the Elk Grove quadrangle is part of the Appalachian Plateau where it is deeply incised by the headwaters of Fishing Creek and where local relief is on the order of 1000 feet. In that area the overall glacial deposit pattern is one of broad ridge crests with a thin, discontinuous till mantle rising above narrow, deep valleys partly filled with 30 to more than 150 feet (10 to 50+ meters) of glacial till (as delineated by the thickness contours on the map) (Braun, 2006b). The southern part of the quadrangle is part of the Valley and Ridge Province where the landscape is one of rolling hills with a local relief on the order of 200-400 feet. The southeastern part of the area is within the late Wisconsinan terminus and there glacial deposits mantle almost the entire landscape. The southwestern part of the area is outside the late Wisconsinan limit and there bedrock hilltops rise above valleys mantled by pre-Wisconsinan aged glacial deposits.

The late Wisconsinan glacial border on the present map shows the glacier to have had a much steeper surface gradient and to be as much as 700 feet thicker than that mapped by Crowl (Crowl and Sevon, 1980). Where the glacier flowed around the east end of Huckleberry Mountain, Crowl placed the edge of the ice at the 1400 feet elevation. This mapping found thin till masses farther west and up to an elevation of 2100 on Huckleberry Mountain. From there the edge of the glacier sloped down southwesterly along the south face of the mountain for two miles and then at the base of the mountain its trend turned to the south and southeast. At that point there is an area of well developed morainic topography, first mapped by Crowl, and an agreement in the placement of the glacier border on both Crowl’s and this map. Southeasterly from there the border on this map is placed a bit east of Crowl's border in the headwaters of West Creek. There, areas of till both northeast and southeast of the village of Divide have a degree of clast rubification and oxidation more characteristic of pre-Wisconsinan aged material than Wisconsinan aged material. There are some less weathered clasts, so the material may represent a short lived late Wisconsinan advance over older material as suggested for similar deposits on the adjacent Sonestown and Picture Rocks quadrangles (Braun, 2004b, 2004c).

On the north side of Huckleberry Mountain the late Wisconsinan border on the present map runs several hundred feet higher and projects 0.7 mile farther east in the West Branch Fishing Creek valley than on Crowl's map. From there the border on this map ascends onto the top of the ridge between the West Branch Fishing Creek and Painter Run instead of staying hundreds of feet lower on the north flank of the ridge as on Crowl's map. At the west edge of the quadrangle, the late Wisconsinan terminus projected southward as a small lobe into the head of Laurel Run. The greater thickness of ice portrayed on this map also buried the Nunatak (ridge projecting out of the ice) that Crowl had on his map northeast of the junction of West Branch Fishing Creek and Painter Run.

The late Wisconsinan terminus dammed a proglacial lake in the headwaters of West Branch Fishing Creek. On Crowl's map, the proglacial lake would have been of limited extent and depth. On the present map the ice front would have dammed the valley to a depth of 500 feet, impounding a lake whose surface at the 2000 feet elevation would have extended onto the adjacent Sonestown quadrangle. Over-ridden and deformed reddish clay, gray silt varves were observed at three sites just within the glacial border (labeled with the letter V on the map). Immediately northeast of the varve outcrops are a series of large slumps that suggest the presence of extensive buried varves along the north flank of West Branch Fishing Creek. No glacial lake varves were observed beyond the late Wisconsinan limit. This is probably due to rapid mass-wasting of the varves off the steep mountain sides after the lake drained. Also varves upstream of the glacial limit under the toe-slopes and valley floor are probably deeply buried by colluvial and alluvial deposits from intense periglacial activity after the lake drained.

There are several well developed meltwater sluiceway channels carved into the eastern end and south flank of Huckleberry Mountain (see map). Those channels would have initially have functioned as subglacial meltwater conduits and then been deepened by subglacial to ice marginal drainage of the proglacial lake on the north side of the mountain in the valley of West Branch Fishing Creek valley. That proglacial lake would have progressively enlarged eastward as the glacier retreated until it could drain around the east end of Huckleberry Mountain.

On the southwestern part of the Elk Grove quadrangle, Illinoian or older till deposits remain in the hollows, as originally noted by Leverett (1934). The surface of the material is marked by common to abundant sandstone erratics from the Huckleberry and North Mountain part of the Appalachian Plateau. 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 material has been transported from upslope and is colluvium derived from what was once till. 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 northeast.

As the glacier receded well north of the Elk Grove 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 ridges in the area. The 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 meter) 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 15 feet (1 to 5 meters) 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 northern Pennsylvania. Nearly all the natural wetlands in the region are depressions dammed on one or two sides by glacial deposits. A few small shallow wetland depressions on hilltops are scoured out of bedrock.

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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**	**Columbia Co. Soil Series**
Fill (F)	Udorthents (Uo)	Udorthents (Uo)	Made land (Ma)
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)	Atherton, (At), Barbour (Ba, Bb), Basher (Bd), Holly (Hs), Middlebury (Mb, Md), Papakating (Pa), Riverwash (Rw)
Wetland (Qw)	Aquepts (Ao), Canadice (Ca), Medisaprists Md), Norwich (No),	Nolo (No), Norwich (Nr, Nx),	Mucky peat (Mu)
Boulder Colluvium (Qbc)	Dystrochrepts (Dy), Ochrepts-rock outcrop (Oc),	Buchanan (Bu), Laidig (Ld, Lb)	Buchanan (Bu, Bv), Laidig (Le, Lf)
Illinoian Till Or Lag (Qit, Qil);		Albrights (Ab), Allenwood (Al), Alvira (Av, Ax), Hartleton (Hh), Leck Kill (Lk), Shelmadine (Sh), Watson (Wb),	Albrights (Aa), Allenwood (Ae), Alvira (Ar, As), Hartleton (Hh), Leck Kill (Lk), Shelmadine (Sd), 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)	Braceville (Br), Chenango (Cg, Ch)
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)	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)	Albrights (Aa), 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 Glacial striation sites, Elk Grove Quadrangle				
Site	Location		Direction	Topographic Position
	Latitude	Longitude		
1	41° 22' 18"	-76° 27' 20"	S 46° W	Northwest facing slope
2	41° 22' 10"	-76° 23' 48"	S 18° W	Hill top
3	41° 21' 59"	-76° 23' 59"	S 23° W	Hill-top
4	41° 21' 59"	-76° 23' 53"	S 32° W	Hill top
5	41° 21' 50"	-76° 24' 40"	S 19° W	Hill-top
6	41° 21' 44"	-76° 25' 44"	S 18° W	Hill top
7	41° 21' 42"	-76° 25' 42"	S 10° W	Upper SW slope
8	41° 21' 28"	-76° 25' 40"	N-S	East facing slope of hollow
9	41° 21' 20"	-76° 25' 50"	N-S	Southwest facing slope
10	41° 21' 11"	-76° 26' 25"	N-S	Upper NE facing slope
11	41° 21' 07"	-76° 24' 52"	S 17° W	Hill top
12	41° 21' 15"	-76° 28' 20"	S 20° W	Hill top
13	41° 20' 46"	-76° 27' 37"	S 18° W	West facing side of saddle
14	41° 20' 34"	-76° 27' 20"	S 5° W	Hill top
15	41° 20' 26"	-76° 28' 15"	S 5° W	Hill top
16	41° 20' 25"	-76° 28' 19"	S 5° W	Hill top
17	41° 17' 44"	-76° 23' 40"	N 62° W	North facing slope
18	41° 17' 25"	-76° 22' 44"	S 57° W	South facing slope
19	41° 17' 05"	-76° 23' 16"	S 76° W	Hill top
20	41° 16' 04"	-76° 23' 13"	S 23° W	North facing side of saddle

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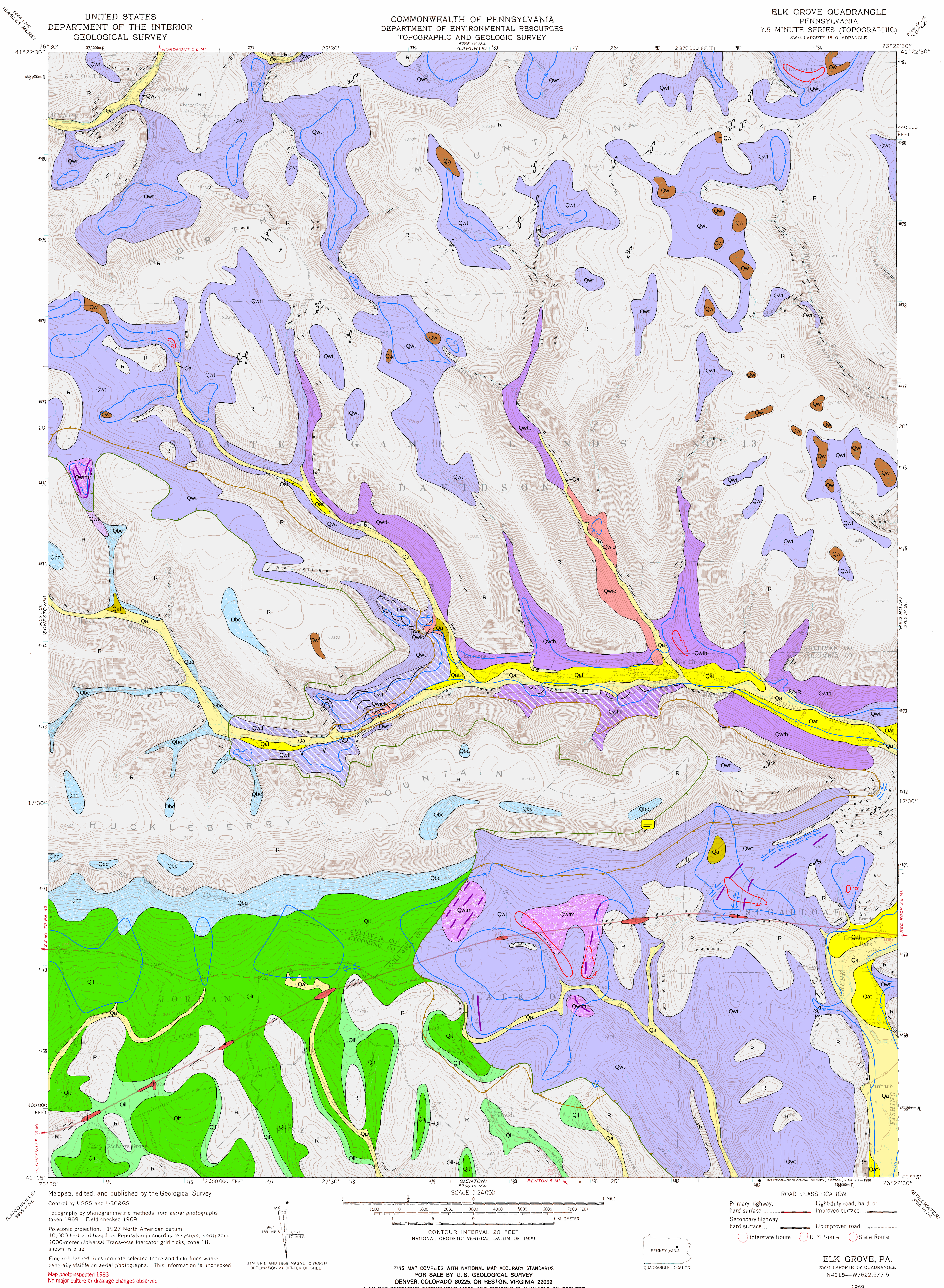


Surficial Geology of the Elk Grove 7.5-minute Quadrangle
Sullivan, Columbia, and Lycoming Counties, Pennsylvania

Geologic Mapping by
Duane D. Braun, Bloomsburg University, 2007

Digital Map Production by
Thomas G. Whitfield
Bureau of Topographic and Geologic Survey, 2007

Description of Map Units

f — **Fill**
Rock fragments and/or soil material; typically in road, railroad, or dam embankments; up to several tens of feet thick.

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 meters) thick in headward tributary valleys, 10 feet (3 meters) or more thick in the Fishing Creek and West Branch Fishing Creek valleys.

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); 6 feet (2 meters) or more thick. Terraces were mapped only along the Fishing Creek and West Branch Fishing Creek valleys.

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 meters) or more thick. Some fans have a series of levels with younger, lower, less steeply sloped segments inset in older, higher, steeper segments.

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 meter), overall thickness of unconsolidated material is usually greater than 6 feet (2 meters).

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 centimeters to 2 meters) in diameter; 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 headwater areas of tributaries and as a blanket of material on the toe-slopes of valley sides; colluvium thickness typically 6 to 15 feet (2 to 5 meters). Glacial till is often under the boulder colluvium. It was only mapped as a separate unit in hollows and on benches on North Mountain and Huckleberry Mountain southwest of the late Wisconsinan limit.

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 meters) thick; typically deposited in valley side kames; often underlain by till.

Qwicl — **Wisconsinan Ice-Conract Stratified Drift Underderlain by Glacial Lake Clays**
Ice-contact stratified drift as described above in Qwic underlain by clay rich proglacial lake sediments. The lake deposits are mostly varves as described below under unit Qwtl. Typically the stratified drift is tens feet or more (10+ meters) thick and is underlain by a few feet to few tens of feet (1 to 10 meters) of varves. The unit was only mapped at one site in the West Branch Fishing Creek valley upstream of the junction with Painter Run.

Qwtf — **Wisconsinan Till Flow**
Resedimented till deposited as a series of debris flows that travel down-valley from the glacial ice front; 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; 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 meter) is often colluviated, displaying a downslope-oriented fabric; thickness is 6 feet (2 meters) to more than 30 feet (10 meters). Only mapped in the valley of Laurel Run.

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 meter) is often colluviated, displaying a downslope-oriented fabric; thickness is greater than 6 feet (2 meters), is typically 15 feet (5 meters), and can be greater than 100 feet (30 meters) in buried to partly in-filled valleys. Locally areas mapped as till may have a thickness of less than 6 feet (2 meters) on hilltops or where there are cliff top edges in the till mantled cliff and bench bedrock topography. It is expected that in more than 90 percent of the area mapped as till, the till has a thickness of more than 6 feet (2 meters). Large areas of the mountain slopes are covered by boulder colluvium derived from rock ledges high on the mountain side that extends down over till lower on the slopes. Generally the till is considerably thicker than the boulder colluvium and those areas have been mapped as till.

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 meter) is often colluviated, displaying a downslope-oriented fabric; thickness is greater than 6 feet (2 meters), is typically 15 feet (5 meters), and can be greater than 100 feet (30 meters) in buried to partly in-filled valleys.

Qwtm — **Wisconsinan Till Moraine**
Till as described above in Qwt with a well developed knob and kettle land surface topography. Kettles typically have 1 to 10 feet (0.3 to 3 meters) of closure and contain vernal pools.

Qwtl — **Wisconsinan Till Underlain by Glacial Lake Clays**
Till as described above in Qwt underlain by clay rich proglacial lake sediments (varves), alternating thin layers of silt and clay. Each layer is usually less than an inch (2.5 cm) thick. A pair of silt and clay layers is called a couplet and represents a single year's summer (silt) and winter (clay) deposition in a proglacial lake. Clay is usually one quarter or less of the volume of the deposit. At some sites the lake deposits are dominated by sands and silts and represent places where melt-water issued from tunnels in the ice. The lake sediment thickness typically ranges from a few feet to a few tens of feet (1 to 10+ meters). Hill-slopes underlain by varves typically show a stepped appearance due to slope failure in a series of slumps. Such slopes are hazardous to build upon and failure can be aggravated by cut and fill excavations when such slopes are built upon. Typically the overlying till is tens of feet or more (10+ meters) thick. Only present along the sides of the West Branch Fishing Creek valley upstream of the junction with Painter Run.

Qwtbl — **Wisconsinan Bouldery Till Underlain by Glacial Lake Clays**
Bouldery till as described above in Qwtb underlain by clay rich proglacial lake sediments. The lake deposits are mostly varves as described above under unit Qwtl. Typically the till is tens of feet or more (10+ meters) thick and is underlain by a few feet to few tens of feet (1 to 10 meters) of varves. The unit was mapped only along the south flank of West Branch Fishing Creek where slumping was prominent south of the village of Elk Grove.

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

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 to 2 meters) 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 meters) thick. Mapped only in the southeastern part of the quadrangle.

R — **Sandstone and Shale Bedrock**
Bedrock outcrops or clast-rich diamict of glacial, residual and/or colluvial material overlying bedrock of interbedded red and gray sandstone and shale; often forming a cliff and bench topography. The diamict is reddish brown to yellowish brown and has 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 to 3 feet (0.5 to 1 meter) of the diamict. On greater than 25 percent slopes, typically less than 3 feet (1 meter) of diamict overlies bedrock. Locally on broad hilltops and benches the diamict is less than 6 feet (2 meters).

Symbols

Glacial Meltwater Sluiceway
An abandoned glacial meltwater channel cut into bedrock and/or glacial deposits.

Bedrock Ledge Outcrops

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

Slump head-wall
Slump scarp, dot on down-dropped side indicates the direction of movement.

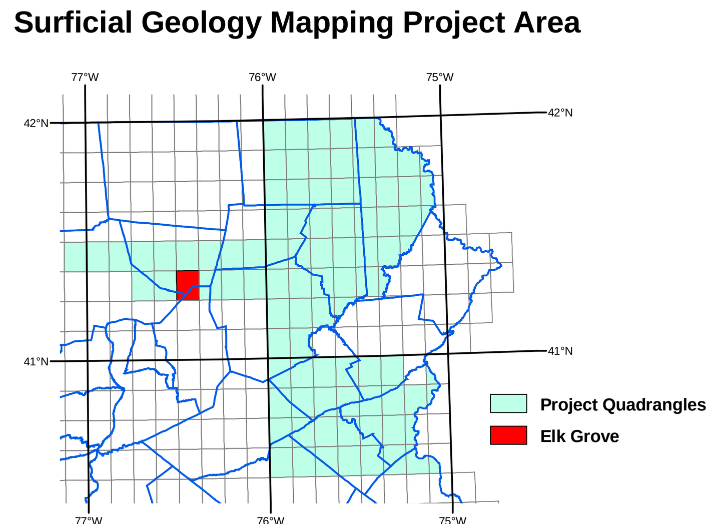
Varves
Clay rich sediments of alternating layers of silt and clay deposited in a proglacial lake. (see text).

Moraine Ridges
Arcuate ridges of till probably representing seasonal re-advance of the glacier producing a "push moraine".

Wisconsinan Terminus
Braun 2007
Crowl and Sevon 1980
Mapping by Braun showing long term equilibrium limit. Mapping by Crowl showing short term, most advanced limit. Tic marks point toward ice.

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.

Surficial Geology Mapping Project Area



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