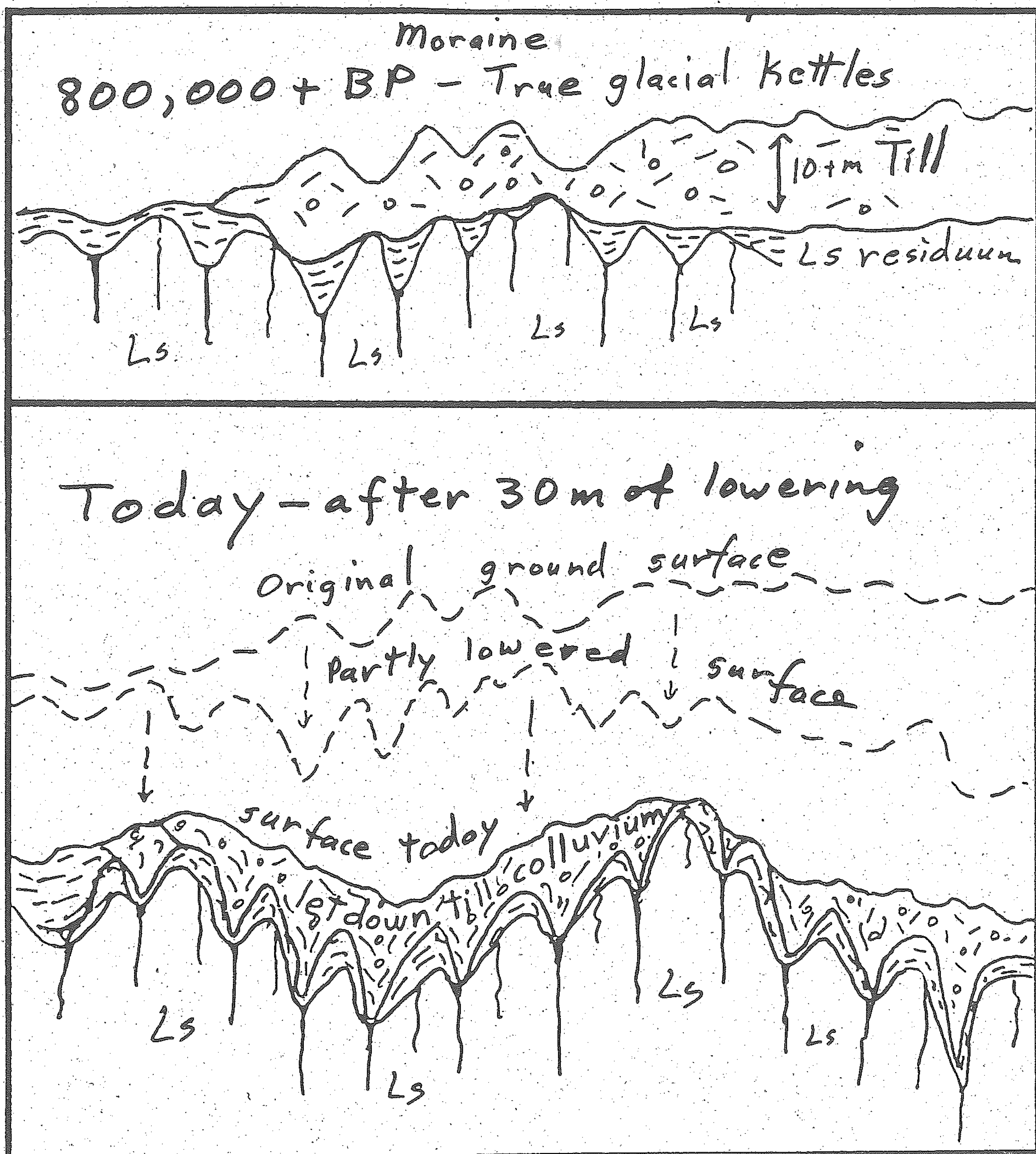
GUIDEBOOK FOR THE 15TH ANNUAL FIELD TRIP

OF THE HARRISBURG AREA GEOLOGICAL SOCIETY

MAY 4, 1996



PSEUDO-MORAINIC TOPOGRAPHY OF THE ALLENTOWN AREA OF EASTERN PENNSYLVANIA

Guidebook for the 15th Annual Field Trip

of the Harrisburg Area Geological Society

May 4, 1996

Pseudo-Morainic Topography of the Allentown Area of Eastern Pennsylvania

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Guidebook copies may be obtained by writing: Harrisburg Area Geological Society, c/o Pennsylvania Geological Survey, P.O. Box 2357, Harrisburg, PA 17120.

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PSEUDO-MORAINIC TOPOGRAPHY IN THE ALLENTOWN AREA

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Introductory overview of the Pleistocene geology

More than sixty years ago Frank Leverett (1934) mapped a moraine trending northwest across the Great Valley carbonate belt just west of Allentown, Pennsylvania (**Fig. 1**). The moraine was about one mile wide, showed subdued swell and sag (knob and kettle) topography, and was thought to date from the Illinoian glacial stage. Since that time it has been generally assumed that the sags were genuine glacial kettles.

During the last two decade the full multiplicity of cold-warm alternations and associated glacial advances has been recognized from marine oxygen isotope records (**Fig. 2**) and radiometric dating of terrestrial deposits of interbedded volcanic and glacial material (**Fig. 3**). The oxygen isotope record has been used as a time-space diagram of glaciation (**Fig. 2**) (Shackleton,1987; Braun, 1989). About ten isotope maxima approach or exceed the amplitude of the late Wisconsinan event and would be expected to have ice extent similar to or greater than the late Wisconsinan limit (LW line on **Fig. 2**). Four early to middle Pleistocene isotope maxima, stages 6,12,16, and 22 (>W line on **Fig. 2**) exceed the late Wisconsinan maximum. The terrestrial record suggests that there may be as many as five or six middle and early Pleistocene ice advances more extensive than the late Wisconsinan advance of the North American Laurentide ice sheet (Bowen and others, 1986) (**Fig. 3**). Nearly all Pleistocene isotope maxima approach the amplitude of the early Wisconsinan isotope maxima (**Fig. 2**). That degree of coldness would have brought ice into New York State and periglacial conditions into Pennsylvania.

Thus, in the Allentown region of eastern Pennsylvania as many as ten glaciations may have approached the late Wisconsinan terminus and four probably reached beyond that limit (**Fig. 4**). The late Wisconsinan advance destroyed nearly all traces of previous advances right up to the late Wisconsinan terminal margin (**Fig. 4**). The four or five more extensive early to middle Pleistocene advances left a fragmentary record as much as 45 miles (70 km) to the southwest of the late Wisconsinan margin (**Fig. 4**). The only area of older glacial deposits that has a significant thickness and retains limited relict constructional topography is in a belt 3 to 7 mile (5-10 km) wide in front of and sub-parallel to late Wisconsinan boundary. This margin is currently interpreted as the late Illinoian limit, the most recent glacial advance to extend beyond the late Wisconsinan limit (**Fig. 4**) though the degree of weathering of the material suggests an even older age. Farther to the southwest and sub-parallel to the Illinoian limit is a 10 to 20 mile (15 to 30 km) wide belt of thin, very discontinuous to almost nonexistent glacial drift materials of pre-Illinoian age (**Fig. 4**). These materials are most likely of pre-Illinoian B, D, and/or G age (**Fig. 3**), the most extreme isotope stages 12, 16, and 22 (**Fig. 2**).

Recent paleomagnetic information (Gardner and others, 1994; Sasowsky, 1994) indicates that the maximal pre-Illinoian limit, the pseudo-moraine near Allentown, is early Pleistocene in age. Samples of pre-Illinoian-aged varves from several sites in the West Branch Susquehanna valley and clay drapes from the Eastern Middle Anthracite field at Jeansville have a strong reversed polarity magnetism. The reversed polarity indicates an older than 788 Ka age (**Fig.3**) for the maximal advance of the Laurentide glacier. The pre-Illinoian-G event at about 850 Ka (**Fig. 2**) is the only cold event to exceed the late Wisconsinan amplitude for the next one million years (Braun, 1989) so it is the only reasonable choice for the age of the glacial limit. Material with a strong normal polarity magnetism is located 2.5 kilometers east of a reversed polarity site in the Eastern Middle Anthracite field near Beaver Meadows. The Beaver Meadows site records an advance younger than 788 Ka, probably either a pre-Illinoian B or D advance (**Fig. 2 & 3**).

Recently completed mapping of the surficial geology of the Allentown area (Braun, to be published by PAGS within the next year as open file reports), done in the context of overall Pleistocene history discussed above, indicates that the "moraine" (pseudo-moraine) has a polygenetic origin only incidentally related to glaciation. The pseudo-moraine does mark the southernmost glacial limit in eastern Pennsylvania and there are subtle differences in the landscape to either side of the limit (**STOP 1**). The glacial deposits have been undergoing weathering and erosion for at least 800,000 years (pre-Illinoian-G age). The degree of erosion of the deposits is most clearly seen in the slate and shale belt where only the broadest hilltops retain any glacial materials (**STOP 2**). On a few hilltops where glacial diamict thicker than two meters remains, numerous depressions form a "patterned" ground effect that suggests a periglacial origin for the depressions (**STOP 2**). In most of the slate and shale belt the glacial materials have been eroded completely from the hills and redeposited as colluvium in the valleys (**Fig. 5, STOP 3).** Any original constructional knob and kettle topography has long since been removed from the landscape. Where remnant glacial deposits still protect the underlying shale bedrock, deep weathering of the bedrock has taken place under the glacial material (**STOP 4**).

In the carbonate belt glacial diamict remnants are more extensive, having been "trapped" by 800,000 years of solutional lowering of the landscape (**Fig. 6**). Reviews of studies of carbonate denudation rates in Pennsylvania indicate that deposits this old should have been lowered on the order of 100 feet (30 meters) or more (Sevon, 1989; Ciolkosz & others, 1995). Also there should be at least a meter to several meters of residuum from the dissolution of the carbonates under the "let down" old glacial material (Sevon, 1989; Ciolkosz & others, 1995) (**STOP 6**). There is a subtle but distinct pattern of thinner diamict remnants on the hilltops and thicker remnants in the valleys and especially in solutional depressions (seen in both outcrop and borehole observations) indicating erosional redistribution of the original glacial deposits (**Fig. 7**). The pseudo-moraine does have a relatively thicker and more continuous glacial mantle than elsewhere and probably once had a genuine morainic topography about 100 feet above the present landscape (**Fig. 6**). Now though the deeply eroded and "let down" colluvium (collapse-uvium??) derived from glacial material is draped over underlying bedrock features (**Fig. 7**). In places on present hill tops, colluvium derived from carbonate residuum overlies the colluvium derived from the glacial diamict (**STOP 8**). This suggests repeated episodes of topographic reversal as the lowering of the landscape has proceeded. The present swell and sag topography is composed of smaller scale periglacial depressions that developed in the reworked glacial material and that are superimposed on larger scale bedrock solution features (**STOP 5 & 7**). (For more discussion of periglacial activity in this region see several review papers in Braun, 1994.) The numerous smaller scale depressions commonly contain wetlands and perennial ponds that make the pseudo-moraine landscape distinctly different from the surrounding more" karstic" landscape. Thick sand and gravel deposits in ice marginal kame deposits at the base of South Mountain are buried by extensive periglacially derived boulder colluvium(**STOP 9**), further attesting to the reshaping of the landscape by periglacial activity.

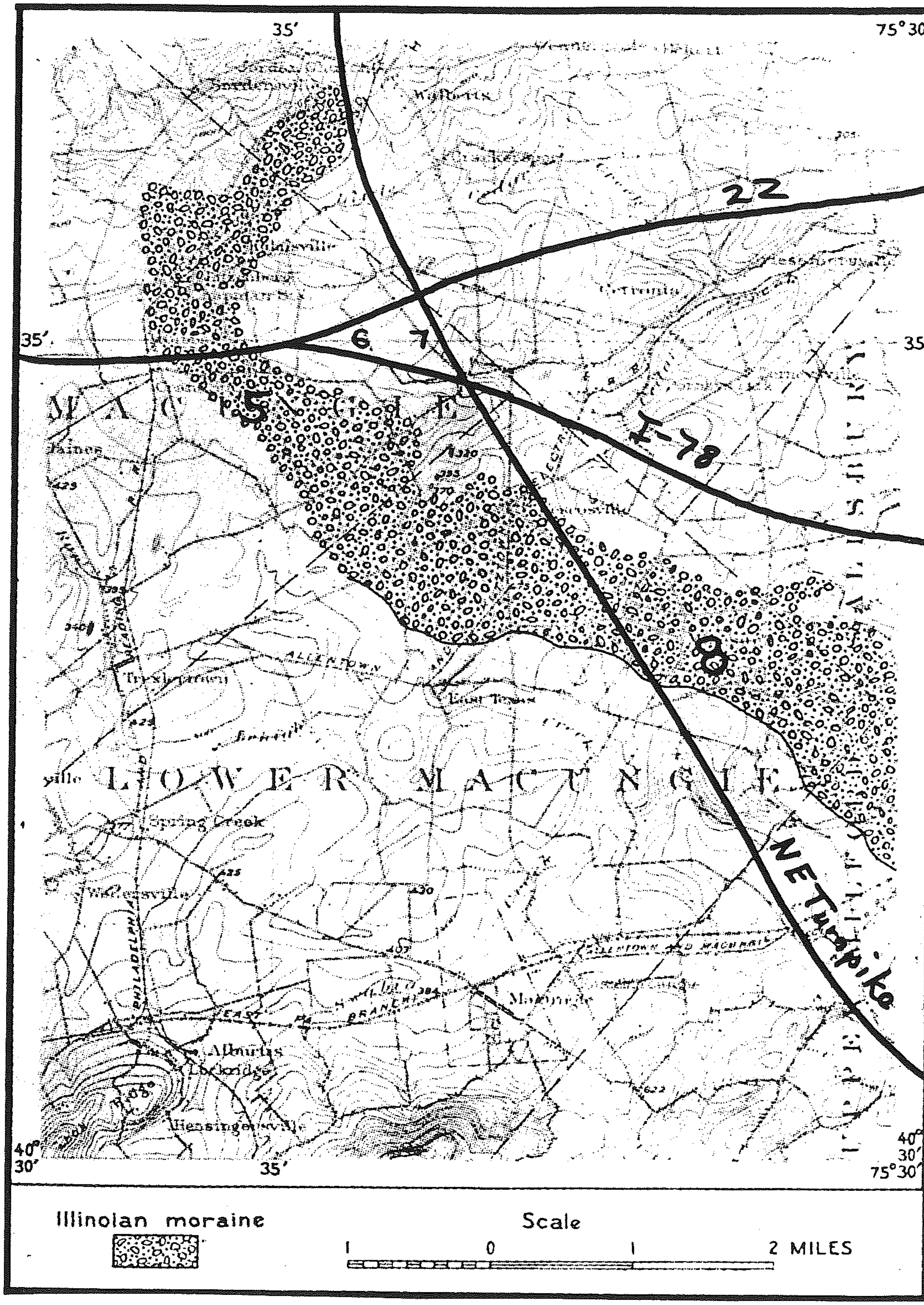


Figure 1. Leverett's (1934, Fig. 31) Illinoian moraine across the Great Valley in the Allentown West 7-1/2' quadrangle. Major highways and field trip STOPS added.

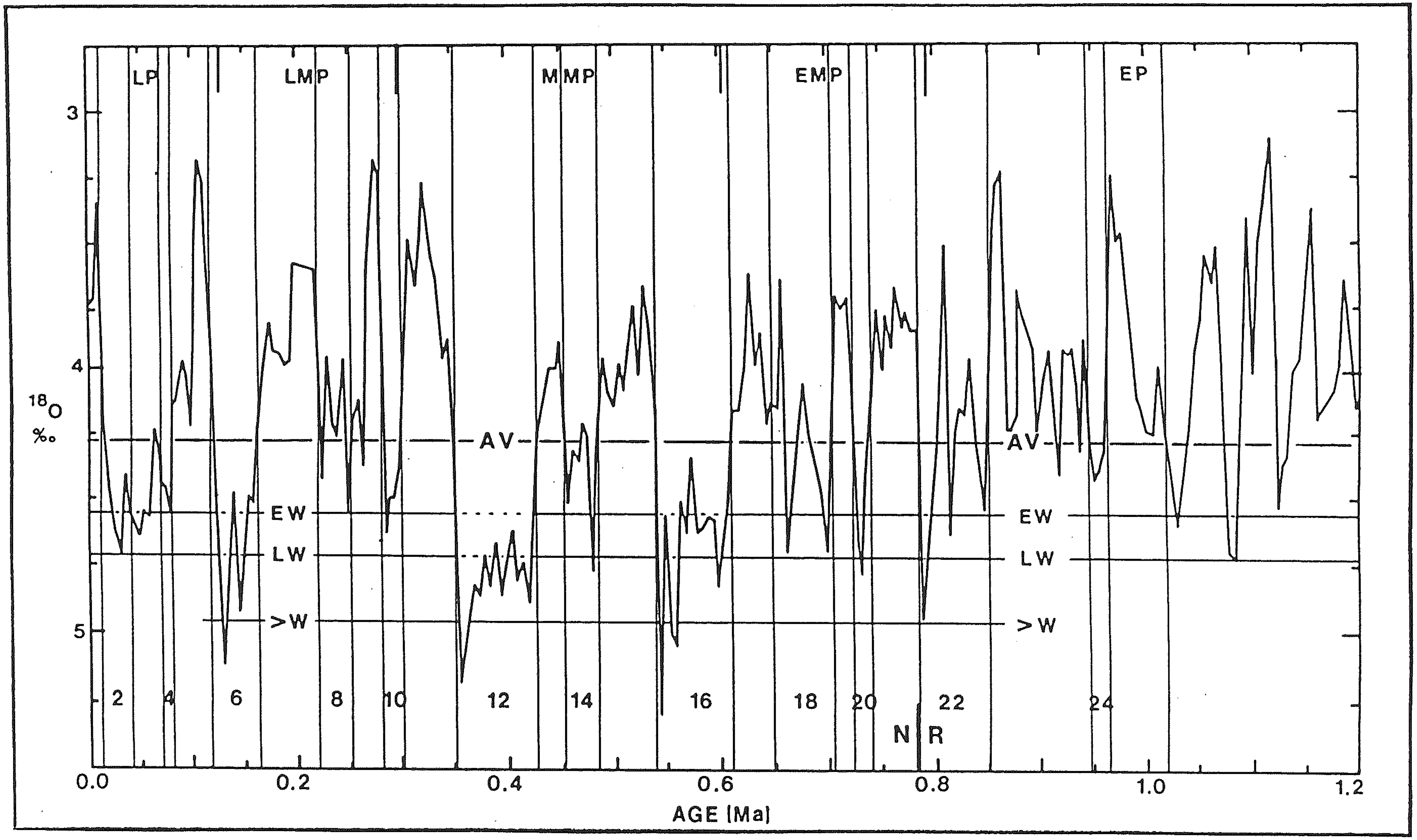


Figure 2. Oxygen isotope record showing the number and amplitude of glacial events during the Pleistocene (Braun, 1989c, Fig. 2A). Ten or more events have a amplitude similar to that of the late Wisconsinan (LW) and should have brought ice near or into eastern Pennsylvania. Four events have a markedly greater amplitude (>W) and should have permitted ice to advance beyond the late Wisconsinan limit. Periglacial conditions should have reached eastern Pennsylvania under early Wisconsinan (EW) or even average conditions (AV)(Porter, 1989). LP, late Pleistocene; LMP, late middle Pleistocene; MMP, middle middle Pleistocene; EMP, early middle Pleistocene; EP, early Pleistocene; N/R, Normal - Reversed magnetic polarity boundary.

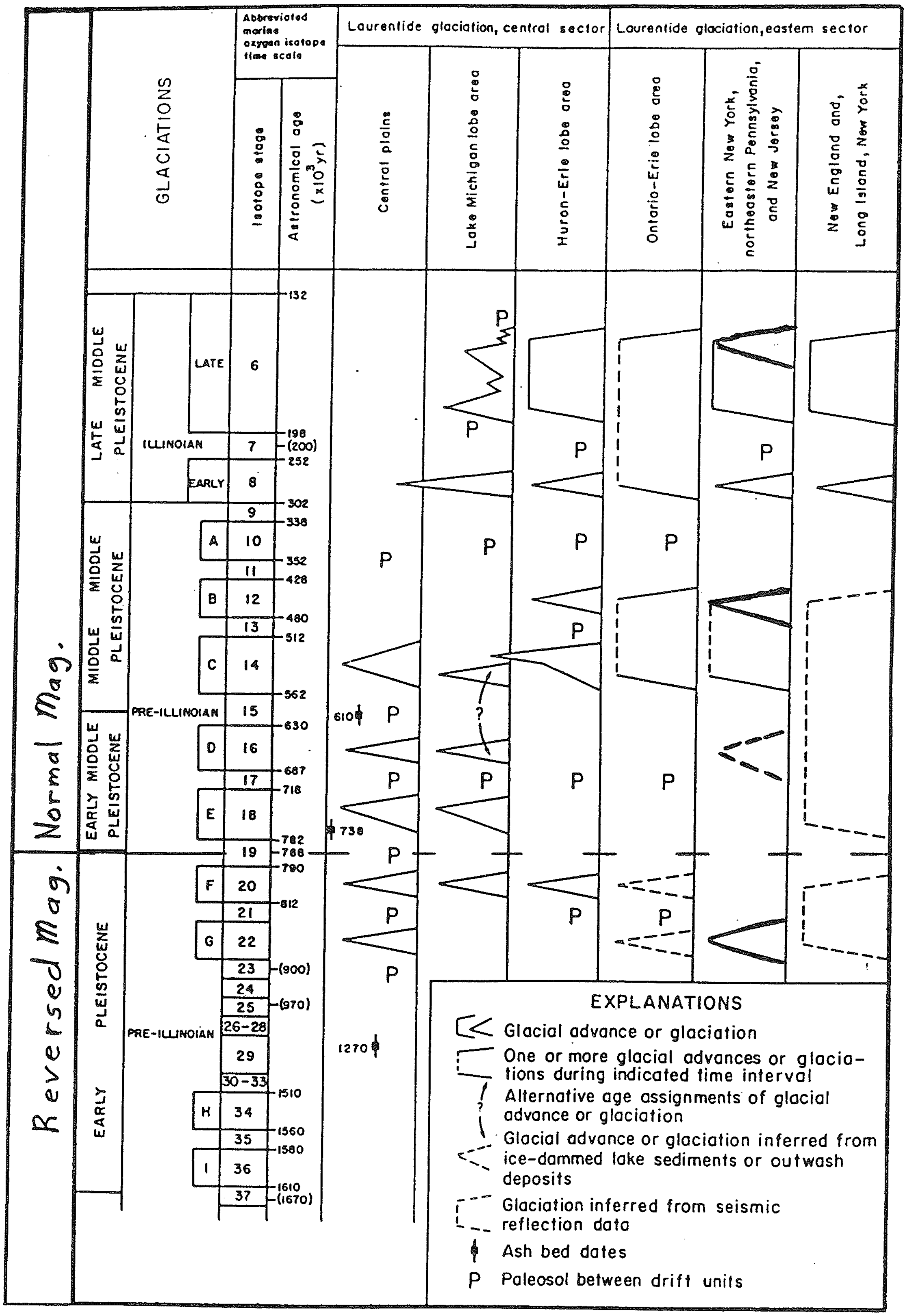


Figure 3. Illinoian and older Pleistocene time divisions, isotope stages, and Central Plains to New England glacial advance record. (Modified from Richmond and Fullerton, 1986) NE Pennsylvania - heavy line triangles (Braun, 1994).

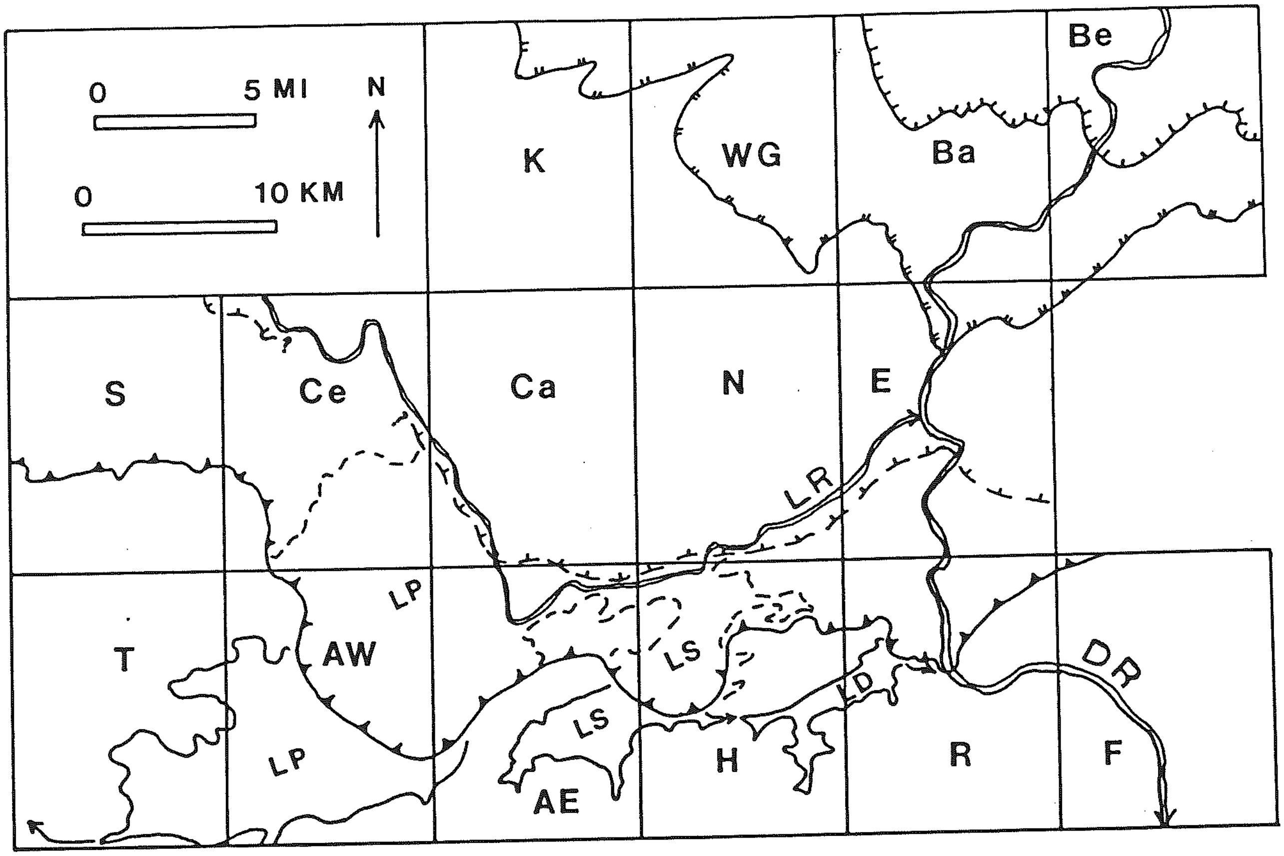


Figure4. Map showing the regional pattern of glacial limits and the grid of Pennsylvania 7.5' quadrangle boundaries.

Late Wisconsinan Limit
Late Illinoian or Pre-Illinoian-B Limit
Pre-Illinoian-D Limit or Pre-Illinoian-G Recessional
Pre-Illinoian-G Limit

LD - Glacial Lake Durham
LP - Glacial Lake Packer
LS - Glacial Lake Saucon
DR - Delaware River
LR - Lehigh River

AE - Allentown East
AW - Allentown West
Ba - Bangor
Be - Belvidere
Ca - Catasauqua
Ce - Cementon
E - Easton
F - Frenchtown
H - Hellertown
K - Kunkletown
N - Nazareth
R - Riegelsville
S - Slatedale
T - Topton
WG - Wind Gap

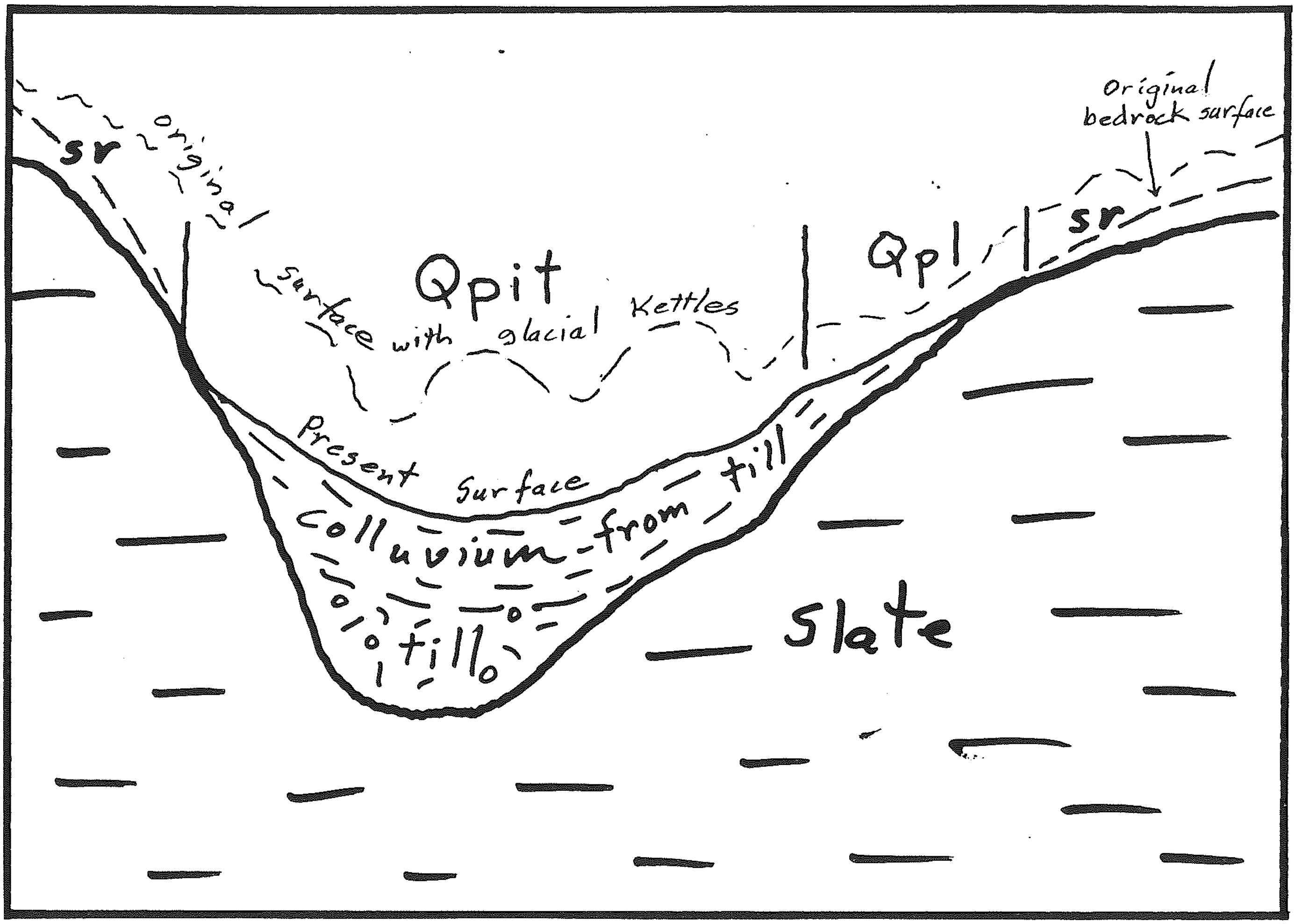


Figure 5. Schematic cross-section across a typical slate or shale valley (like at STOP 3) showing the probable position of the original ground surface and the surficial geology map units. Qpit = > 2m of "till'; Qpl = < 2m of "till", often just sandstone erratics in shaly colluvium; sr = shaly residuum and colluvium.

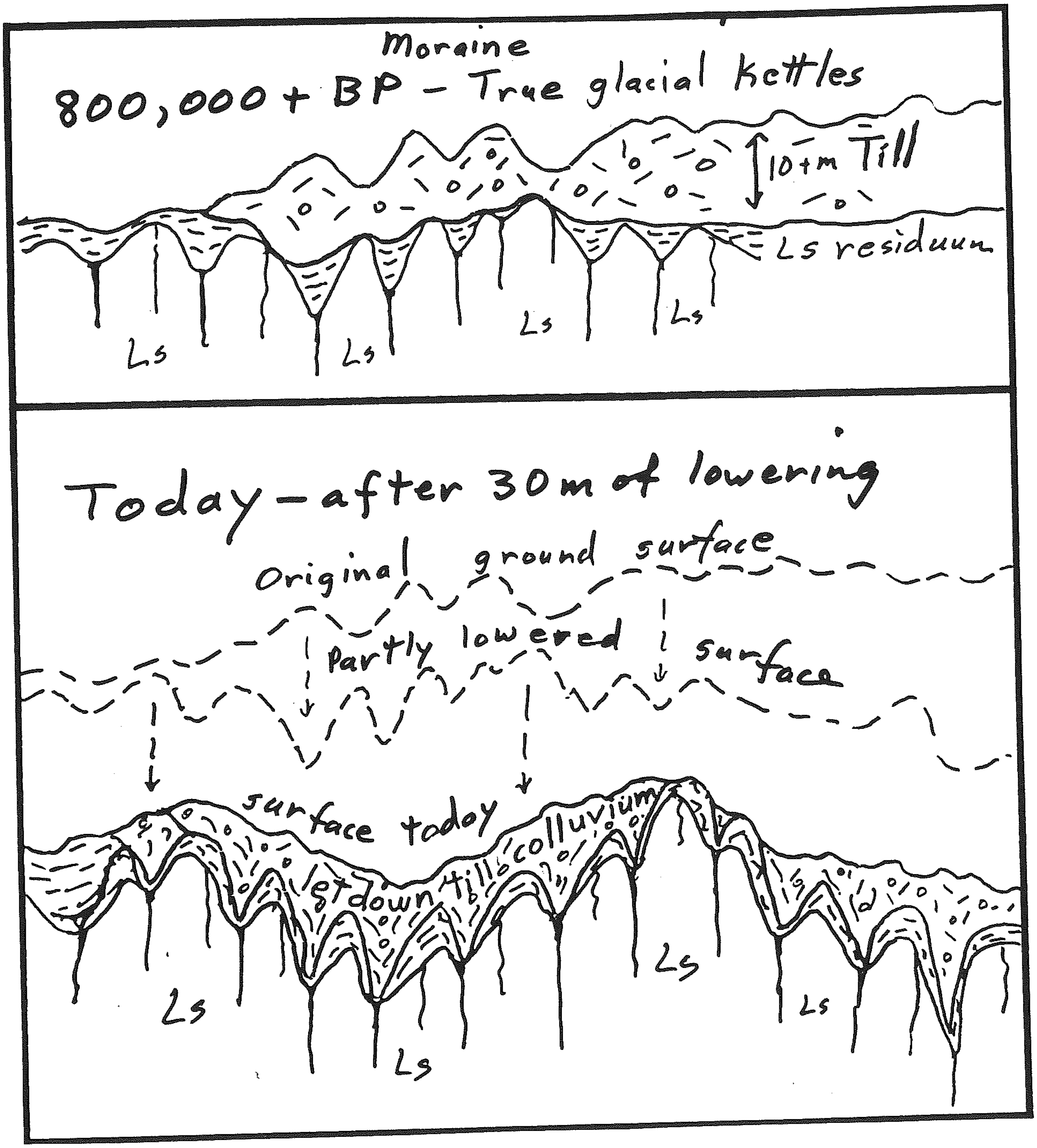


Figure 6. Schematic cross-sections showing the development of the " pseudo-moraine". The upper cross-section shows the more than 800,000 year old moraine with genuine glacial kettles. The cross-section shows the more than 800,000 year old moraine with genuine glacial kettles. The limestone pinnacles were in direct contact with the till while limestone residuum remained in the weathered fractures. The lower cross-section shows the original ground surface as dashed lines, the present "pseudo-moraine" surface, the layers of remnant let down "till", a continuous layer of residuum under the "till", and the fractured limestone.

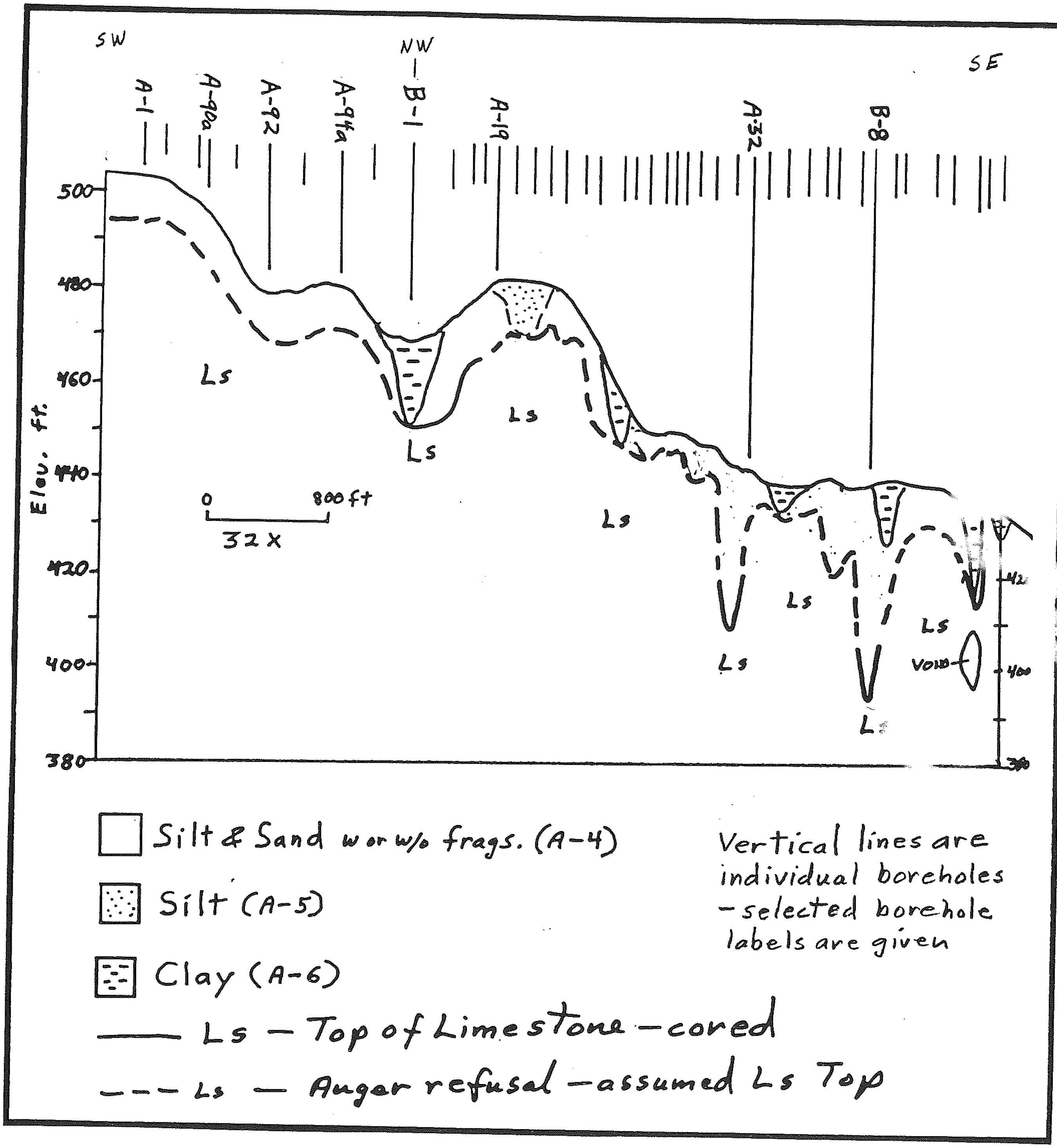
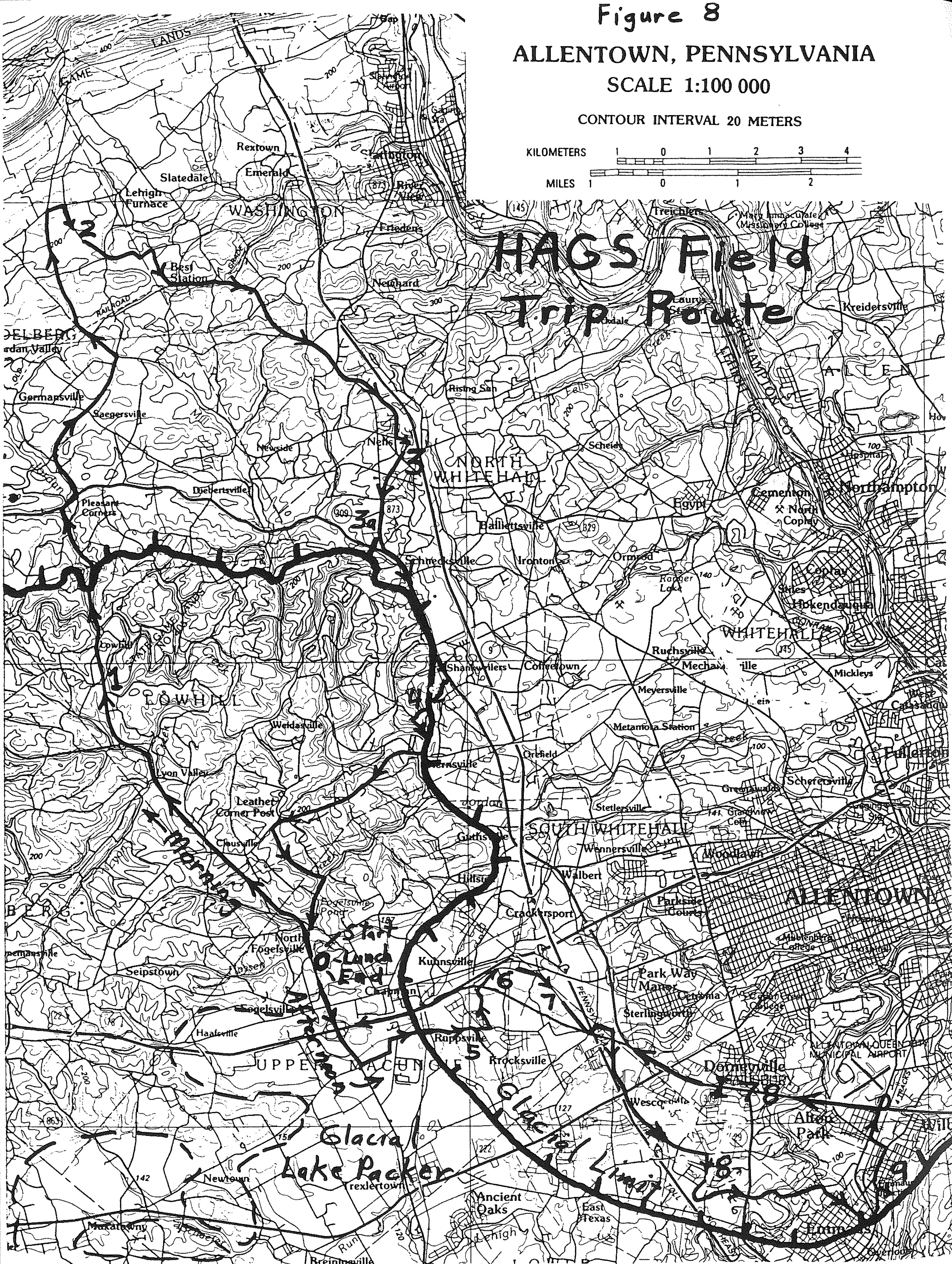


Figure 7. Cross-section of unconsolidated materials and the bedrock surface constructed from borehole logs for I - 78 where it diverges from Rt. 22 (section line shown on Fig. 14). This is within an area of abundant shallow depressions of the " pseudo-moraine". Note how the overall ground surface follows the bedrock surface except in genuine sinkholes. The more prominant sinkholes are several hundred feet across, much larger than the depressions at the surface (from Senior Research Project by Aaron Wright).

Figure 8


ALLENTOWN, PENNSYLVANIA
SCALE 1:100 000
CONTOUR INTERVAL 20 METERS
KILOMETERS 1 0 1 2 3 4
MILES 1 0 1 2
HAGS Field Trip Route
Start
0-Lunch
End
Moraine
Afternoon
Glacial Lake Packer
Glacial Limit
ALLENTOWN
NORTH WHITEHALL
SOUTH WHITEHALL
WHITEHALL
LOWHILL
WASHINGTON
UPPER MACUNGIE
Schnecksville
Northampton
Coplay
Fullerton
Emmaus
Trexlertown
Kuhnsville
Rexmont
Slatedale
Emerald
Newtown
Macungie

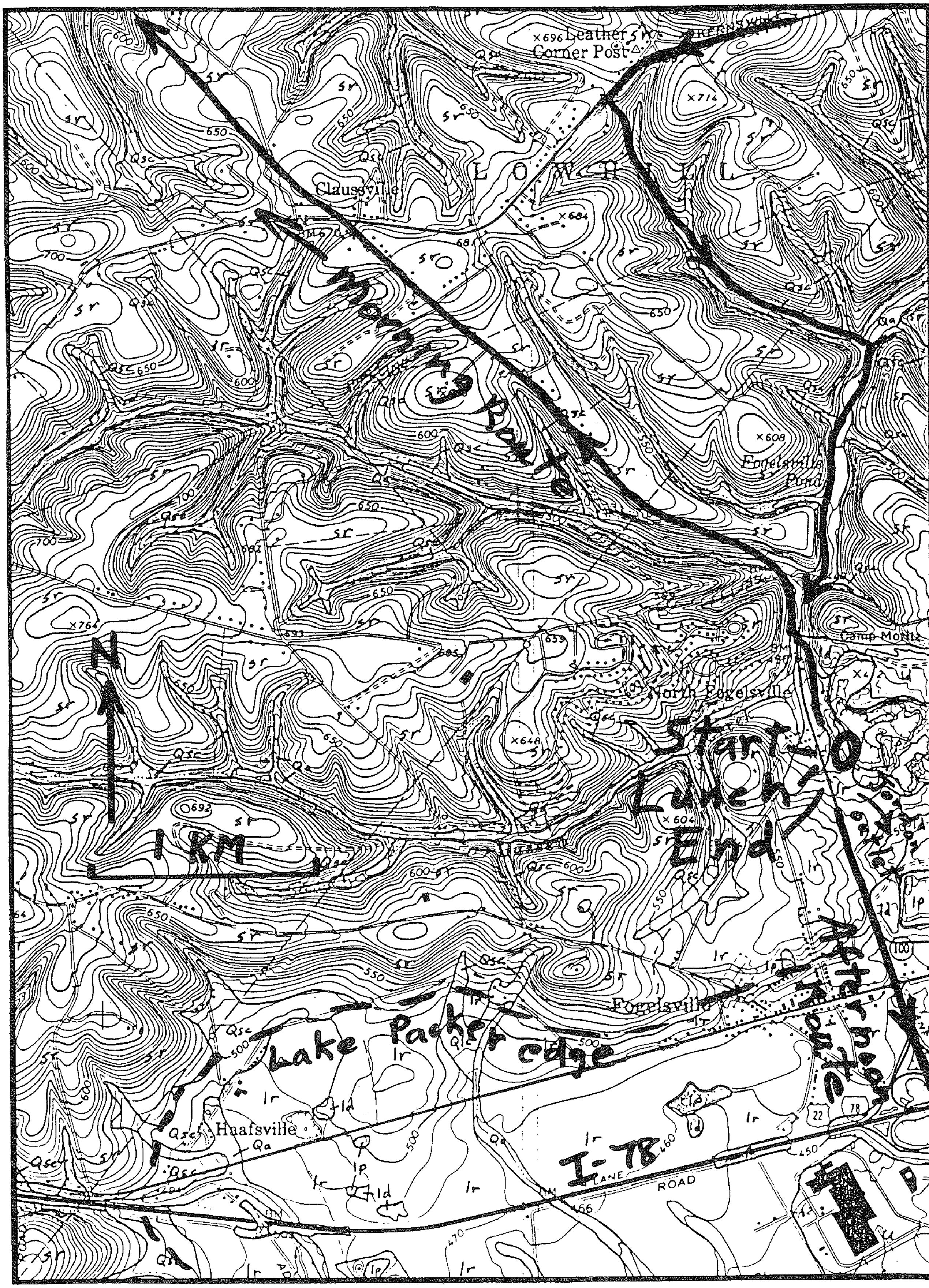


Figure 9. Northeastern part of the Topton 7-1/2' quadrangle showing Field Trip start, lunch, and endpoint, Glacial Lake Packer, and outlet of Jordan Creek when it was blocked at Stop 4.

STOP DESCRIPTIONS

STOP 0 Start, lunch, and finish point at the Upper Macungie Park.

STOP 1 Overview of the unglaciated shale belt

At this brief stop we will review the landform and soil character of unglaciated shale belt. Narrow V-shaped valleys are incised into landscape (southern part of **Fig. 10**). The soils are shallow and have a yellow brown color typical of Wisconsinan aged residual/colluvial materials. This suggests significant erosion of the landscape and renewal of the soils in late Pleistocene times even outside the glacial limit. There are no erratics anywhere on the landscape including the stream valleys.

These features are in contrast to those within the glacial limit (northern part of **Fig. 10** and **Fig. 11**). In the pre-Illinoian-G glacial limit, the valleys are wider because they are partly filled by redeposited glacial material eroded off the adjacent hill sides possibly underlain by genuine till (**Fig. 5**). Shawangunk erratics are common on the valley floors and where patches of till remain on the broader hilltops. The soil in the area of in-place or transported glacial material tends to have a bright reddish yellow color. Overall, the area has had the glacial materials mostly removed, only the last few remnants are left on the landscape. Constructional glacial topography has long since been erased from the landscape.

Immediately to our east are the deeply incised meanders of Jordan Creek. At STOP 4 we will be where the glacier dammed Jordan Creek to an elevation of at least 620 ft. A proglacial lake, named Glacial Lake Jordan (Braun, in prep.) flooded the valley below to within 30 ft., vertically, of where we stand (at 650 ft.). While there are no lake deposits remaining in the valley below, there are strath terraces 100 ft. above the valley floor that have glacial erratics upon them.

STOP 2 Pseudo-moraine on slate

At this stop we are on the belt of high quality slate that has been extensively mined to the east at Slatedale. The area is a broad hilltop with an exceptionally gentle south facing slope. The entire area is covered by a continuous mantle of pre-Illinoian-G aged glacial till greater than two meters thick (**Fig. 11**). We will walk across a field showing a distinctly hummocky (swell and sag or knob and kettle) topography with a few feet of relief over 10's of feet horizontally. These depressions and the first one in the forest have been drained by underground stone drain trenches constructed in the 1950's. The second depression in the forest is undrained and contains a perennial wetland. That depression is distinctly oval shaped as are most of the drained ones. Other forested areas around this site also have a number of these pocket wetlands and that is why they have never been farmed.

The key observation here is that this hummocky topography only occurs where the remnant glacial material is greater than two meters in thickness and the slope is very gentle (hill top Qpit areas, **Fig. 11**). Hummocks are not observed elsewhere in the area where the glacial materials are thin or non-existent (Qpl and sr areas, **Fig. 11**). This suggests that a significant thickness of unconsolidated material is needed to form the hummocks. A process that is quite effective in forming hummocks in such material is ground ice segregation and melting under a periglacial environment. Such hummocks and pocket wetlands are a common feature of low relief periglacial areas in such places as Alaska today. The hummocky pseudo-moraine is not a constructional glacial landform, but rather is a constructional periglacial landform.

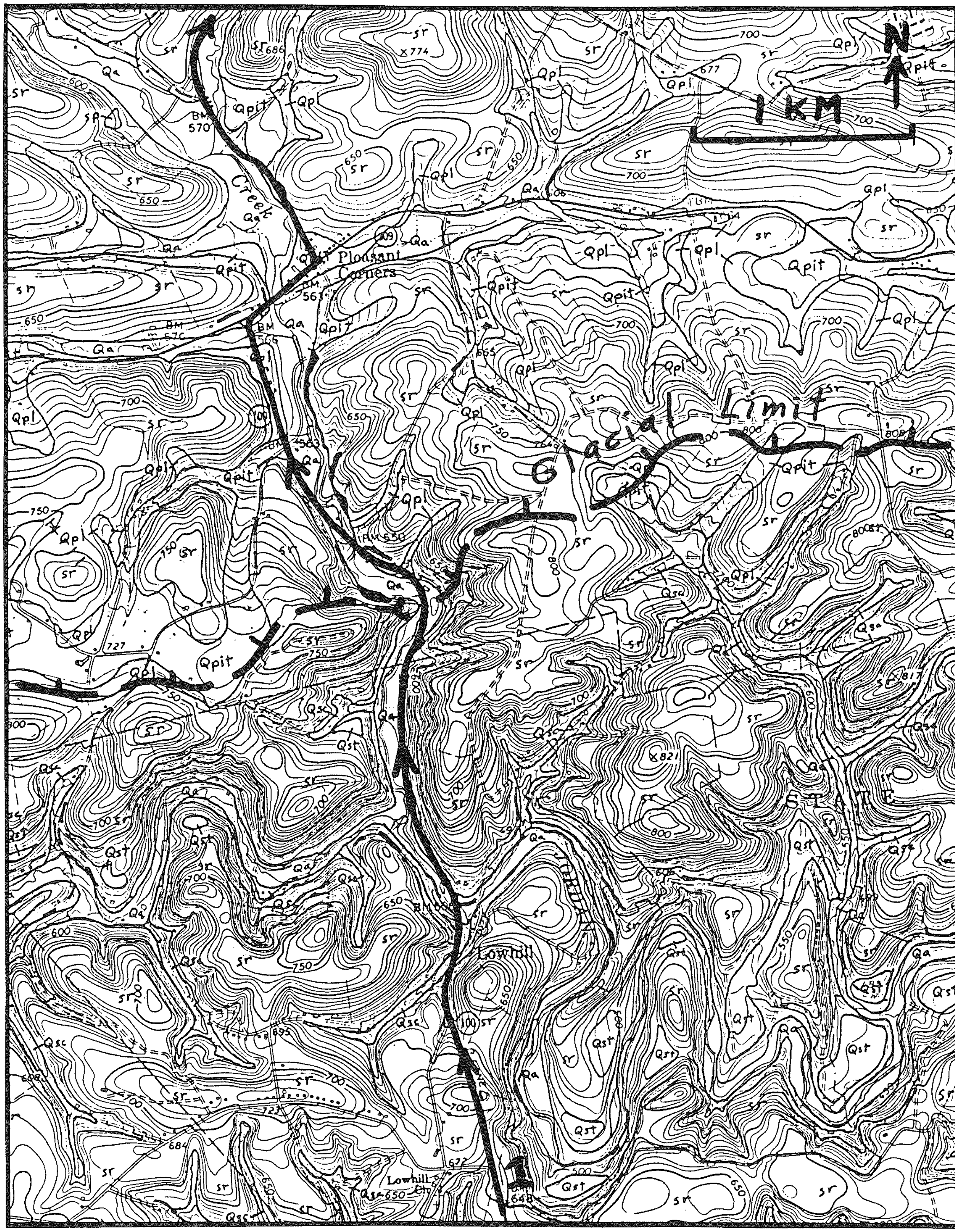


Figure 10. Surficial geology map of south central part of the Slatedale 7-1/2' quadrangle showing narrower V-shaped valleys south of the glacial limit and wider, glacial material-floored valleys north of the glacial limit.

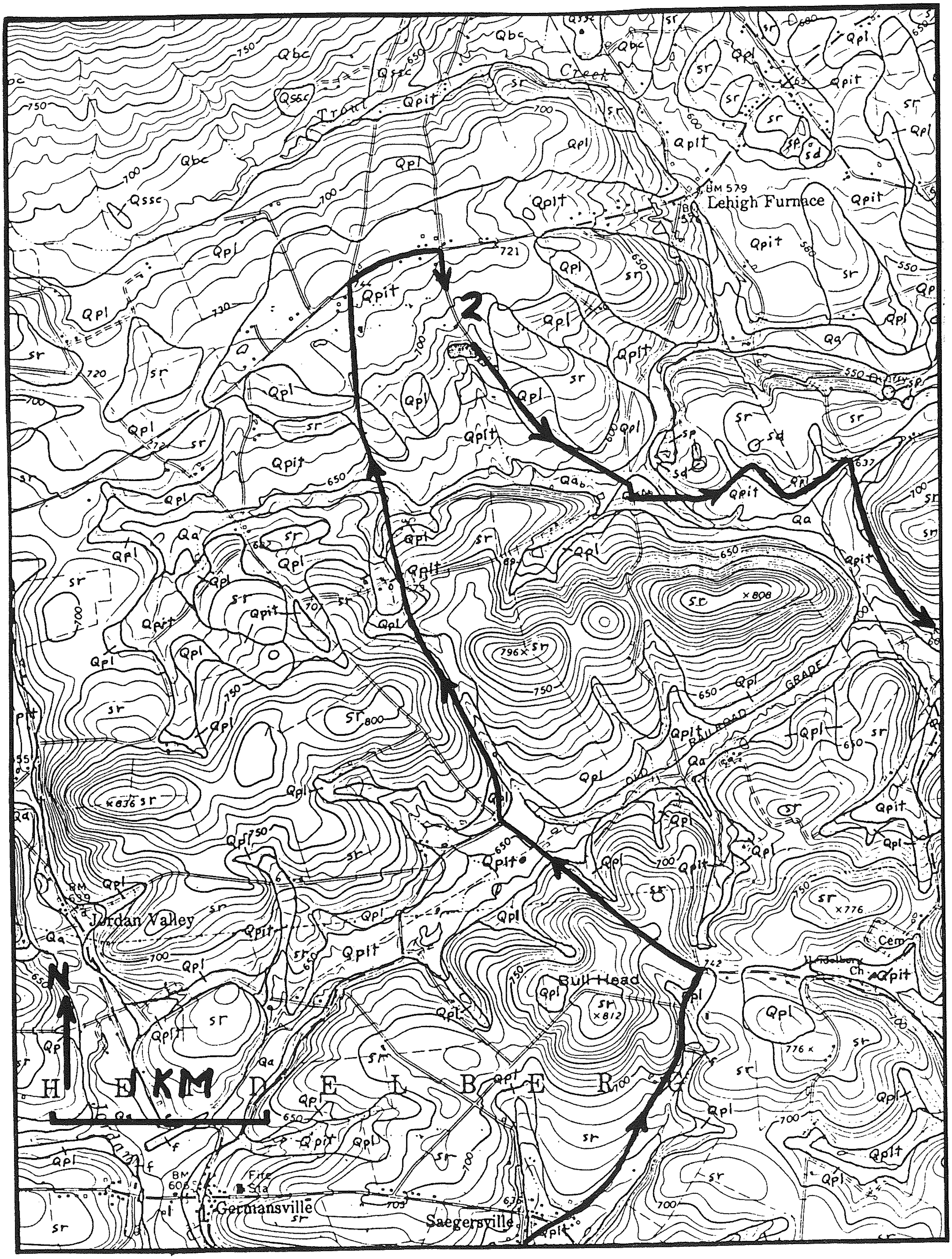


Figure 11. Surficial geology map of the north central part of the Slatedale 7-1/2' quadrangle showing the discontinuous, eroded distribution of redeposited glacial materials around Stop 2.

STOP 3 A typical erratic rich hollow in the shale area

At this stop we will walk through a wooded area along a first order tributary stream and observe the abundance of Shawangunk sandstone and conglomerate erratics. Along the road, power line pole excavations in 1994 showed reddish yellow glacial material at least two meters thick (Qpit area, **Fig. 12**). A shallow gully at the up hill edge of the woods exposes erratics in a shaly colluvium (Qpl, **Fig. 12**). The hill side that rises above the hollow to the south is just shaly residuum/colluvium (sr, **Fig. 12**). The broad hilltop to the southwest between Stop 3 and Stop 3a has a broad band of Qpl that probably represents the remains of the Pre-Illinoian-G aged terminal position.

STOP 3a Rest Room stop

We will make a short stop at the McDonald's restaurant to use the rest room facilities and pick up food supplies if you like. We plan to eat lunch after the next stop when we return to our starting point.

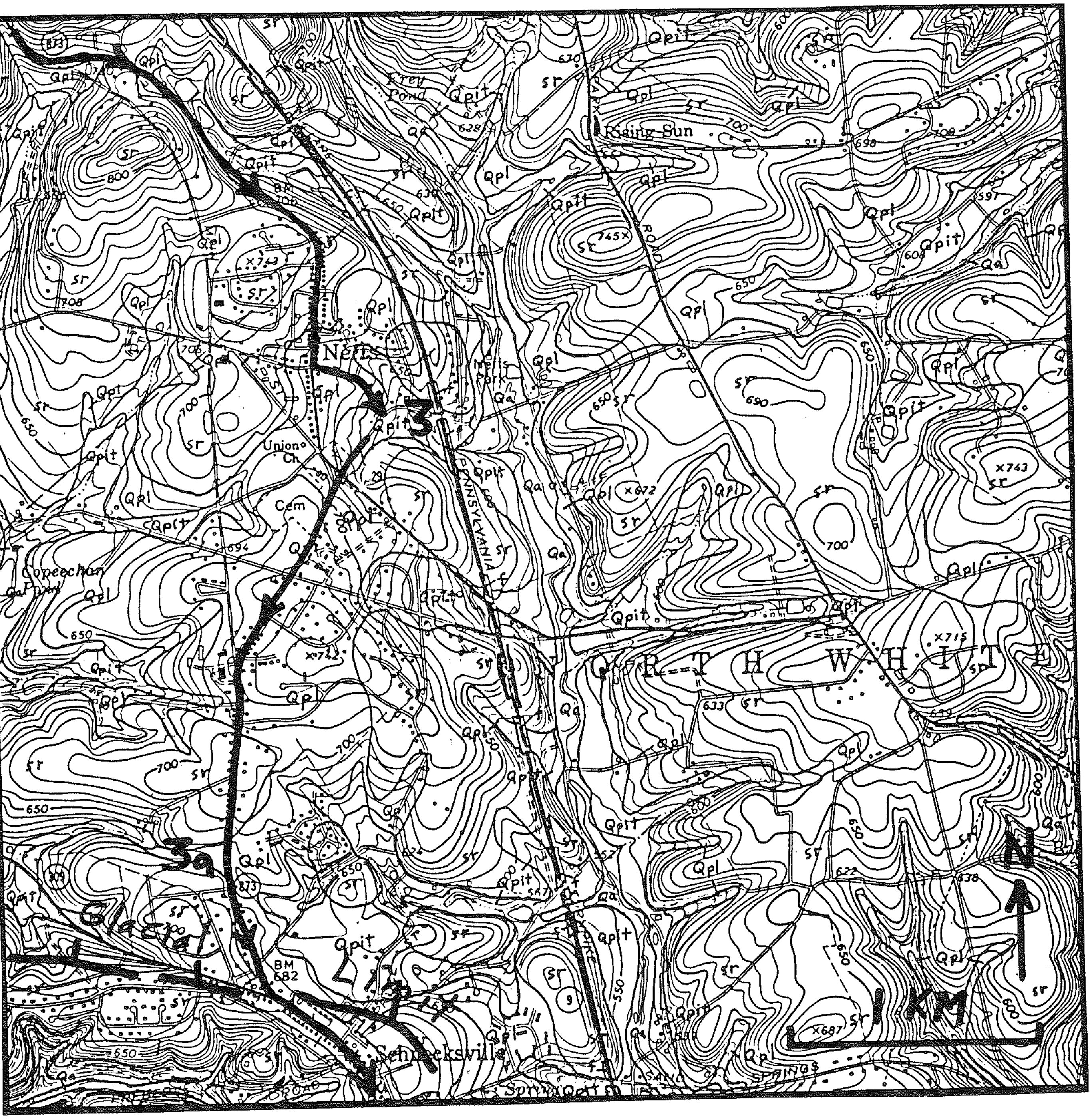


Figure 12. Surficial geology map of the northwestern corner of the Cementon 7-1/2' quadrangle. Stop 3 is a typical glacial material-covered valley floor on the shale belt. Stop 3A is an optional rest room stop.

STOP 4 Remnants of a kame on the north edge of the Great Valley

At this site we are on the edge of a large kame remnant that extends back to where we turned off of Rt. 309 (Qpio area, **Fig. 13**). The gravel contains many erratic clasts from north of Blue Mountain, mainly red sandstone and white chert. Most clasts on this hill top show weathering rinds and rubification (reddening) and some clasts are rubified throughout. The material is a reddish yellow colored, matrix supported roundstone diamict. The originally stratified material was turned into a diamict by a combination of cryoturbation and bioturbation destroying the stratification and combined chemical and physical weathering destroying the weaker clasts to produce the fine grained matrix. In 1994, stratification was observed below a depth of two meters in foundation excavations in the valley immediately to the east of where we stand. Immediately to the north of where we stand excavations this spring have exposed deeply weathered shale underneath the "feather" edge of the remains of this gravel deposit. This indicates that considerable weathering of the shale has occurred under the gravel. A short distance farther north, only slightly weathered shale is exposed. This suggests that under late and middle Pleistocene alternating periglacial and fluvial erosion conditions, the shale is eroded from the hills before a significant weathering profile can develop. Only where remnant gravel cap protects the shale is the full extent of post-glacial weathering preserved.

This gravel was deposited on the shale hilltops and adjacent carbonate lowland where the glacial limit crosses into the Great Valley (**Fig. 13**). Coincidently, Jordan Creek also enters the Great Valley at this site. Gravel deposits at the 620 ft. (190 m) elevation indicate that Jordan Creek should have been impounded to at least that level and probably higher because the top of the kame appears eroded. Glacial Lake Jordan would have extended from here back to north of STOP 1 (**Fig. 10**) where the creek is crossed again by the glacial limit. The outlet of the lake would have been in the lowest saddle in the drainage divide of the Jordan Creek basin upstream of the ice dam. That point is at the only place that the Jordan Creek basin "breaks into" the Great Valley carbonates and is where we started the field trip (STOP 0, **Fig. 9**). The present elevation of the saddle is 525 ft. (160 m), but as argued elsewhere, the pre-Illinoian-G aged landscape on carbonates should have been about 30 meters (100 ft.) above the present landscape. This would have placed the saddle at about a 625 ft. (192 m) elevation during glaciation, the same as the highest elevation of gravels observed at STOP 4.

No lake sediments have been observed in the Jordan valley and none would be expected to survive given the narrow, deeply incised valley form present today (**Fig. 10 & 13**). What is observed are a series of strath terraces at about 100 ft. (30 m) above the present channel (Qst, **Fig. 10 & 13**). Those straths have glacial erratic gravel clasts from north of Blue Mountain on their surfaces. That indicates that the straths were cut during or before pre-Illinoian-G time. It is likely that they were cut during glacial recession when Glacial Lake Jordan drained and Jordan Creek functioned as a braided outwash channel for ice to the north. Outwash streams are particularly active in their lateral migration and have a tendency to undercut the bedrock sides of a valley. Since glaciation, Jordan Creek has cut a much narrower valley 100 ft into the shale bedrock. Could it be that the stream is just trying to keep up with the lowering of the carbonate bedrock area in its valley downstream of here?!

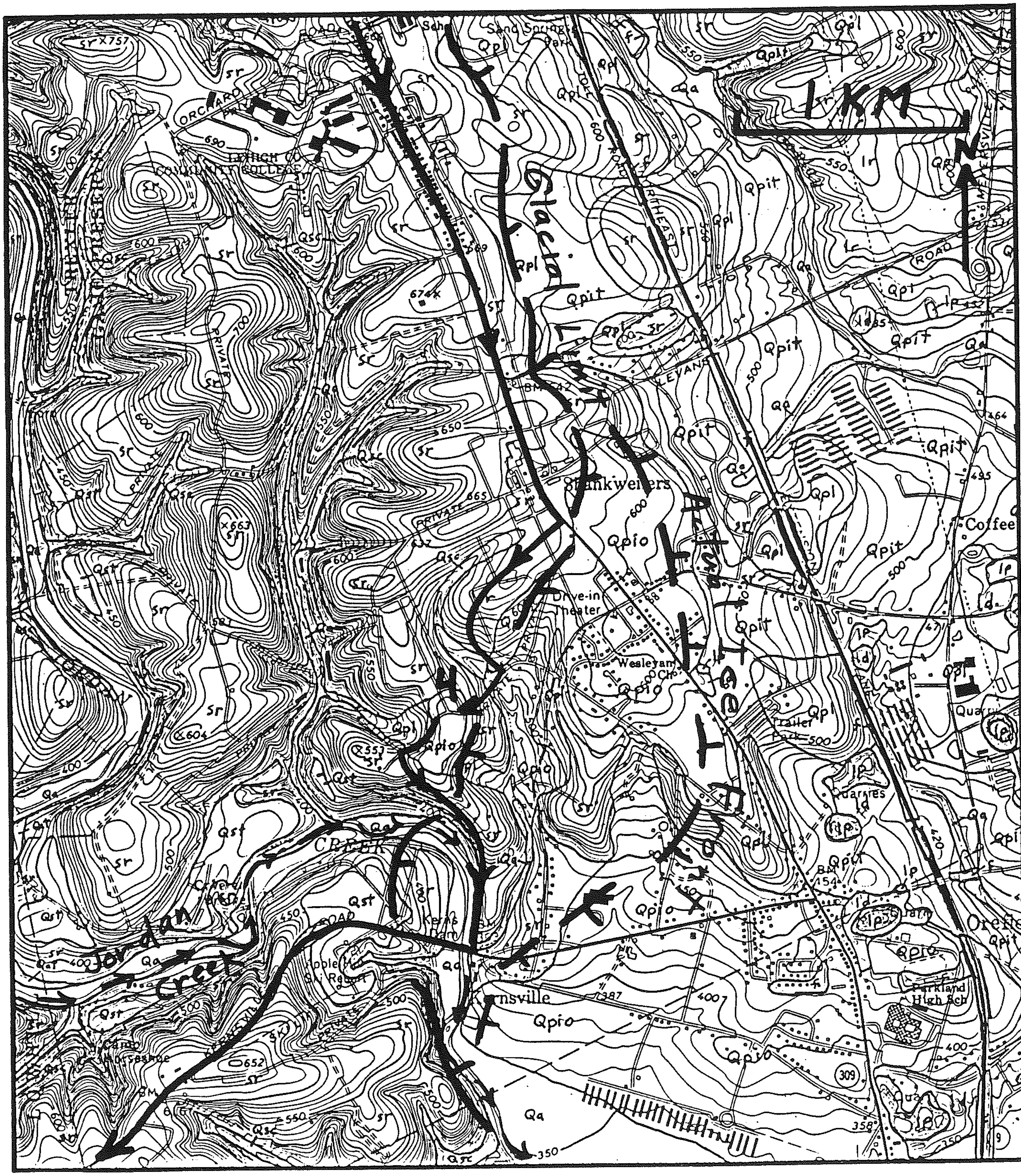


Figure 13. Surficial geology map of the southwest corner of the Cementon 7-1/2' quadrangle. Stop 4 is at the kame that is at the north edge of the Great Valley. The ice blocked the Jordan Creek valley and forced the creek over its lowest headward col at the Field Trip Start Point

LUNCH BACK AT THE STARTING POINT

Remember, the saddle on the south side of the park is the lowest outlet for Glacial Lake Jordan and you are picnicking on what was once the floor of the lake

STOP 5 Pseudo-morainic topography in a forested area on carbonates

This site is within Leverett's moraine (**Fig. 1**) and shows the hummocky (swale and sag) topography with water filled depressions. In the fields around us the hummocks have been smoothed and drained by 200 years of farming. Along this pseudo-moraine belt is the highest percentage of unfarmed forested area found anywhere in the Great Valley in this region, thanks to these depressions. That this landscape is a pseudo-moraine rather than a genuine moraine is argued in the introductory overview and illustrated in **Fig. 7**. Referring back to **Fig. 7**, note that the original genuine glacial moraine once existed about 100 feet (30 m) over our heads. More than 800,000 years of carbonate dissolution has lowered and repeatedly redeposited (by mass wasting and wash) the till derived colluvium to the present elevation. Periglacial ground ice development and melting, during each cold event since 800,000 years ago, has formed the pseudo-moraine in the let down material. The pseudo-moraine is developed here simply because there is a relatively thicker, more continuous mantle of till derived colluvium under the old moraine than elsewhere outside of the old moraine belt.

STOP 6 Carbonate residuum under the glacial material

This hilltop site exposes from one to three meters of carbonate residuum under one to two meters of let-down till derived colluvium. As noted in the introductory material, studies of the rate of development of such residuum indicate that such a thickness of material should take on the order of 1,000,000 years to develop. This thickness of residuum supports the pre-Illinoian-G age of the glacial material and the 100 ft. (30 m) lowering of the landscape since glaciation.

STOP 7 Pseudo-morainic topography in a pasture area on carbonates

This stop is primarily a picture stop for the pocket wetlands in the depressions on the pseudo-moraine. I did not get permission to enter the fields so please take your pictures from the shoulder of the road.

STOP 8 Glacial material overlain by washed in carbonate derived material

On the east side of the park, a gully cut into the side of an abandoned iron ore pit exposes the reddish yellow colored till derived colluvium. On top of that material is yellowish brown clayey silt with no clasts. The color of the material and the lack of sandstone clasts suggests the material was derived from carbonate residuum and washed onto the "till". We are standing on a hilltop so the material must have come from a once higher, nearby carbonate pinnacle area now collapsed below this elevation. Alternately, the overlying material may have somehow been deposited here during the operation of the iron pit. What do you think?

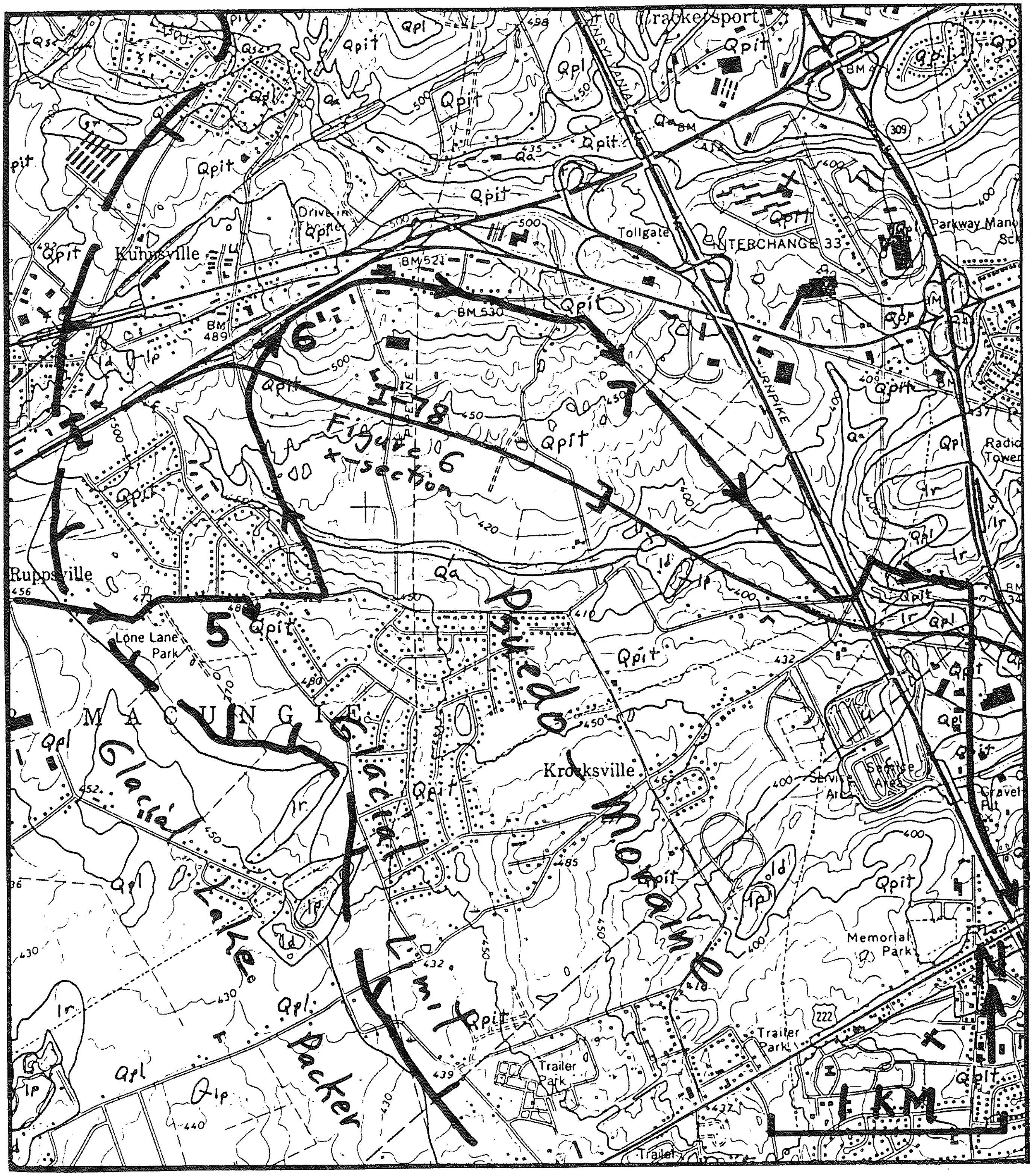


Figure 14. Surficial geology map of the western central part of the Allentown West 7-1/2' quadrangle. Stop 5 shows the swell and sag topography in a forested area on the pseudo-moraine. Stop 6 shows weathered limestone residuum under the glacial material. Stop 7 shows the swell and sag topography in an area of open pasture.

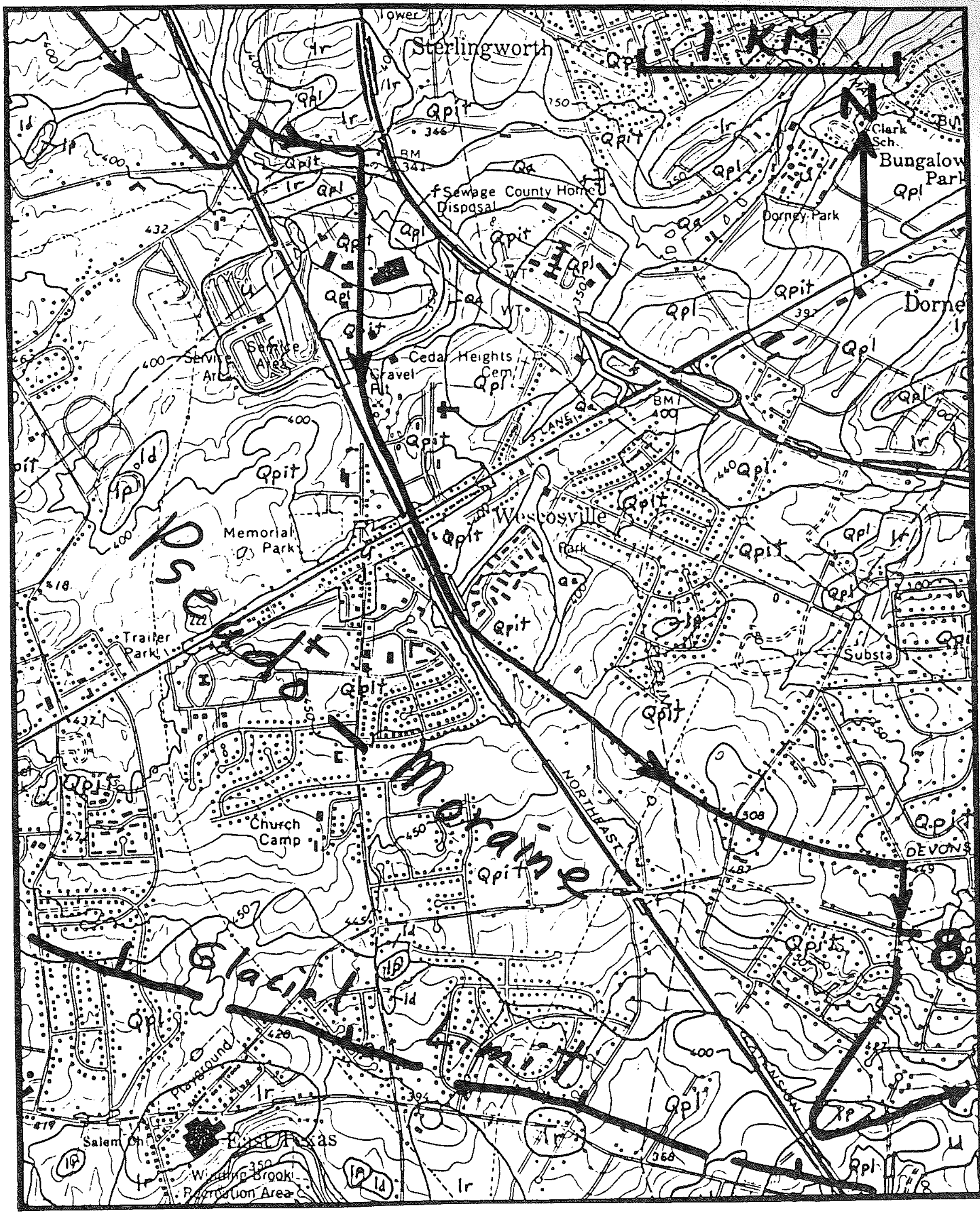


Figure 15. Surficial geology map of the central part of the Allentown West 7-1/2' quadrangle. Stop 8 is an exposure of the redeposited glacial material overlain by washed-in limestone residual material.

STOP 9 A deeply weathered and eroded Kame

After parking the cars, we will take a 15 minute walk along the base of South Mountain to an abandoned gravel pit (**Fig.**16.) Along the way we will cross boulder colluvium from the mountain and abandoned iron ore pits that indicate the area is underlain by limestone. Beware, this area is tick heaven.

The ice lobe that occupied the Great Valley lowland blocked the east-draining Little Lehigh Creek and impounded a shallow proglacial lake named Glacial Lake Packer by Williams (1893)(**Fig. 4 &16**). The lowest available outlet col westward to the Schuykill River system is at an elevation of about 500 feet (152 meters) at Topton, Pennsylvania. The large mass of outwash deposited between the ice lobe and South Mountain at Emmaus Junction has a top elevation of 500 feet (149-152 meter). This suggests that the outwash deposit represents a large kame delta built into Glacial Lake Packer and graded to the outlet at Topton. (Again, these elevations relate to the present elevation of an area underlain by carbonate rock. Such elevations were probably 30 meters or more higher at the time of glaciation.)

The upper two meters of the material exposed in the pit are a roundstone diamict with a bright reddish yellow clayey matrix. Below that there are 2 to 4 meters of gravel with some fine matrix material. Below a covered interval and exposed elsewhere in the floor of the pit is yellow brown sand. The entire thickness of the exposure show evidence of weathering, as would be expected in >788,000 year old material.

This deposit at Emmaus Junction is separated by a broad, shallow valley from the remainder of the kame sand and gravel underneath Emmaus (**Fig. 16**). The Emmaus deposit remnant caps a large oval shaped hilltop. Earlier workers (Williams, 1917) called the deposit the Emmaus drumlin because of its landform. The form though is not from glacial activity but from long term post-glacial periglacial and fluvial erosion.

Williams (1893,1917) described outcrops of clay rich material (Packer Clay) that he thought represented the deposits of Glacial Lake Packer. Leverett (1934) thought that the material was glacial till. A few outcrops examined in this project, within the proposed area of Lake Packer, did have a clay rich, very sparsely stony upper layer one to two meters thick. The clayey material probably represents lake sediments that have been "homogenized" by long term cryoturbation, bioturbation, and mass wasting of the material as the entire mass of glacial deposits have been "let down" by dissolution of the carbonates. Reviews of studies of carbonate denudation rates in Pennsylvania indicate that deposits that are greater than 788,000 years old should have been lowered on the order of 30 meters or more (Sevon, 1989; Ciolkosz & others, 1995).

Return to starting point by way of I-78.

Follow route outlined on **Fig. 16**.

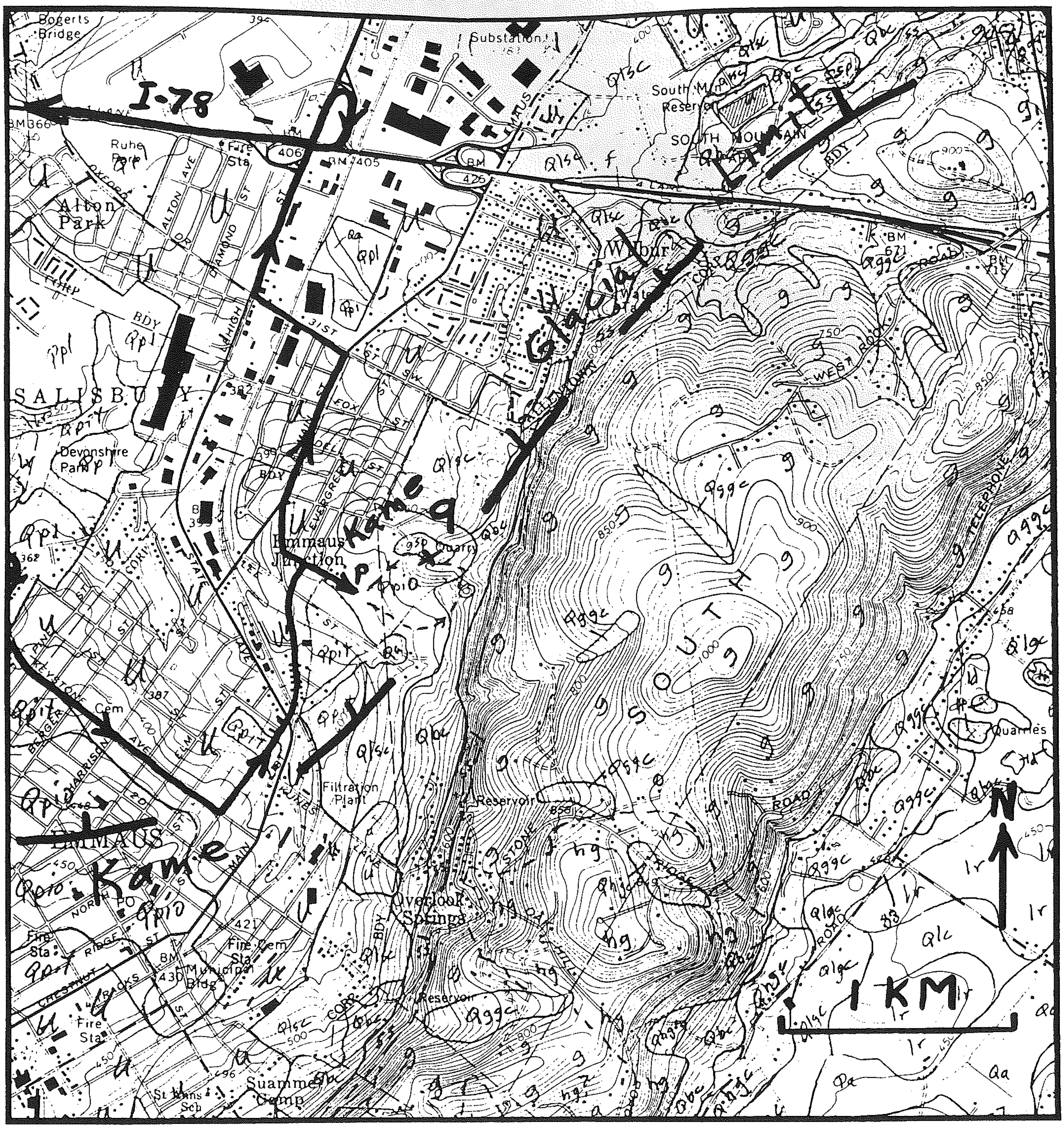


Figure 16. Surficial geology map of the central western part of the Allentown East 7-1/2' quadrangle. Stop 9 is in the deeply dissected and weathered remnants of a kame delta built into Glacial Lake Packer where the ice front swung away from South Mountain to cross the Great Valley.

SURFICIAL GEOLOGY OF THE ALLENTOWN AREA
EXPLANATION OF MAP UNITS

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

gp **GRANITE OR GRANITIC GNEISS PIT:**
Granite pits typically have steep sides and are meters to 10's of meters deep.

ld **LIMESTONE and/or IRON ORE DUMP:**
Waste piles of limestone fragments, iron ore fragments, and/or unconsolidated overburden.

lp **LIMESTONE and/or IRON ORE PIT:**
Limestone and/or iron ore pits typically have steep sides, are meters to 10's of meters deep, and are partly to completely flooded with water.

sgp **SAND AND GRAVEL PIT:**
Sand and gravel pits typically have steep sides and are meters to 10's of meters deep.

ssp **SANDSTONE PIT:**
Sandstone pits typically have steep sides, are meters to 10's of meters deep, and are sometimes flooded with water.

u **URBAN LAND:**
Cut and fill disturbing more than 50 percent of the ground surface; includes most areas with homes on one-half acre or smaller lots, commercial sites, and industrial sites.

ca **COALY ALLUVIUM:**
Stratified silt, sand, and some gravel-sized material whose fragments are primarily composed of coal from historic mining operations; dark gray to black; usually 1 to 3 meters thick; often underlain by non-coaly alluvium.

Qa **ALLUVIUM:**
Stratified silt, sand, and gravel, with some boulders; subrounded to rounded clasts; contains localized lenses of silty or sandy clay; yellowish brown to yellowish red color; at least 2 meters thick in smaller valleys; up to 5 meters thick in larger valleys.

Qat **ALLUVIAL TERRACE:**
Stratified silt, sand, and gravel, with some boulders; yellowish brown to yellowish red color; the deposits form benches running parallel to and a few meters above the present floodplain; generally 2 to 5 meters thick; present as discontinuous segments along the Lehigh River.

Qst **STRATH TERRACE:**
Gravel lag on a bedrock cut terrace form.

Qlc **COLLUVIUM DERIVED FROM LIMESTONE:**
Sparsely stony, matrix-supported diamict*; yellowish brown, clayey to silty matrix; clasts are limestone or dolostone with variable amounts of chert and/or limonite; the angular to subangular, equidimensional to tabular clasts exhibit a strong downslope orientation or form crudely layered lenses; clasts are typically a few to a few 10's of centimeters long and a few centimeters thick; accumulates in small valleys in headwater areas, usually in the center of such valleys stratified alluvium overlies the colluvium and intertongues with colluvium towards the valley walls; also accumulates as gently sloping, coalescent lobes at the toe-slopes of ridges; generally 2 to 5 meters thick.

Qlgc **COLLUVIUM DERIVED FROM LIMESTONE AND GNEISS:**
Sparsely stony, matrix-supported diamict; yellowish brown, clayey to silty matrix; clasts of granitic gneiss, limestone, dolostone, and chert; cobble to boulder-sized clasts; the angular to subangular, equidimensional to tabular clasts exhibit a strong downslope orientation or form crudely layered lenses; overlies carbonate bedrock; thickness typically from 2 to 5 meters; accumulates as coalescent lobes at the base of the ridges of the Reading Prong.

Qlsc **COLLUVIUM DERIVED FROM LIMESTONE AND SANDSTONE:**
Sparsely stony, matrix-supported diamict; yellowish brown, clayey to silty matrix; clasts of sandstone, granitic gneiss, limestone, dolostone, and chert; cobble to boulder-sized clasts; the angular to subangular, equidimensional to tabular clasts exhibit a strong downslope orientation or form crudely layered lenses; overlies carbonate bedrock; thickness typically from 2 to 5 meters; accumulates as coalescent lobes at the base of the ridges of the Reading Prong.

Qsc **COLLUVIUM DERIVED FROM SHALE AND SLATE:**
Sparsely stony, yellowish brown,matrix-supported diamict; clayey silt matrix; the angular, tabular shale and sandstone clasts exhibit a strong downslope orientation or form crudely layered lenses; shale clasts are typically a few centimeters long and less than a centimeters thick; sandstone clasts are usually 10 to 25 centimeters across and a few centimeters thick; accumulates in small valleys in headwater areas, usually in the center of such valleys stratified alluvium overlies the colluvium and intertongues with colluvium towards the valley walls; also accumulates as gently sloping, coalescent lobes on the toe-slopes of ridges; generally 2 to 5 meters thick.

Qssc **STONY COLLUVIUM DERIVED FROM GRAY SANDSTONE:**
Gray cobble-sized sandstone clasts cover more than 15 percent of the ground surface; yellowish brown, matrix-supported stony diamict; often there are lenses or pockets of clast-supported diamict or clasts without matrix; the angular to subangular, tabular clasts exhibit a strong downslope orientation or form crudely layered lenses; clasts are typically 10 to 25 centimeters across and a few centimeters thick; occurs as gently sloping, coalescent lobes on the toe-slopes of ridges underlain by the Hardyston quartzite within the Reading Prong; generally 2 to 5 meters thick.

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* diamict: a nonsorted or poorly sorted, unconsolidated deposit that contains a wide range of particle sizes, commonly from clay to dobble- or boulder-size, rounded and/or angular fragments.

Qgsc **COLLUVIUM DERIVED FROM GRANITIC GNEISS AND SANDSTONE:**
Cobble-sized clasts of mostly granitic gneiss and sandstone cover more than 15 percent of the ground surface; yellowish brown matrix-supported diamict; sometimes there are lenses or pockets of clast-supported diamict or clasts without matrix; most clasts are equidimensional and subangular; tabular clasts exhibit a downslope orientation or form crudely layered lenses; clasts are usually 10 to 25 centimeters across; accumulates as gently sloping, coalescent lobes on the toe-slopes of ridges in the Reading Prong; thickness variable, usually 2 to 5 meters thick.

Qggc **COLLUVIUM DERIVED FROM GRANITIC GNEISS:**
Gray cobble-sized clasts, mostly of granitic gneiss, cover more than 15 percent of the ground surface; yellowish brown, matrix-supported diamict; often there are lenses or pockets of clast-supported diamict or clasts without matrix; the angular, tabular clasts exhibit a strong downslope orientation or form crudely layered lenses; clasts are typically 10 to 25 centimeters across and a few centimeters thick; accumulates in small valleys in headwater areas, usually in the center of such valleys stratified alluvium overlies the colluvium and intertongues with colluvium towards the valley walls; also accumulates as gently sloping, coalescent lobes on the toe-slopes of ridges in the Reading Prong; generally 2 to 5 meters thick.

Qhgc **COLLUVIUM DERIVED FROM HORNBLENDE GNEISS:**
Gray cobble-sized clasts, mostly of hornblende gneiss and other more mafic material, cover more than 15 percent of the ground surface; yellowish red to yellowish brown, matrix-supported diamict; often there are lenses or pockets of clast-supported diamict; many clasts are equidimensional and subangular; tabular clasts exhibit a downslope orientation or form crudely layered lenses; clasts are typically 10 to 25 centimeters across; accumulates in small valleys in headwater areas, usually in the center of such valleys stratified alluvium overlies the colluvium and intertongues with colluvium towards the valley walls; also accumulates as gently sloping, coalescent lobes on the toe-slopes of ridges in the Reading Prong; generally 2 to 5 meters thick.

Qbc **BOULDER COLLUVIUM:**
Quartz sandstone and/or granitic qneiss boulders and cobbles cover more than 25 percent of the ground surface in hollows in the flank of Blue Mtn. and in the flanks of the ridges in the Reading Prong; clasts are generally from 25 centimeters to 2 meters in diameter, subangular to subrounded, tabular to equidimensional, and concentrated at the surface of the deposit; matrix-supported diamict with lenses or pockets of clast-supported or matrixless clasts underlies the boulders; clayey sand to sandy silt matrix; usually 2 to 5 meters thick, locally is 50 meters thick.

Qpl **PRE-ILLINOIAN LAG:**
Discontinuous cobbly to bouldery mantle of glacial erratics of subrounded sandstone clasts; the surface is underlain by less than 2 meters of matrix-supported diamict derived from glacial deposits that in turn is underlain by bedrock; over most of the area, the material is less than 0.5 meters thick and is underlain by much thicker limestone residuum; near the contact of the pre-Illinoian lag with bedrock residuum and in places within areas of pre-Illinoian lag, the unit is composed of glacial erratic cobbles and boulders imbedded in a bedrock residuum diamict.

Qpit **PRE-ILLINOIAN TILL:**
Matrix-supported diamict at least 2 meters thick that contains glacial erratics; clayey silt matrix; yellowish red where the weathering profile is only partly truncated, yellowish brown where the original weathering profile is completely truncated; erratic clasts are dominantly Tuscarora sandstone of cobble-size with rarer boulder-size clasts as large as 1 meter; clasts mostly subrounded; usually the upper 1 to 2 meters and sometimes all of the material has been transported and redeposited as a colluvium derived from till; in places includes deeply weathered outwash whose upper 2 to3 meters has been weathered and cryoturbated into an unstratified diamict; generally only 2 to 5 meters thick; thicker near the glacial limit, under valley floors, and in carbonate sinkholes.

Qpio **PRE-ILLINOIAN OUTWASH:**
Roundstone diamict, matrix-supported, yellowish red color; 1 to 3 meters thick; underlain in places by reddish yellow, stratified silt, sand, and pebble to cobble gravel, with some boulders; pebbles and cobbles rounded to well rounded with weathering rinds up to 1.0 centimeter thick on quarztz sandstone clasts, weaker clasts weathered throughout; smooth-sloping to relatively flat surfaces; maximum thickness about 30 meters; observed only in the Emmaus and the Emmaus Junction area of the quadrangle.

g **GRANITIC GNEISS BEDROCK:**
Clast-rich diamict of residual and colluvial material derived from the directly underlying bedrock of granitic gneiss and minor amounts of more mafic material; clasts are typically matrix-supported with lenses of clast-supported material with or without matrix; yellowish brown to yellowish red, clayey to silty sand matrix; clasts are typically 10 to 25 centimeters across; most clasts are equidimensional and subangular; tabular clasts generally exhibit a downslope orientation within the upper 0.5 meter of the material; less than 2 meters to saprolite or unweathered bedrock; on greater than 15 percent slopes, typically less than 1 meter thick.

hg **HORNBLENDE GNEISS BEDROCK:**
Clast-rich diamict of residual and colluvial material derived from the directly underlying bedrock of hornblende gneiss and minor amounts of more mafic material or more felsic material; clasts are typically matrix-supported with lenses of clast-supported material with or without matrix; brown to yellowish red, clayey silt to sandy silt matrix; tabular clasts often exhibit a downslope directed orientation within the upper 0.5 meter of the material; less than 2 meters to saprolite or unweathered bedrock; on greater than 15 percent slopes, typically less than 1 meter thick.

lr **LIMESTONE BEDROCK:**
Matrix dominated diamict of residual and colluvial material derived from the directly underlying bedrock of gray limestone or dolostone with variable amounts of chert and limonite; clasts are typically matrix-supported and become more common with depth; yellowish brown to yellowish red matrix; tabular clasts generally exhibit a downslope orientation; less than 2 meters to saprolite or unweathered bedrock on greater than 15 percent slopes, typically less than 1 meter deep; often thicker in depressions.

ss **SANDSTONE BEDROCK:**
Clast-rich diamict of residual and colluvial material derived from the directly underlying quartz to feldspathic sandstone bedrock; clasts are typically matrix-supported with lenses of clast-supported material with or without matrix; yellowish brown, clayey to silty sand matrix; tabular clasts generally exhibit a downslope directed orientation within the upper 0.5 meter of the material; less than 2 meters to weathered or unweathered bedrock.

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