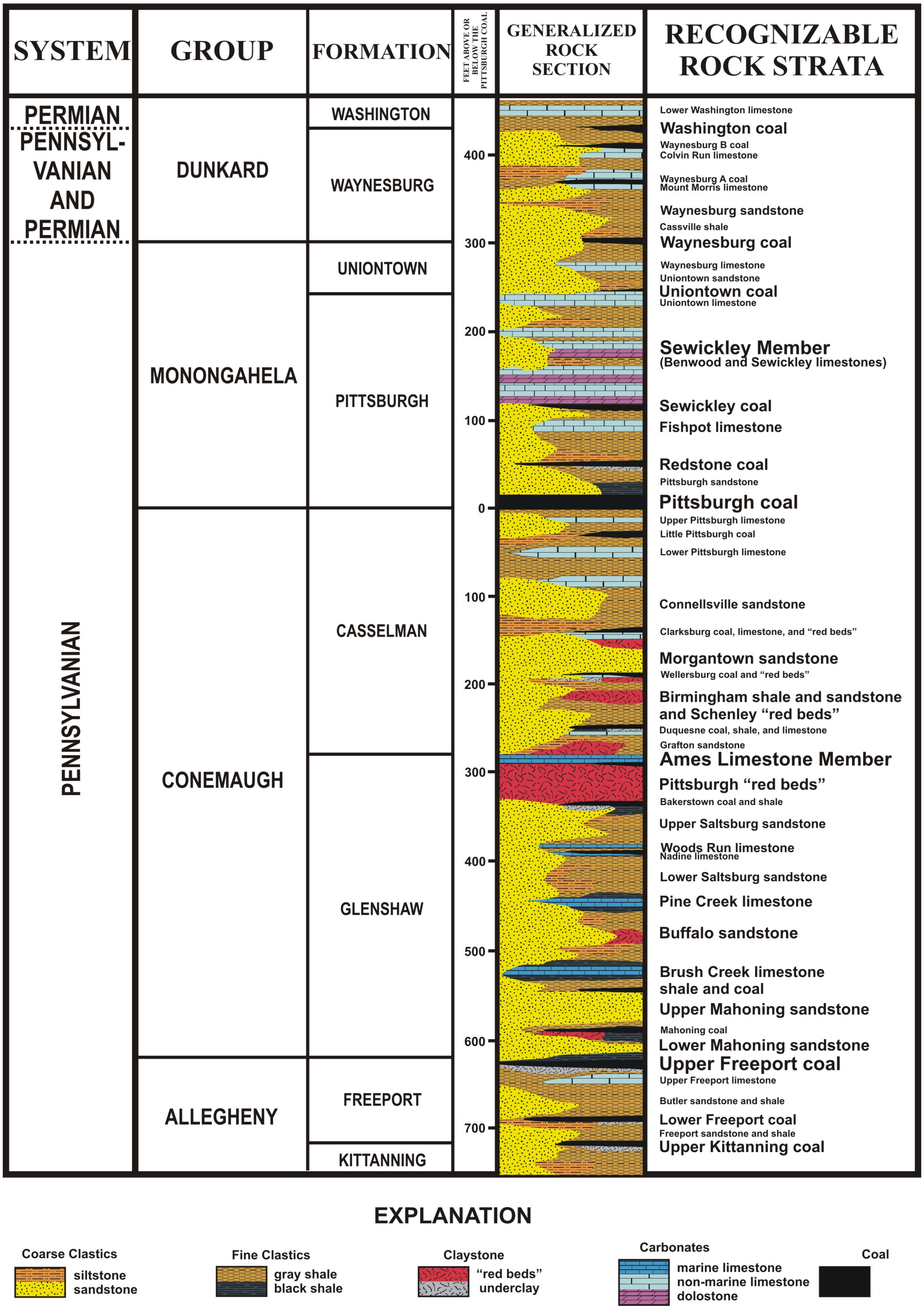
Pittsburgh Geological Society
75th Anniversary Field Trip
March 2022

Interstate Route 79 and Toms Run Nature Reserve Landslide Areas North of the Ohio River and Northwest of Pittsburgh

I-79 Station 916-918 Progressive Failure of Colluvial Slope – March 13, 1969

Field Trip Leader: James V. Hamel, Ph.D., P.E., P.G.
PGS Honorary Member



Columnar section of the rocks in Allegheny County

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Additional copies of this field trip guidebook are available on the PGS website at:

https://pittsburghgeologicalsociety.org/pgs-field-guides.html

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Brian Dunst, Jim Hamel, and Mary Ann Gross enjoying a cool one after video of Stop 1 for Virtual Field Trip.

Introduction

On January 15, 2020, I gave a talk entitled *I-79 Landslides near Pittsburgh, PA – A 50 Year Perspective* at a joint meeting of the American Society of Civil Engineers (ASCE) Pittsburgh Chapter Geo-Institute, the Greater Pittsburgh Chapter of the Association of Environmental and Engineering Geologists (AEG), and the Pittsburgh Geological Society (PGS). After this talk, I was asked by PGS representatives to lead a field trip to the I-79 landslide area as part of celebration of the 75th Anniversary of PGS.

Despite the relatively short notice, I agreed to lead this field trip at the end of March because (1) people need to see this slide area, and (2) I had led several previous field trips to this slide area and guidebook sections on two of the stops were available. Along with PGS Honorary Members Dick Gray and Bill Adams, I led a landslide field trip at the Joint Meeting of the Geological Society of America (GSA) Northeastern and North-Central Sections held in Pittsburgh in March 2011. We prepared a guidebook section *Landslides in the vicinity of Pittsburgh, Pennsylvania* for that meeting (Gray, et al., 2011). We repeated this landslide field trip at the 58th Annual Meeting of AEG held in Pittsburgh in September 2015. GSA gave permission to use the 2011 guidebook section for the AEG field trip, and they have also given permission to use the 2011 guidebook section for the present PGS field trip. The 2011 guidebook section is included in this guidebook as Appendix A. Selected photographs of field trip stops are included in Appendix B.

The introductory portion of Appendix A (pp. 61-67) provides an overview of landsliding in the Pittsburgh area. Stop 1 on Mt. Washington (Appendix A, pp. 67-71) provides additional background on Pittsburgh and its landslide history. Stop 2, at Webster Road in Plum Borough (Appendix A, pp. 71-75), includes typical examples of small landslides affecting a local road. We will not visit these two stops because of time limitations and our emphasis on the I-79 landslide area.

Stops 3 and 4 of the 2011 field trip (Appendix A, pp. 75-84) are Stops 1 and 4, respectively, of the present field trip. Stops 2 and 3 of the present field trip were not included on previous trips to the I-79 landslide area. Stop 2 was added to make a full day trip and to visit an additional nearby landslide area. Stop 3 was added as a lunch stop and an opportunity to discuss the nearby Kilbuck landslide.

This field trip was originally planned for Saturday, March 28, 2020. COVID-19 shut everything down in mid-March, and this field trip was postponed indefinitely. Snow cover and foliage limit visibility of landslide features, so this field trip can only be done from early March to mid-April and from late October to late November each year. The best time is early March to mid-April.

In early 2021, with continuing COVID-19 concerns and shut downs, PGS decided to prepare a virtual version of this field trip to be made available until an actual field trip could be run. This original field trip guide has been revised to include additional material developed over the past year and a half and included in the virtual field trip.

Field Trip Itinerary

As noted above, Stops 3 and 4 of the 2011 field trip are Stops 1 and 4 of the present field trip (Figure 1). The information in Appendix A on these two stops is still relevant. Stop 2 of the present field trip is at the Toms Run Nature Reserve of the Western Pennsylvania Conservancy (WPC) on the border between Ohio and Kilbuck Townships, about ½ mile (mi.) east of Stop 4. Stop 2 is about one mi. north of the infamous 2006 Kilbuck landslide which we will pass and briefly discuss, but not visit. Stop 3 is our lunch stop at the Ohio Township Community Park. See Figures 2 and 3 for topographic maps of our field trip stops.

All four of these stops, along with the Kilbuck landslide, are in close proximity (Figures 1-3). The overall field trip area is about 3 mi. north-south by 1.5 mi. east-west.

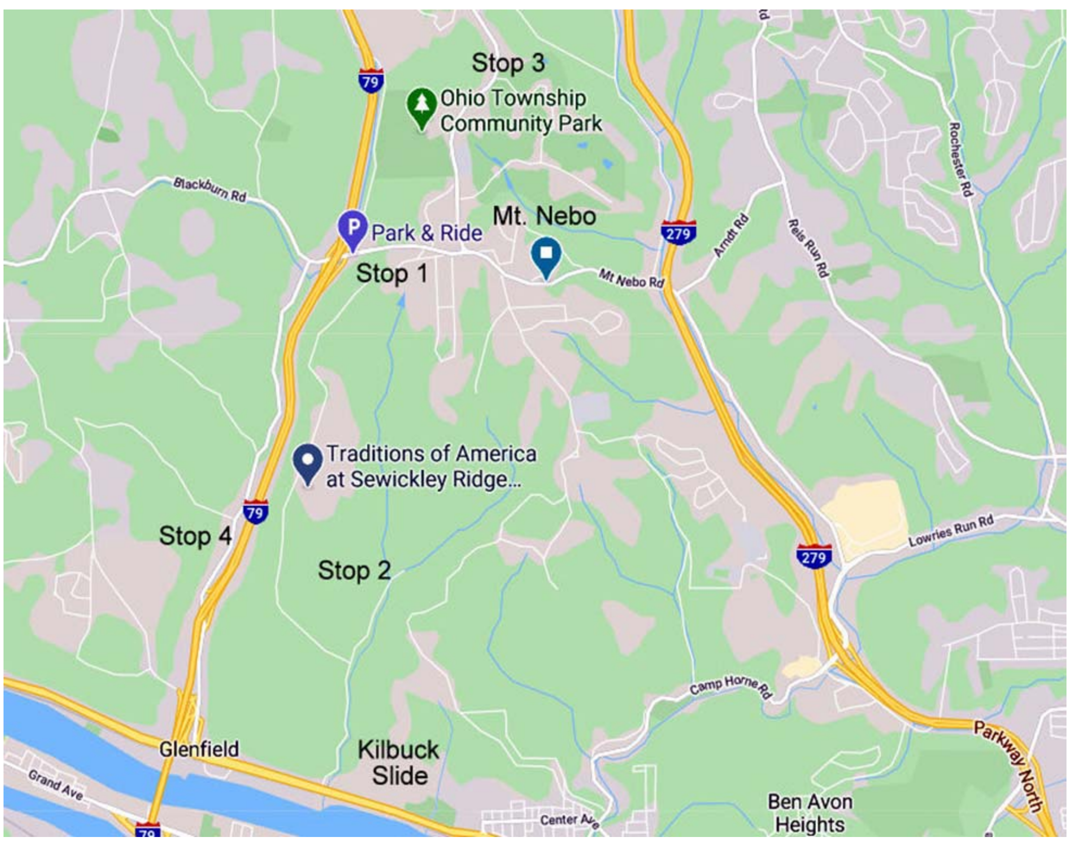

Figure 1. Map of field trip stops – North is at the top.

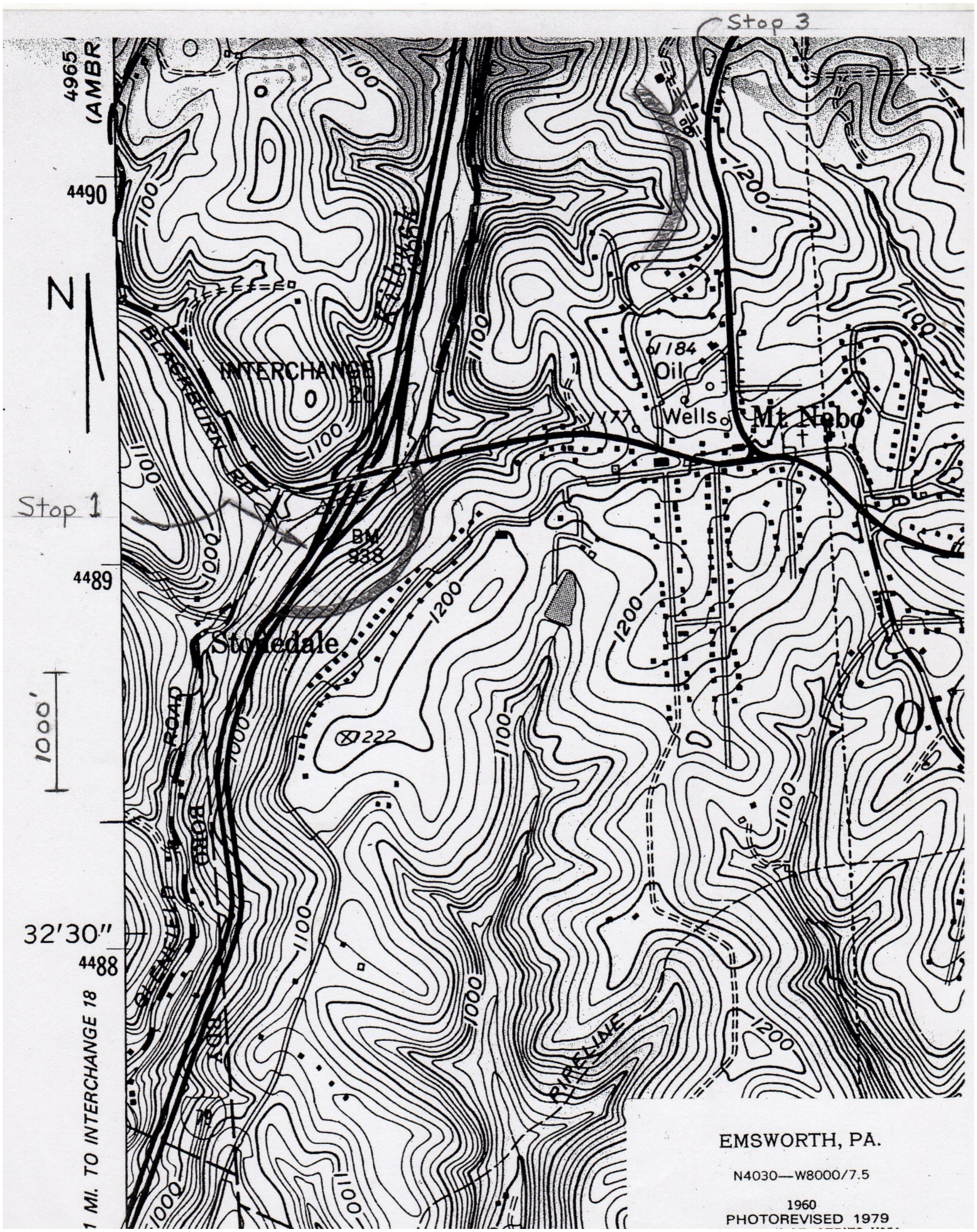

Figure 2. Portion of USGS Emsworth 7.5-minute topographic map showing the locations of Stops 1 and 3.

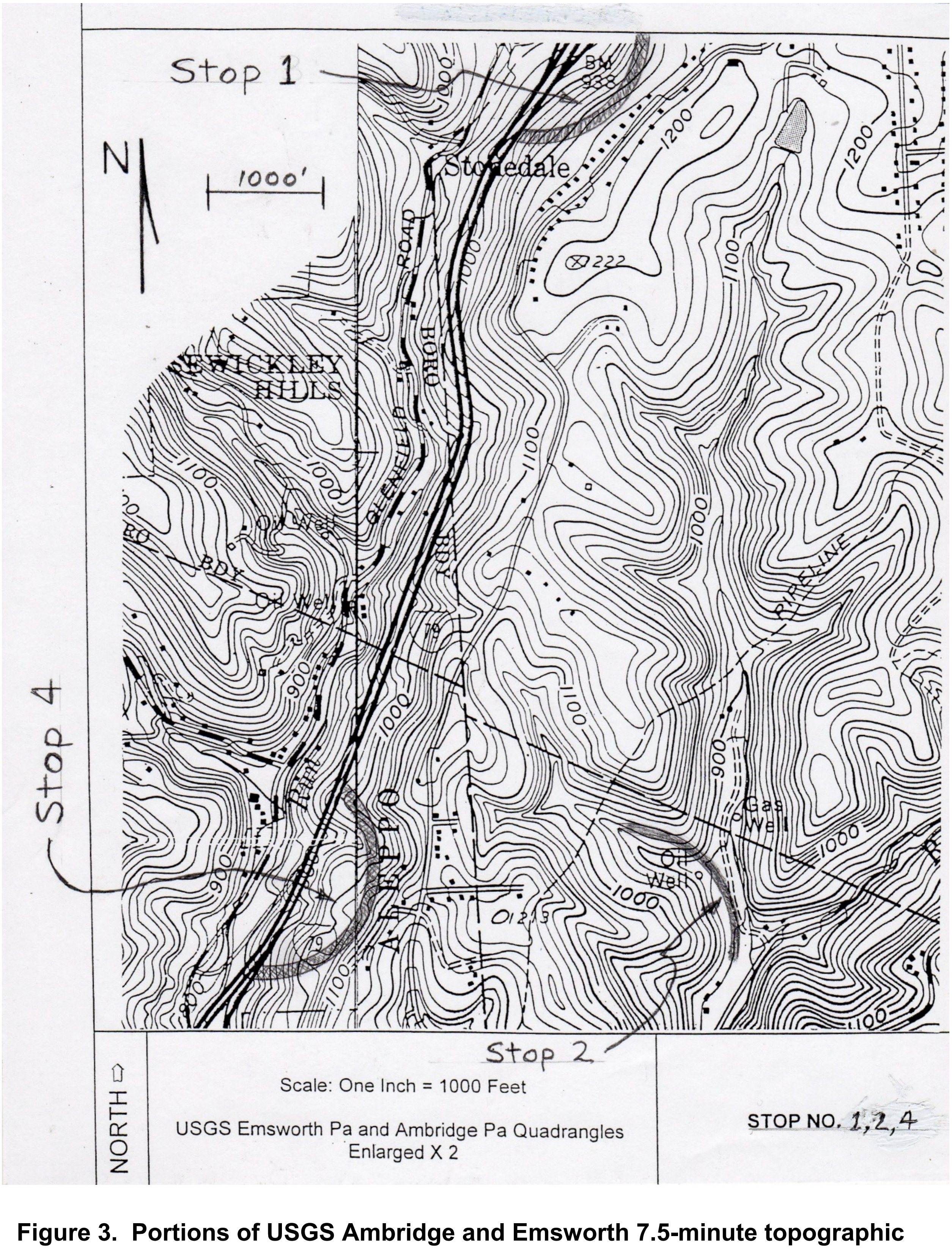

Figure 3. Portions of USGS Ambridge and Emsworth 7.5-minute topographic quadrangle maps showing the locations of Stops 1, 2, and 4.

We will meet at the appointed time at the Mt. Nebo Park & Ride lot where there should be sufficient parking spaces for our cars. Additional parking, if needed, is available at the Sheetz across Mt. Nebo Road from the Park & Ride lot. At Stop 1, we will walk south along the wide shoulder of the Mt. Nebo Road northbound exit ramp as described on p. 82 of Appendix A. We will view and discuss features described and illustrated on p. 80-82, Appendix A, then walk back north along the exit ramp shoulder to the Park & Ride lot where we will board the vehicles.

From the Park & Ride lot, we will drive west on Mt. Nebo Road about 1/4 mi. to the southbound entrance ramp to I-79, then about 2.5 mi. south on I-79 to the Glenfield exit. We will drive south on Glenfield Road, turn left on Ohio River Boulevard (PA Route 65), drive east about one mi., then turn left on Toms Run Road. We will pass the Kilbuck landslide site and drive north about one mi. on Toms Run Road to the WPC parking area on the left. We will leave the vehicles there and walk to Stop 2, which is described below.

From the WPC parking area, we will drive about 1/2 mi. south on Toms Run Road, turn right (west) on Duff Road, drive about 2 mi. north and then turn left on to short Riya Lane. We will turn right onto Mt. Nebo Road at the traffic light, then left at the next traffic light on to Nicholson Road. We will drive about 1/2 mi. north on Nicholson Road and turn left into the Ohio Township Community Park, Stop 3. There we will have lunch in the picnic pavilion (with adjacent restrooms). We will briefly discuss the Kilbuck landslide during lunch at Stop 3.

After lunch, we will retrace our path back to I-79 southbound and the Glenfield exit. We will follow Glenfield Road east under I-79 to the northbound entrance ramp, then drive along this ramp to its north end at Stop 4. We will leave the vehicles on the wide shoulder of the highway and walk upslope to view and discuss features as described and illustrated on p. 83-84 of Appendix A. Then we will return to the vehicles and drive back north to the Mt. Nebo Park & Ride lot. There the field trip will end.

Stop 1 – I-79 Stations 973-988

Stop 1 is described and illustrated in Appendix A (pp. 80-82) where it was Stop 3 on the 2011 field trip. The plan, stratigraphic column, and slope cross-section in Appendix A, figs. 20-22 on pages 80-82, are included below as Figures 4-6 for reference purposes. Supplemental material on Stop 1 is also provided below.

The slope here was excavated in 1969. The ravine at Station (Sta) 976 (Figures 4 and 5) was eroded in the slope since then by surface-water runoff from upslope areas. This ravine exposes stratigraphy from the top of the Saltsburg shale and sandstone up through the Morgantown sandstone (Figure 5). Concrete rubble in the lower part of the ravine was placed by PennDOT for erosion protection.

Strata at Stop 1 (Figure 5) differ significantly from those 1.3 mi. farther south at Stop 4. At Stop 1, the claystones of the Pittsburgh red beds are 26 ft. thick, which is fairly typical for the Pittsburgh region. At Stop 4, this unit is about 60 ft. thick. The maximum thickness of Pittsburgh red beds that I have encountered to date was 72 ft. measured from a drill core at a site in Ohio Township about 3 mi. southeast of Stop 1 and 3 mi. east of Stop 4. There is considerable variation in thickness of the Pittsburgh red beds in this area north of the Ohio River. The greater thicknesses increase landslide potential.

Also at Stop 1, the 2-ft.-thick Duquesne coal is underlain by 3 ft. of carbonaceous shale and overlain by 7 ft. of carbonaceous shale beneath the 11-ft.-thick Birmingham shale unit (Figure 5). At Stop 4, the Duquesne coal and Birmingham shale are absent and the Morgantown sandstone overlies the unnamed claystone above the Ames Limestone.

From the Mt. Nebo Park & Ride lot, we walk south along the wide shoulder of the Mt. Nebo northbound exit ramp from I-79 for a distance of about 1,800 ft. We pass along the toes of partially excavated colluvial slide masses with springs, some with moderate flows. We pass the ravine at Station (Sta) 976 to which we will return.

From the ravine at Sta 976, we walk south approximately 600 ft. observing the toes of partially excavated colluvial slide masses with hummocky topography, bent trees, small localized scarps and slide benches, and localized spring discharge. Then we turn around and walk back to the ravine at Sta 976.

We follow deer trails zigzagging up the partially excavated colluvial slope south of the ravine to a small slide bench at the level of the Duquesne coal and carbonaceous shale. The carbonaceous shale is slumped in the scarp at the rear of this bench. From the south side of the ravine at the first stratigraphic observation point (Duquesne coal level),

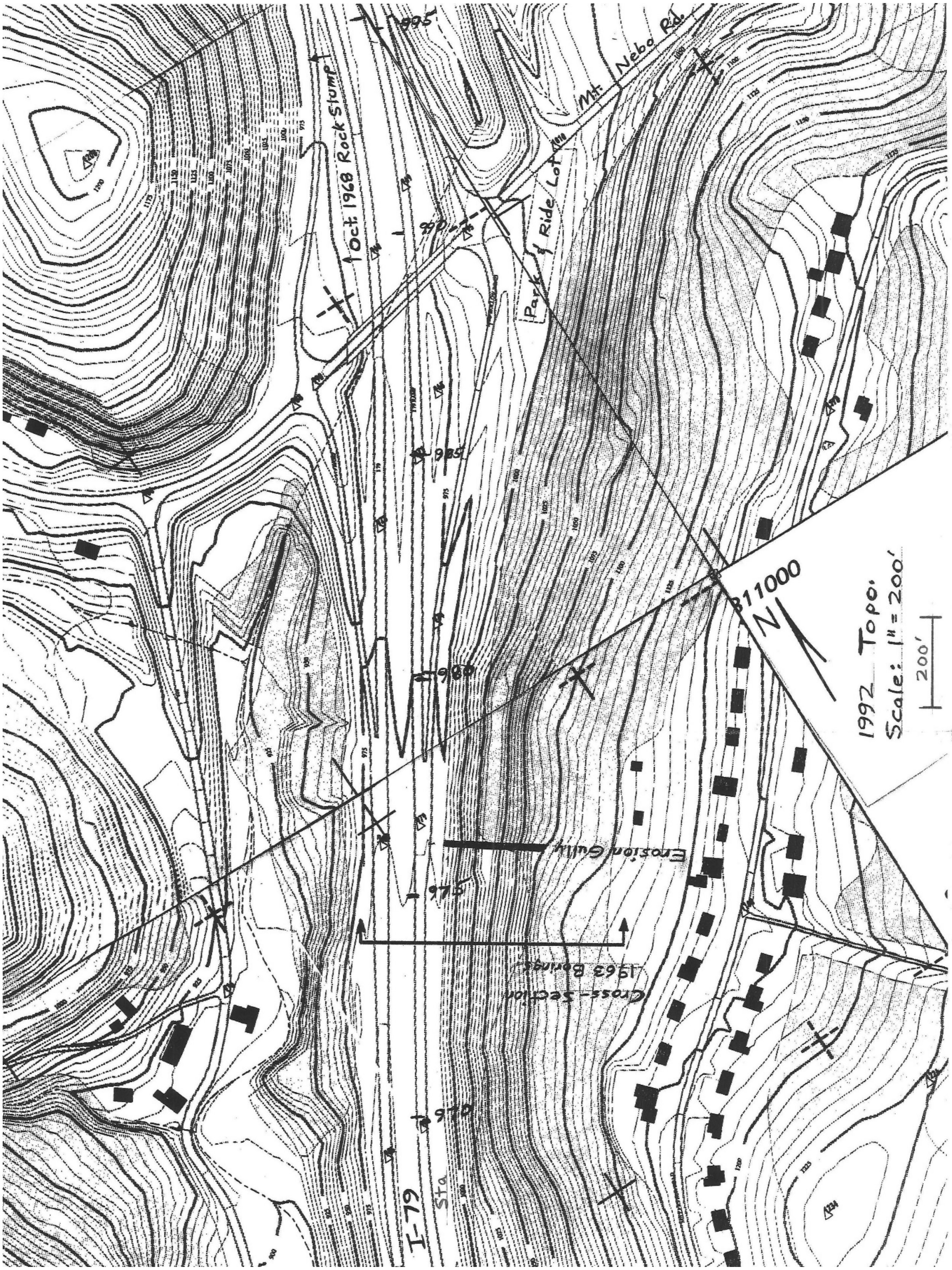

Figure 4. Annotated portion of 1992 Allegheny County topographic map showing features at Stop 1 (modified slightly from Gray, et al., 2011, fig. 20).

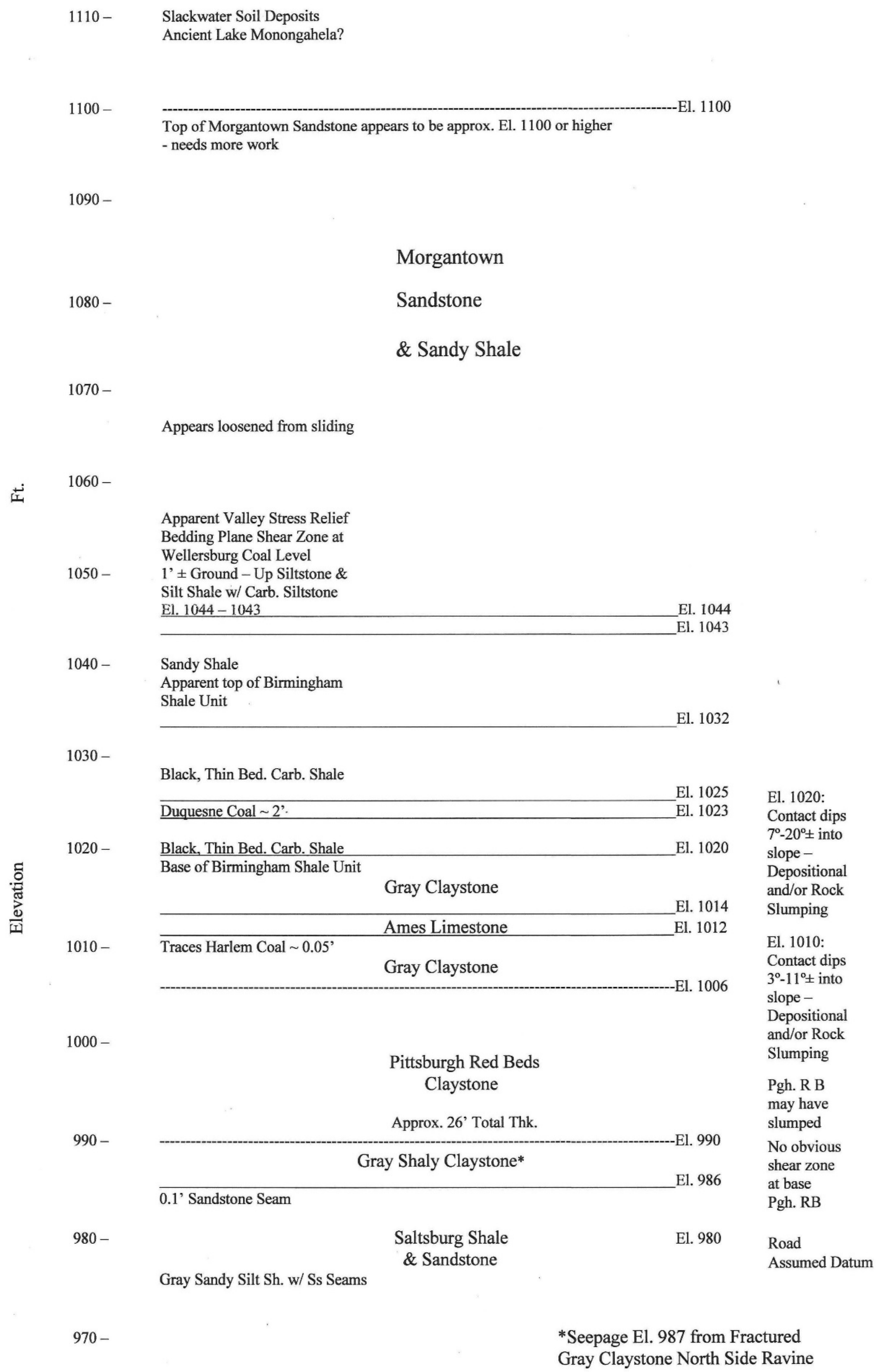

Figure 5. Stratigraphic column measured up the ravine at Sta 976, Stop 1 (from Gray, et al., 2011, fig. 21).

we see the top of the Pittsburgh red beds, Ames Limestone, Duquesne coal and carbonaceous shale, and base of Birmingham shale and sandstone.

We continue upslope south of the ravine, then drop into the ravine to the second stratigraphic observation point where we see an exposure from the top of the Birmingham shale through the Wellersburg claystone and coal to the base of the Morgantown sandstone. We follow deer trails farther upslope south of the ravine to the top of the slope. Along the way, we see Morgantown sandstone loosened by stress-release, sliding, and creep, as well as numerous trees of various species and sizes bent from sliding and creep of underlying colluvium.

Remnants of slackwater soil deposits, perhaps from Pleistocene Lake Monongahela (Harper, 2002), exist along the small stream discharging into the top of the ravine. Large trees bent by creep and intermittent sliding of underlying Morgantown sandstone blocks also exist near the top of the ravine.

From the top of the ravine, we hike north along haul roads left from I-79 construction, generally following and staying inside of the PennDOT right-of-way fence and angling downslope toward I-79. We see hummocky colluvium, numerous bent trees, occasional spring discharges, and a depression pond in colluvium.

From the depression pond, we angle down to the I-79 exit ramp and hike back to the Park & Ride lot. Hiking down and back to see the features of Stop 1 typically requires 1.5 hours (hr.), based on past field trips.

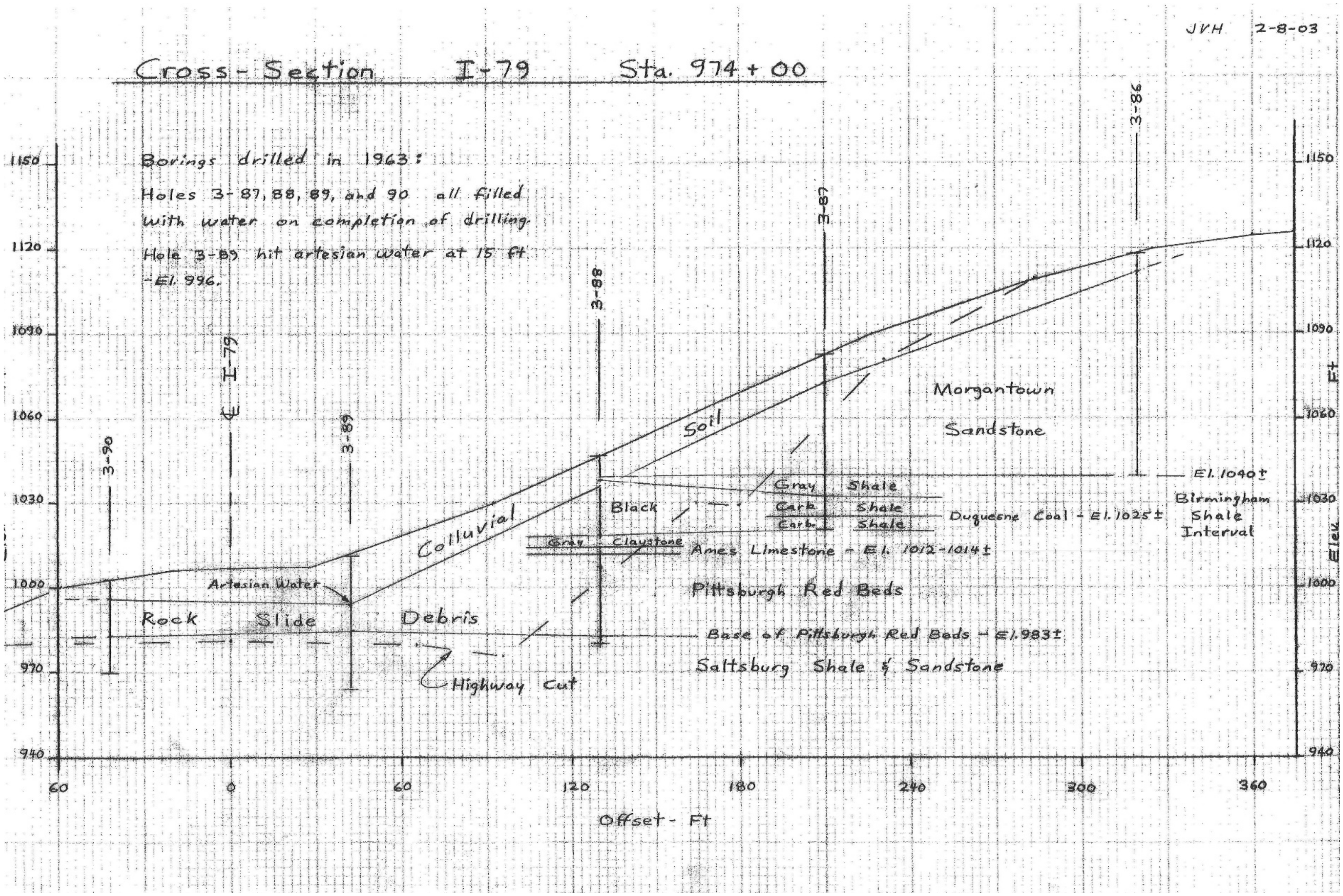

Figure 6. Cross-section of the slope at Sta 974 (from Gray, et al., 2011, fig. 22).

Stop 2 – Toms Run Nature Reserve

The Western Pennsylvania Conservancy (WPC) acquired 300 acres (ac.) of land for the Toms Run Nature Reserve in 1977. I learned of this property while seeking hunting areas in Allegheny County and obtained the map in Figure 7 from the WPC in October 2000. This property map is plotted on a portion of the U.S. Geological Survey (USGS) Emsworth, PA, 7.5-minute topographic quadrangle map, 1960, photorevised in 1979. I have observed numerous landslide features while hunting on this property over the past two decades, but I had not investigated them until preparing for this field trip in January 2020.

Aerial photographs taken in May 1957 show the ridgetops above approximate elevation (el.) 1100 ft. in the square central parcel of the property (Figure 7) cleared and rough graded. The intended development was subsequently abandoned as shown on aerial photographs taken in March 1969. Road and fill remnants still exist on these ridgetops, along with an apparent storm water retention pond. It is not presently known if abandonment of this project resulted from landslide activity on the slopes around the edges of the area being graded, though this possibility certainly exists.

In 2018, the WPC acquired an additional 69 ac. of land south and east of the original property and east of Toms Run Road as shown on Figure 8. The WPC has recently made improvements to the original property. Oil and gas wells in the southern part of the property, along with two abandoned houses on the west side of the central valley, just south of the Pipeline (Figures 7 and 9) have been removed. A new, larger parking area was constructed on the west side of Toms Run Road at the south end of the original property in 2019 (Figure 9). The WPC has recently improved trails and stream crossings along the central valley.

The northern segment of Toms Run Road extends ½ mi. south from Roosevelt Road in Ohio Township. The mile-long central segment of Toms Run Road extending to the north edge of Kilbuck Township (Figure 7) has been abandoned since at least 2000. Extensive landslide deposits exist on both sides of Toms Run valley along this central segment of the road (Figure 10). This road segment may have been abandoned due to landsliding. The mile-long southern segment of Toms Run Road is open from the north edge of Kilbuck Township (the approximate south edge of the original WPC property) to Ohio River Boulevard (Figures 7 and 8).

Older maps (e.g., Figures 7 and 9) show Toms Run flowing along Toms Run Road. Some newer maps (e.g., Figure 8) have the previously unnamed stream in the central part of the WPC property labeled as Toms Run. For this field trip, we will consider Toms Run as the original first-order tributary of the Ohio River (Figure 9). The southerly flowing stream

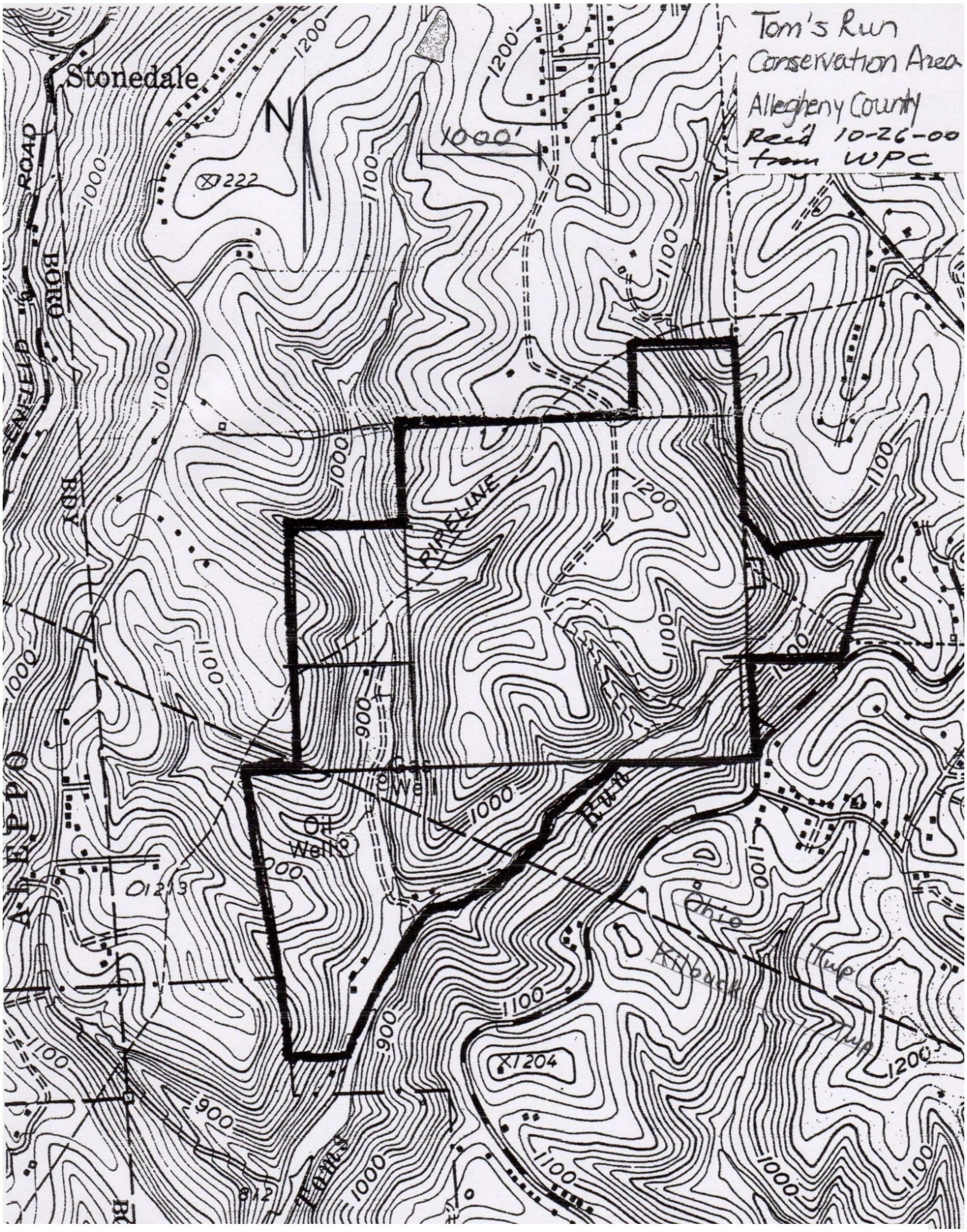

Figure 7. Portion of USGS Emsworth 7.5-minute topographic quadrangle map showing the configuration and location of the original WPC property.

Figure 8. Property map of the Toms Run Nature Reserve (WPC, 2020) - North is at the top.

in the central part of the WPC property (second-order tributary of the Ohio River) and the stream in the westerly valley in the southern part of the WPC property (third-order tributary of the Ohio River wholly within Kilbuck Township) will still be considered unnamed.

Because of time limitations, this field trip will go only to the westerly (third-order tributary) valley in Kilbuck Township (Figure 9), as described below. Field trip participants can explore the other two valleys later on their own if they wish.

Since Stop 2 is only ½ mi. east of Stop 4, the stratigraphy and structure shown in Appendix A, figs. 18 and 19 for Stop 4 on pp. 78 and 79 can reasonably be expected here. Thus, Stop 2 can be expected to have rocks from the Saltsburg silt shale and sandstone up through the Morgantown sandstone. The Birmingham shale and sandstone unit is likely thin, or perhaps missing as at Stop 4, where the Ames Limestone and thick Pittsburgh red beds are just below the Morgantown sandstone (Appendix A, fig. 18). The Ames Limestone can be expected to lie approximately at el. 1010 ft. at Stop 2 (Appendix A, fig. 19). The Pittsburgh red beds can be expected to be about 60 ft. thick here.

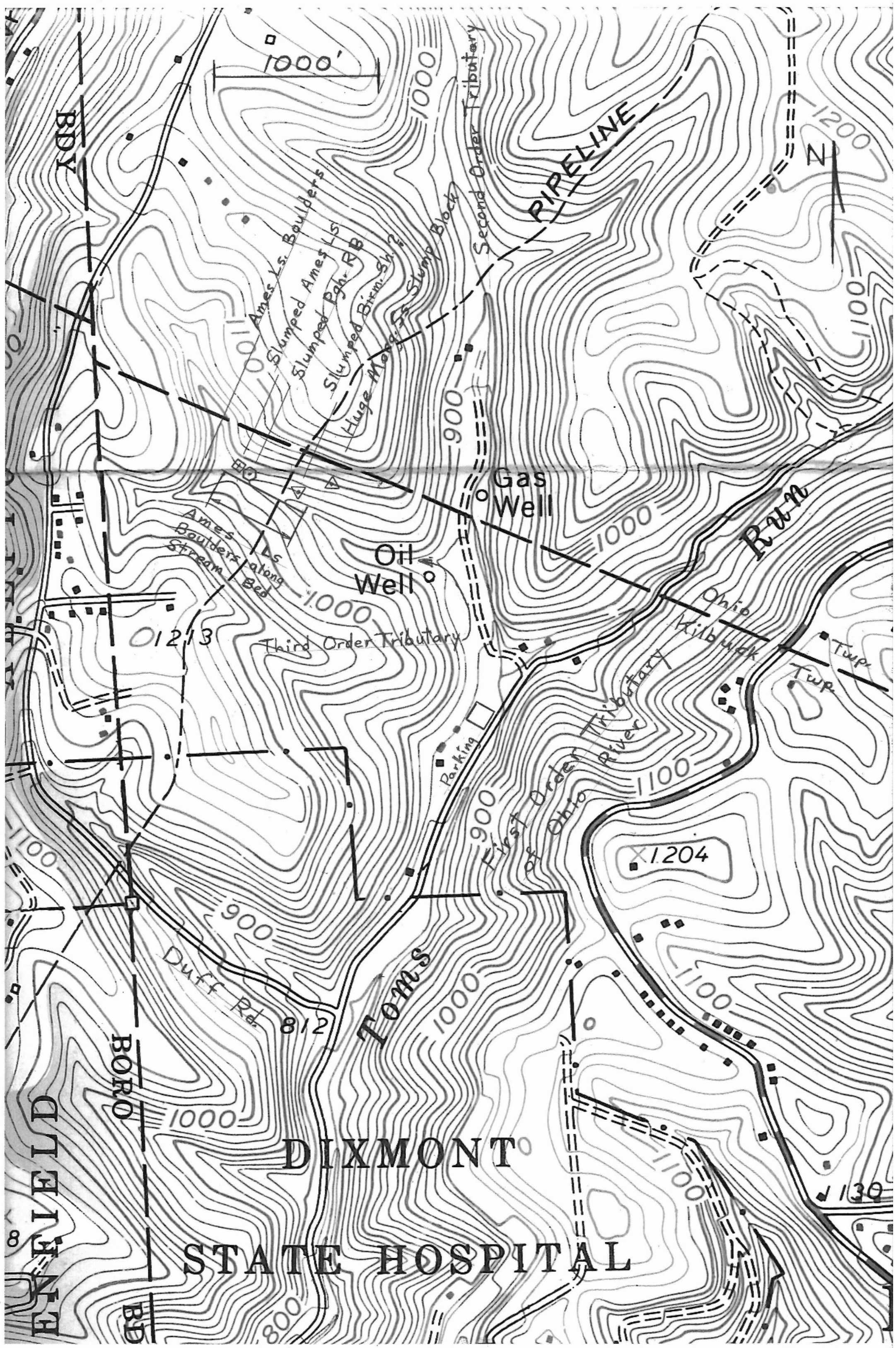

Figure 9. Portion of USGS Emsworth topographic quadrangle map showing the westerly valley of Toms Run Nature Reserve with landslide features.

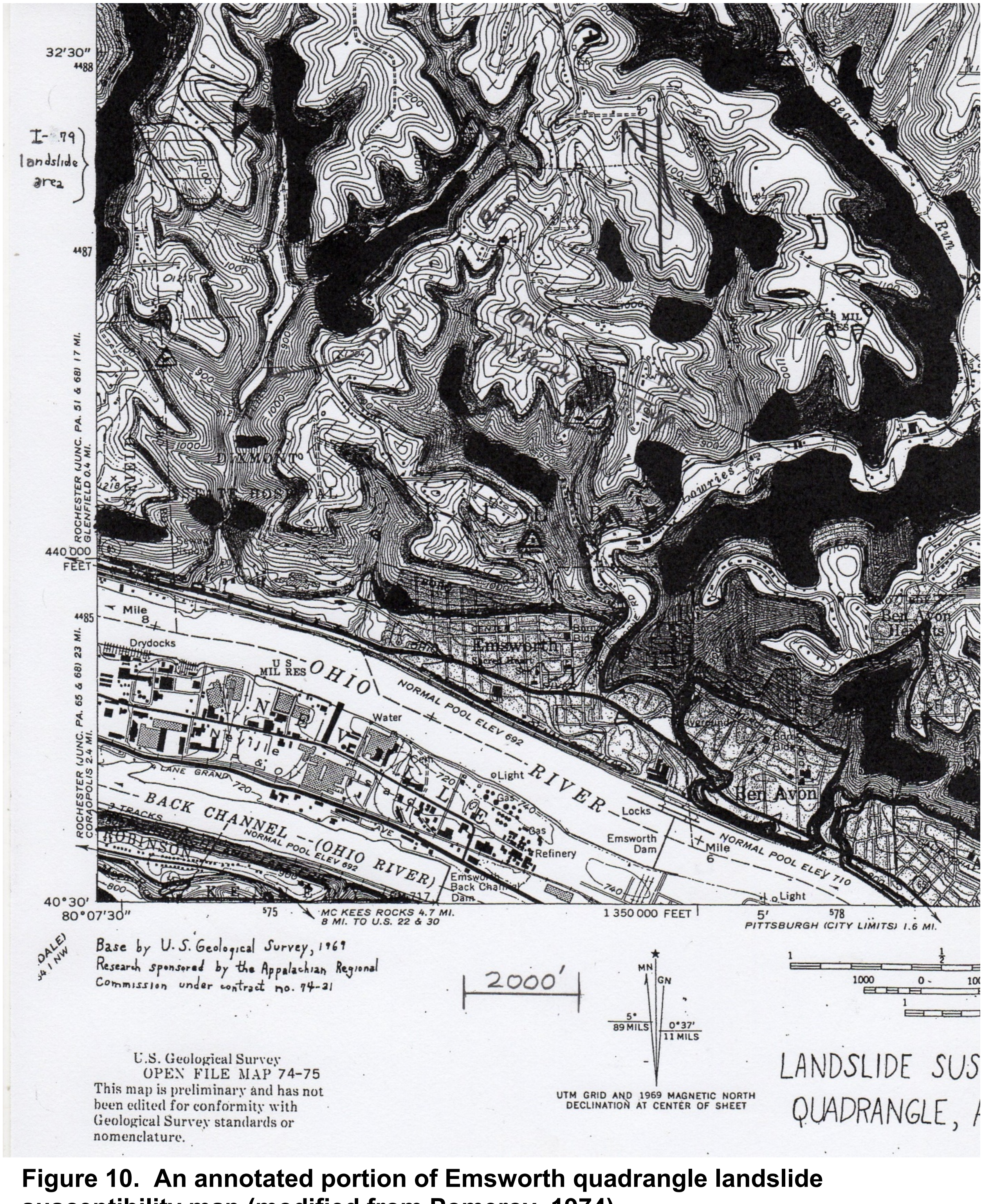

Figure 10. An annotated portion of Emsworth quadrangle landslide susceptibility map (modified from Pomeroy, 1974).

My preliminary reconnaissance of the westerly valley of Stop 2 in late January 2020 confirmed this general stratigraphy, but considerable additional work, including borings, would be needed to better characterize stratigraphy. On February 24, 2020, I found Ames Limestone boulders approximately at el. 1010 ft. below Morgantown slide debris at the west end of the westerly valley of Stop 2. These boulders appeared to be at or near the expected level of in-place Ames Limestone.

My recent reconnaissance also showed extensive landslide deposits, including slumped Morgantown sandstone, Ames Limestone, and claystones of the Pittsburgh red beds, along both sides of the westerly valley plus numerous Ames Limestone boulders along the stream channel in the valley bottom (Figure 9). Well-defined benches, some with closed topographic depressions, exist at the tops of slumped Morgantown sandstone masses along both sides of the western half of the valley.

At Stop 2, we will park in the new parking area on the west side of Toms Run Road (Figure 9), then walk about 800 ft. north up the central valley (Saltsburg unit exposed in east valley wall), to the westerly valley. There we will turn left (west) and walk about 1,500 ft. westerly along this valley observing and discussing various landslide features. Lobes of colluvium (old landslide debris) exist along the lower portions of both valley sides. The head of this valley is filled with coalescing landslide masses. A huge Morgantown sandstone slump block is perched on the north valley wall approximately at el. 1000 ft. about half way up the valley. A ridge of slumped Morgantown sandstone blocks exists farther upstream along the south side of the valley. Beds of these blocks dip back into the slope at about 20^{o}. A colluvial apron extends from these blocks down to the valley bottom. A few small collapse sinkholes exist in colluvium in the valley bottom.

Slumped Ames Limestone overlain by slumped Morgantown sandstone exists farther west along the north valley wall approximately at el. 980 ft. Just to the east, slumped claystones of the Pittsburgh red beds are exposed in the north valley wall. Farther east, slumped rock, possibly Birmingham shale, is exposed in the north valley wall. Numerous Ames Limestone boulders occur in the stream channel approximately from el. 930 – 970 ft. (Figure 9).

Walking up the valley, we see that the right (north) valley side is generally steeper with thinner colluvium. The left (south) valley side is generally somewhat flatter with lobes of colluvium extending into the stream channel where their toes are being actively eroded (Figure 11). Bent trees are everywhere. Numerous large grapevines, common in old landslide areas (Briggs, et al. 1975), exist on the colluvium.

The cleared gas line right-of-way, which crosses the valley in a northeasterly direction (PIPELINE, Figures 7 and 9), is the only significant landmark in this area that can be seen on topographic maps and aerial photographs. North of the valley, the gas line right-of-way cuts across the southeast corner of the Traditions of America at Sewickley Ridge townhouse development (Figure 1) constructed ca. 2014-2018 on a fill plateau where spoil from I-79 slope excavation was placed ca. 1969-1970. Some of the townhouses have their backyards along the gas line right-of way and along the crest of the slope at the head of this valley.

We hike upstream along the left (south) side of the stream to the head of the valley. There we see: Ames Limestone blocks in the stream; a large partially buried tire from earth moving equipment; orange, apparently iron stained and acidic, water discharging from the colluvial slope toe; and the backs of townhouses along the crest of the north slope. We turn around here and hike back to the parking area. Several trial runs, including three with PGS members, indicate that hiking in to see the features of Stop 2 and back to the parking area will require approximately 2 hr.

Figure 11. View upstream (west) at the stream eroding the toe of the slide mass on the left, with a tree bent from creep and sliding on the right.

Stop 3 – Lunch at Ohio Township Community Park

We will drive through the east entrance of Ohio Township Community Park (Figure 1) and have lunch at the Picnic Pavilion (restrooms in adjacent tan building).

The west entrance to this park is from Red Mud Hollow Road which extends north from Mt. Nebo Road across from the Park & Ride lot (Figure 1). Red Mud Hollow Road is named for the Pittsburgh red beds and associated colluvium exposed along much of its length. During reconnaissance in 2002, I observed Ames Limestone boulders and red clay colluvium along this road. Two large Ames Limestone boulders are displayed at the west park entrance.

During and after lunch, we will discuss the Kilbuck landslide. Then we will drive to Stop 4.

Kilbuck Slide

The Kilbuck landslide (Figure 12) occurred on September 19, 2006. This slide was 1,000 ft. long, extended 600 ft. upslope, and dumped 500,000 cubic yards ($yd^{3)}$ of material across four lanes of Ohio River Boulevard (PA Route 65) and two of three tracks of the Norfolk Southern Railroad. Slide debris did not reach the third railroad track or the Ohio River.

The Kilbuck landslide site is located about one mi. south of Stop 2 and one mi. southeast of Stop 4 (Figure 1). The stratigraphic interval here is the same as at these two stops and similar colluvium can be expected. A preliminary geotechnical cross-section provided by Bill Adams in October 2009 shows the Ames Limestone at el. 1011 ft.; this is about 170 ft. above Ohio River Boulevard. The Buffalo sandstone (Appendix A, fig. 18) is exposed in the cut slope along the north side of Ohio River Boulevard below the Kilbuck landslide area.

This slide is on the southern portion of the former Dixmont State Hospital property (Figures 9 and 10). Stereoscopic inspection of March 1969 aerial photographs strongly suggests that the hospital complex was constructed on a partially eroded colluvial slide mass at or below the level of the Pittsburgh red beds.

The following information on the Kilbuck landslide was summarized from newspaper articles and Joint State Government Commission (2008).

Dixmont State Hospital, the oldest mental health institution in Pennsylvania, operated from 1862 to 1984. The site had a long history of

Figure 12. Oblique aerial photograph of the Kilbuck landslide, taken September 19, 2006 (Pennsylvania Department of Transportation).

landslides. Several landslides occurred during construction and expansion of the facility from 1865 to 1878. A building under construction in 1949 slid over the hill. Ackenheil (1954) reported an earth slide of 15,000 yd^3 on March 26, 1951, after heavy rain.

From 1984 to 1999, the State tried unsuccessfully to sell the 407-ac. property. In February 1999, a local family Limited Partnership (LP) purchased the property, much of which was described as *hillsides unsuitable for construction, and the ruins of about 12 buildings from the abandoned institution*. A system of tunnels also existed beneath these buildings.

The family LP subsequently sold 75 ac. on the slope above Ohio River Boulevard for a $28 million commercial development to be anchored by a Walmart Super Center. Walmart purchased 37.5 ac.; a local developer, Kilbuck Properties, LP, purchased approximately 35 ac.; and the national chain restaurant Applebee's purchased 2.75 ac. Initially, Kilbuck Properties, LP served as developer for the entire 75 ac. site.

Initial site plans for the proposed development were submitted to Kilbuck Township in February 2002. In April 2002, Kilbuck Township amended its grading ordinance to expedite review and conditionally approved the project. Soon thereafter, local citizens began to protest and oppose the project.

The rather convoluted history of additional studies, variances, plan revisions and approvals, protests, public hearings, and legal actions from 2002 through 2005 is summarized in Joint State Government Commission (2008) and various newspaper articles. In October 2005, Kilbuck Township issued a grading permit and in November 2005 the Pennsylvania Department of Environmental Protection (PA DEP) issued a blasting permit.

Grading and other site work began in March 2006. On April 26, 2006, blasting caused a rock slide that temporarily closed Ohio River Boulevard. During the spring and summer of 2006, up to 100 ft. of fill was placed over colluvium which had not been recognized and/or had been ignored during site investigation and design. Relatively small landslides of unspecified size and location occurred in July and early September 2006. Heavy blasting of rock on September 18, 2006, may have contributed to initiation of the large landslide on September 19, 2006.

After this landslide, heroic clean-up efforts began. The railroad tracks were re-opened on September 23. The two southbound lanes of Ohio River Boulevard were re-opened on September 30. One northbound lane re-opened on October 2. The other northbound lane along the slope toe opened sometime later.

Kilbuck Properties, LP directed clean-up work and engineering investigations for slide remediation. Landslide movements continued during this work which was monitored by state and local government agencies. Over a weekend in early October, an area about 800 by 550 ft. in the south-central part of the slide moved 14 ft. in 24 hr.

On March 22, 2007, Walmart took over operational control of site work and remedial design from Kilbuck Properties, LP. Then on September 16, 2007, Walmart cancelled development plans and agreed to restore the hillside to pre-development conditions with vegetation and trees.

Portions of the slide continued to move until at least 2012. A May 12, 2014, newspaper article stated that remedial work was nearly finished with an estimated cost of $60 million. A fence was constructed around the slide site, vegetation was established, and trees were planted (Figure

13). We drive past the west side of the fenced and vegetated site on our way to Stop 2.

The Kilbuck Slide never should have happened. It represents a monumental failure to apply all that we had learned regionally and locally about colluvial landslides over the prior 35 years, particularly what we learned from the I-79 landslides only a mile away.

Figure 13. Google Earth photo of the restored Kilbuck Landslide site.

October 8, 2020

Stop 4 – I-79 Stations 900-910

Stop 4 extends for a length of approximately 1,000 ft. from Sta 900 to 910. This is the largest and most spectacular landslide area along this section of I-79, and it was the main one investigated by Hamel (1969) and Hamel and Flint (1969). Stop 4 is described and illustrated in Appendix A, pp. 82-84. The plan (Appendix A, fig. 23 on p. 83,) is included below as Figure 14 for reference purposes. An updated topographic map prepared by Helen Delano of the Pennsylvania Geological Survey in 2007 using 2006 LIDAR data is included as Figure 15. Other supplemental material on Stop 4 is also provided below.

As noted above for Stop 1, the Pittsburgh red beds are about 60 ft. thick at Stop 4. Along with the Ames Limestone and the 10-ft.-thick unnamed claystone above the Ames, this gives a weak rock zone about 70-ft.-thick high on the valley wall (Appendix A, fig. 18 on page 78). This weak rock zone is overlain by about 100 ft. of Morgantown sandstone extending up to ridgetop level. Deep-seated landsliding in the weak rock zone (probably in Illinoian time or earlier, based on regional Pleistocene time correlations) brought down large blocks of sandstone and claystone (Figure 16). Highway slope excavation in 1968-1969 re-activated old slide masses. These slide masses were partially excavated in 1969-1970. This excavation caused additional large movements and loosening of Morgantown sandstone farther upslope. Unexcavated slide remnants have continued to creep downslope over the past half century. These creeping masses pose no threat to the highway because a wide catchment bench was excavated at the top of the in-place Saltsburg shale and sandstone unit in 1969-1970.

The failure surface along which creep is occurring is inferred to be at or near the base of the Pittsburgh red beds at approximate el. 940 to 950 ft. (Figure 16). The tops of displaced Morgantown sandstone blocks are at approximate el. 1060 to 1100 ft. (Figures 15 and 16). Thus, the inferred surface of sliding and creep is on the order of 110 to 160 ft. below the ground surface. In April 1978, I could not reach the bottom of cracks between sandstone blocks with a weighted 100-ft. tape.

In September 2019, I presented a paper *Estimation of Long-Term Rock Slide Creep Movement from Tree Trunk Deformation* at the 62th Annual Meeting of AEG in Asheville, North Carolina. Here is the Abstract of this paper:

Marginally stable Pleistocene age rock slides were reactivated by slope excavation for Interstate Route 79 near Pittsburgh, Pennsylvania, in 1968-1969. I studied these slides as part of my Ph.D. research at that time, then left the area from 1969 to 1972. Portions of these slides

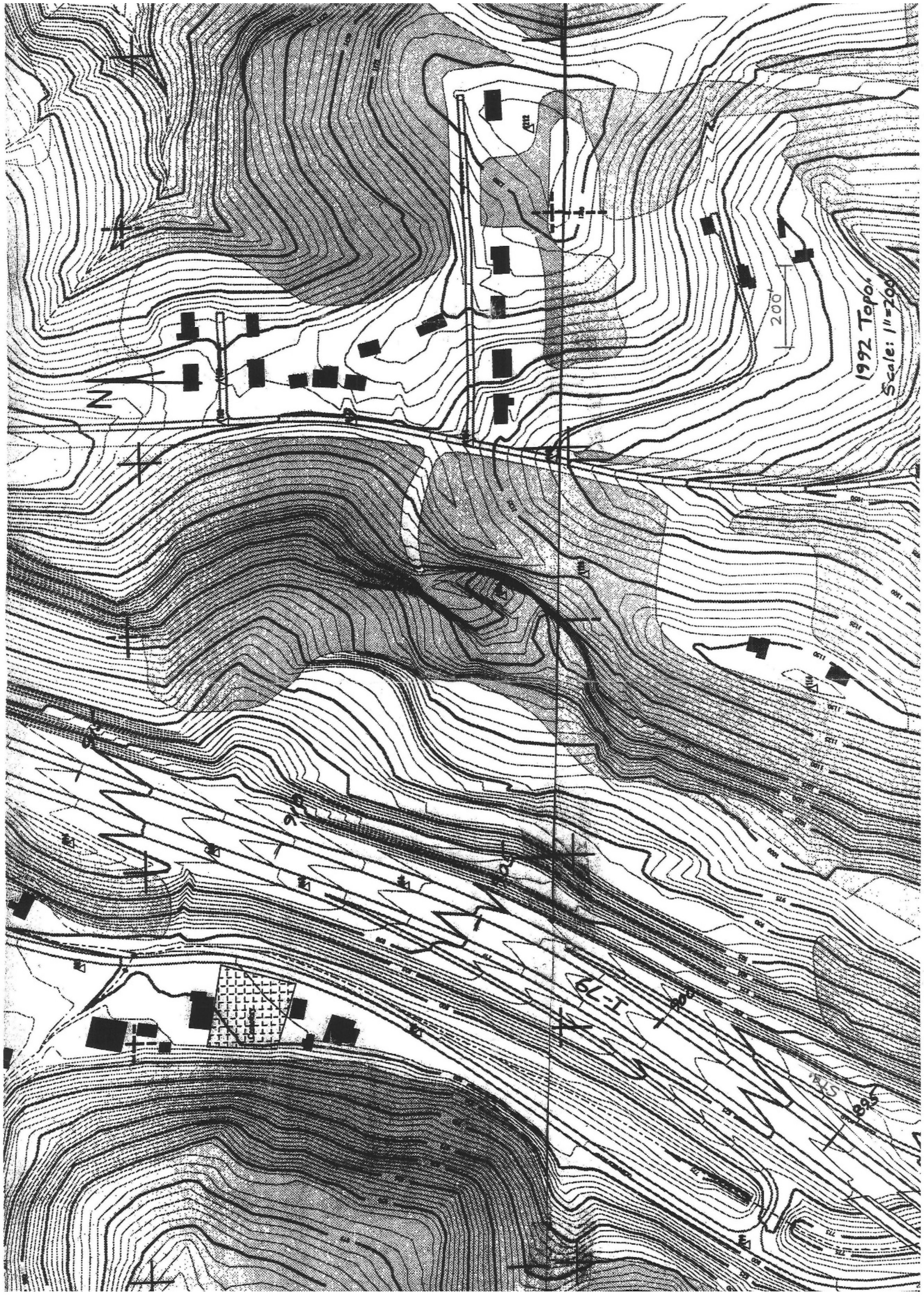

Figure 14. Annotated portion of 1992 Allegheny County topographic map showing features at Stop 4 (modified slightly from Gray, et al., 2011, Figure 23).

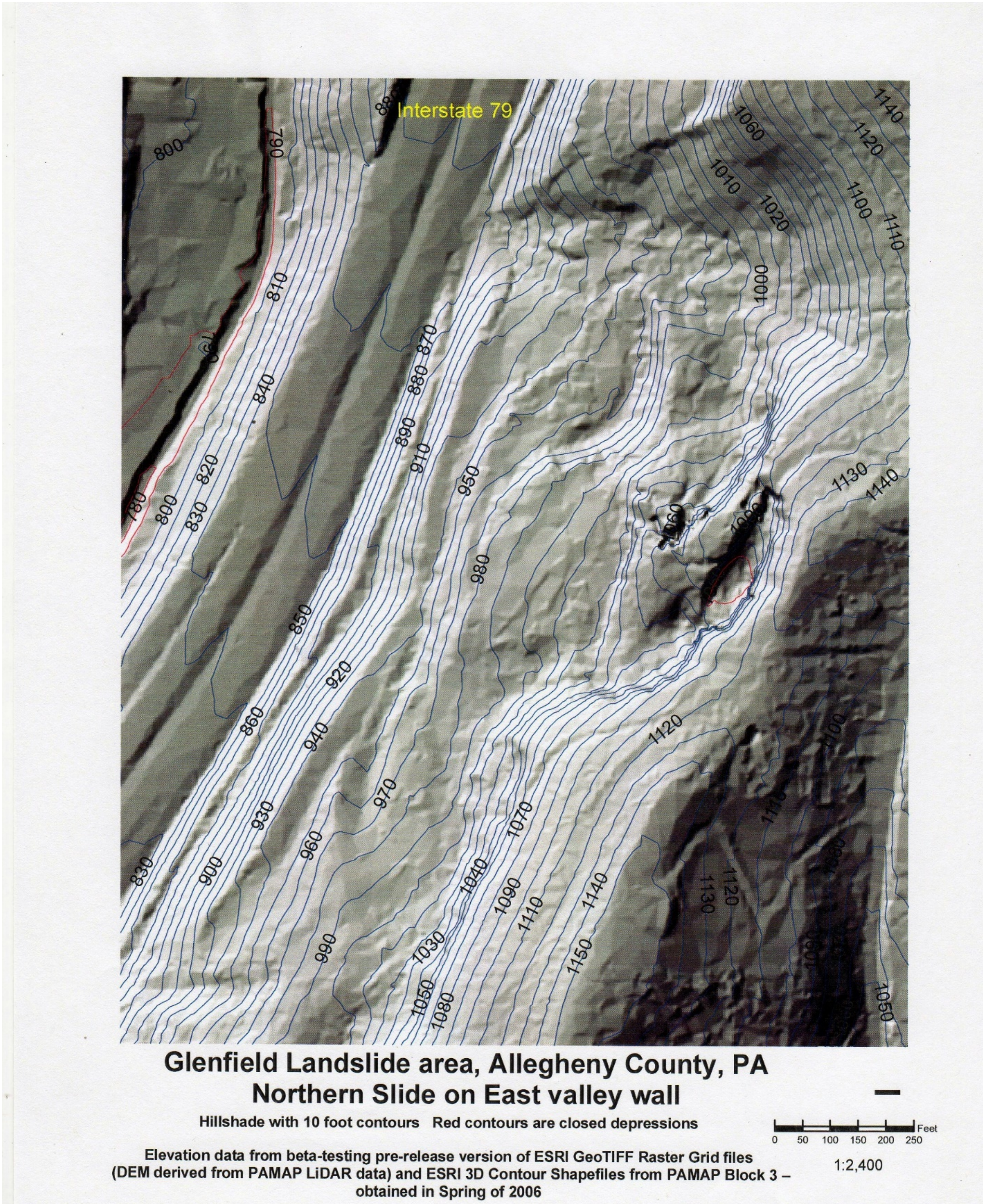

Figure 15. Hillshade topographic map of the area around Stop 4, based on 2006 LIDAR data (prepared by Helen Delano, Pennsylvania Geological Survey, 2007).

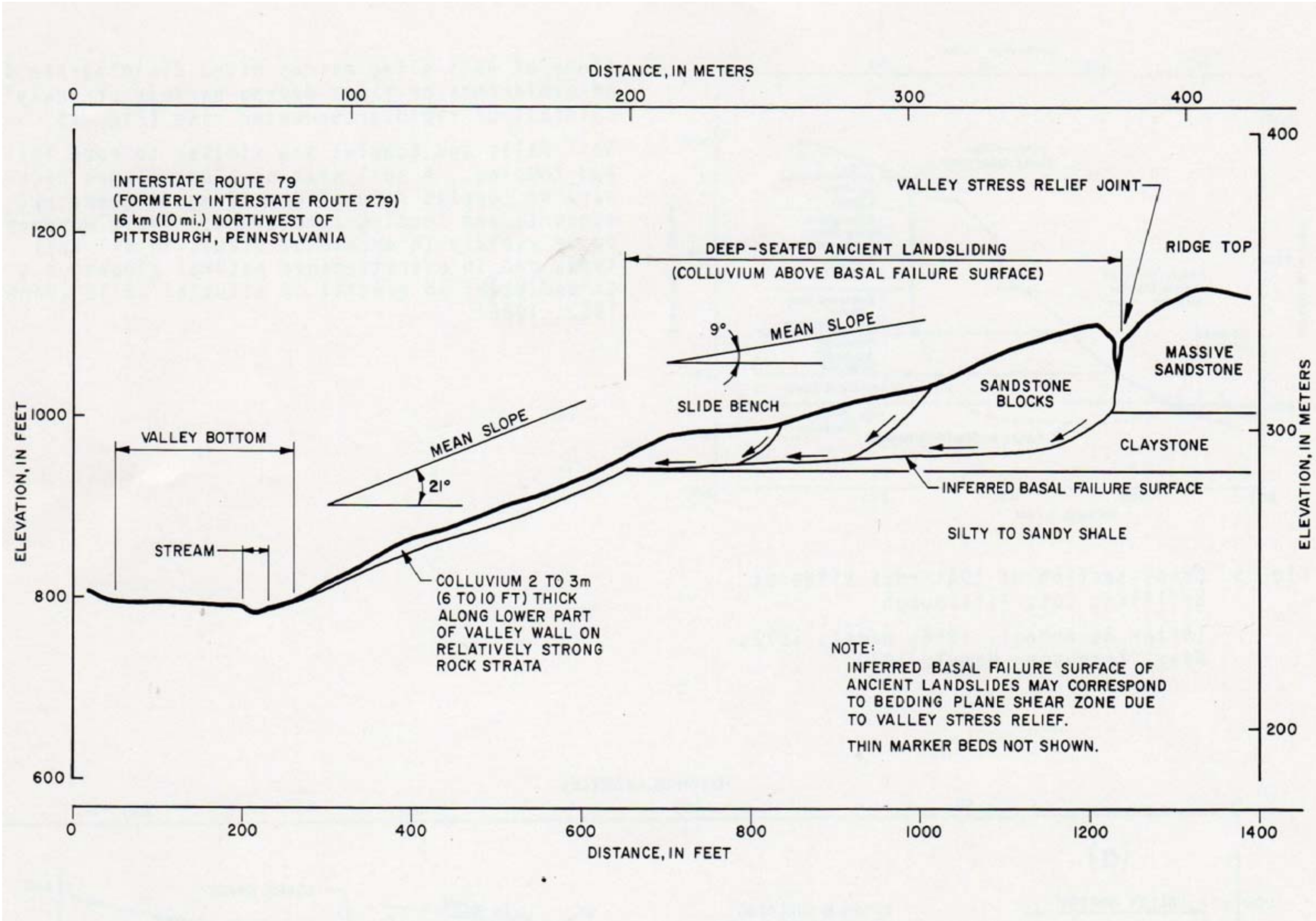

Figure 16. Slope cross-section at Sta 909, Stop 4 (from Hamel, 1980).

were excavated in 1969-1970 to stabilize the slopes. Unexcavated slide remnants have continued to creep downslope; because of a large buffer zone, they pose no threat to the highway. I have visited the slide area intermittently as time permitted since 1972 for visual monitoring of slide behavior, with annual visits, typically each spring, since 2014. One of the major areas I studied in 1968-1969 is 1,000 feet long between Stations 900 and 910. This area has partially excavated slide remnants still creeping. In April 2019, on the fiftieth anniversary of my original research, I measured tree root-trunk offsets in the most active part of this major slide area. This part extending from Station 906 to 909 had horizontal movement of approximately 60 feet from 1969-1970. This movement created a graben approximately 240 feet long and 30 feet deep on its downslope side with a 50 foot high near-vertical sandstone face on its upslope side. Nine trees (six maple; one each elm, oak, hickory) with trunk diameters of 0.6 to 4.0 feet, located in the graben and along its downslope side, had root–trunk offsets of 1.2 to 4.0 feet, typically about 2 feet. Because of tree sizes and locations, these deformations are considered to reflect mainly geotropism, with only minor, if any, phototropism influence. These offsets imply average creep rates of 0.024 to 0.08 feet per year (about 0.3 to 1.0 inch per year), with a typical rate of about 0.04 feet per year (0.5 inch per year), over the past half century.

This is a promising area for further research as we have many landslides with trees in the Appalachian Region. The critical thing is knowing the time interval of landslide and/or creep movement. Here at the I-79 site, I was fortunate to have it from 50 years of observations.

The USGS has been monitoring this landslide since April 2011 (Ashland and Delano, 2015; Ashland, 2021). Monitoring includes total station surveying at two locations near portions of the slide toe and one location near the slide scarp, a cable extension transducer across the graben at the scarp, and two continuously monitoring meteorological stations. Data presented by Ashland (2021) indicate that the excavated toe of colluvium above the catchment bench moved at the rate of 1.5 to 1.9 inches per year over a 4.7 year observation period (2013-2018) and that slide debris downslope from the graben moved 0.51 inch per year over a 3.8 year observation period (2014-2018). This latter short-term movement rate is essentially identical to the long-term rate of 0.5 inch per year that I estimated from tree trunk deformation.

At Stop 4, we park on the road shoulder at approximate Sta 908 and hike upslope along a deer trail on the excavated face of the Saltsburg unit to the excavated bench at the top of the Saltsburg. We walk south along this bench to approximate Sta 905, then hike up a deer trail on the excavated face of slide debris to a second excavated bench on slide debris. There we see ground cracks and sinkholes between creeping

Morgantown sandstone blocks as well as numerous large ant hills in Pittsburgh red beds colluvium. We continue south along this bench to approximate Sta 902, then hike easterly up to the main Morgantown sandstone slide scarp.   We follow this scarp north to the graben extending from approximate Sta 905 to 908, then inspect the graben and large Morgantown sandstone slide blocks separated by deep fissures downslope from the graben. The front (west) face of these blocks forms an intermediate scarp downslope from the graben.   North of the graben, we descend the steep slope at approximate Sta 910 while holding on to the PennDOT right-of-way fence. At the base of this slope, we see a former Appalachian stock watering trough – a cast iron bathtub with spring flow piped from the toe of landslide debris. Farther downslope toward I-79, we see an Ames Limestone slump block and Pittsburgh red beds colluvium exposed in a gully eroded since ca. 1970. Hiking around and viewing the above-mentioned features at Stop 4 typically requires 2.5 – 3.0 hr, based on past field trips.

Acknowledgements

I thank all the PGS members who helped with planning and logistics of this field trip and review and assembly of this field trip guidebook. I particularly thank PGS Honorary Members Mary Ann Gross and John Harper in this regard. Mary Ann is the godmother of this field trip and John edited this guidebook. Mary Ann and Brian Dunst took some of the 2020 and 2021 photographs included in Appendix B.

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Appendix A

Gray, R. E., Hamel, J. V., and Adams, W. R., Jr., 2011, Landslides in the vicinity of Pittsburgh, Pennsylvania, *in* Ruffolo, R. M., and Ciampaglio, C. N., eds., From the Shield to the Sea: Geological Field Trips from the 2011 Joint Meeting of the GSA Northeastern and North-Central Sections: Geological Society of America Field Guide 20, p. 61-85 (reproduced by permission of the Geological Society of America).

Photo of a rockslide, I-79 Sta 990, October 11, 1968.

The Geological Society of America
Field Guide 20
2011

Landslides in the vicinity of Pittsburgh, Pennsylvania

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ABSTRACT

The Pittsburgh region has long been recognized as one of major landslide activity. This results from the geology and geomorphic processes shaping the region. The underlying bedrock of flat-lying interbedded strong and weak sedimentary strata has been acted upon by erosion, stress relief, and mass wasting, including creep and landsliding processes, to produce masses of marginally stable colluvial rock and soil on many of the steep hillsides common to the region. Landsliding often involves re-activation of such rock and soil masses. Recent landsliding is often triggered by heavy precipitation and by human activities, i.e., slope excavation, fill placement, and changes in long-established patterns of surface and subsurface drainage.

This field trip has four stops, all within 20 mi of downtown Pittsburgh. Each stop is along a transportation corridor (railroad, local road, and two along an interstate highway). Each stop has various sized examples of the types of landslides common to the region. Most of these examples involve reactivation of unrecognized colluvial landslide masses.

INTRODUCTION

By Richard E. Gray and James V. Hamel

Pittsburgh is located in the Appalachian Plateau physiographic province (Fig. 1). With its steep hillsides, interbedded strong and weak sedimentary rocks, thick soil cover and precipitation of 890–1140 mm (35–45 in) per year, with the greatest amounts occurring in late winter and early spring, the Appalachian Plateau has long been recognized as an area of major landslide severity. Past landslides, both ancient and recent, have left unstable or marginally stable rock and soil masses (colluvium, i.e., old landslide debris) on many of the hillsides of the region.

This field trip includes four stops (Fig. 1) which present examples of slope movements common to the Pittsburgh region:

Stop 1—Grandview Avenue, Mount Washington, overlooking downtown Pittsburgh.

- Regional geology and history.
- Landsliding along Mount Washington Slope.

Stop 2—Webster Road, Municipality of Plum Borough.

- Typical colluvial hillside with common landslide features.

Gray, R.E., Hamel, J.V., and Adams, W.R., Jr., 2011, Landslides in the vicinity of Pittsburgh, Pennsylvania, *in* Ruffolo, R.M., and Ciampaglio, C.N., eds., From the Shield to the Sea: Geological Field Trips from the 2011 Joint Meeting of the GSA Northeastern and North-Central Sections: Geological Society of America Field Guide 20, p. 61–85, doi: 10.1130/2011.0020(04). For permission to copy, contact editing@geosociety.org.

- Local road closed by small- to medium-sized landslides involving road fill over colluvium.

Stop 3—Interstate Route 79 ~2.5 mi north of Ohio River.

- Exposures of common local stratigraphy (including infamous Pittsburgh red beds) often involved in landslides, small masses of slumped bedrock, and a valley stress relief bedding plane shear zone.
- Typical colluvial landslide features.

Stop 4—Interstate Route 79 ~1 mi north of Ohio River.

- Partially excavated colluvial soil and rock slide remnant.
- Large sandstone blocks separated by open stress relief joints creeping and intermittently sliding downslope.
- Huge amphitheater at rear of ancient rock slide.
- Rock slide scarp along stress relief joints in sandstone.

Most of the information that follows on physiography, geology, slope formation, landsliding and geotechnical data has been derived from "Slope Stability in the Appalachian Plateau, Pennsylvania and West Virginia" by Gray et al. (1979). Most of this information is still applicable 32 years after original publication.

There have, however, been some significant advances in our understanding of slope development and landslide processes over the past three decades (Ferguson and Hamel, 1981; Hamel, 1980; Hamel and Adams, 1981; Adams, 1986; Hamel, 1998; Hamel et al., 1998; Hamel, 2004). Some of these recent developments are inserted in the following text and others are presented in the descriptions of Stops 1–4.

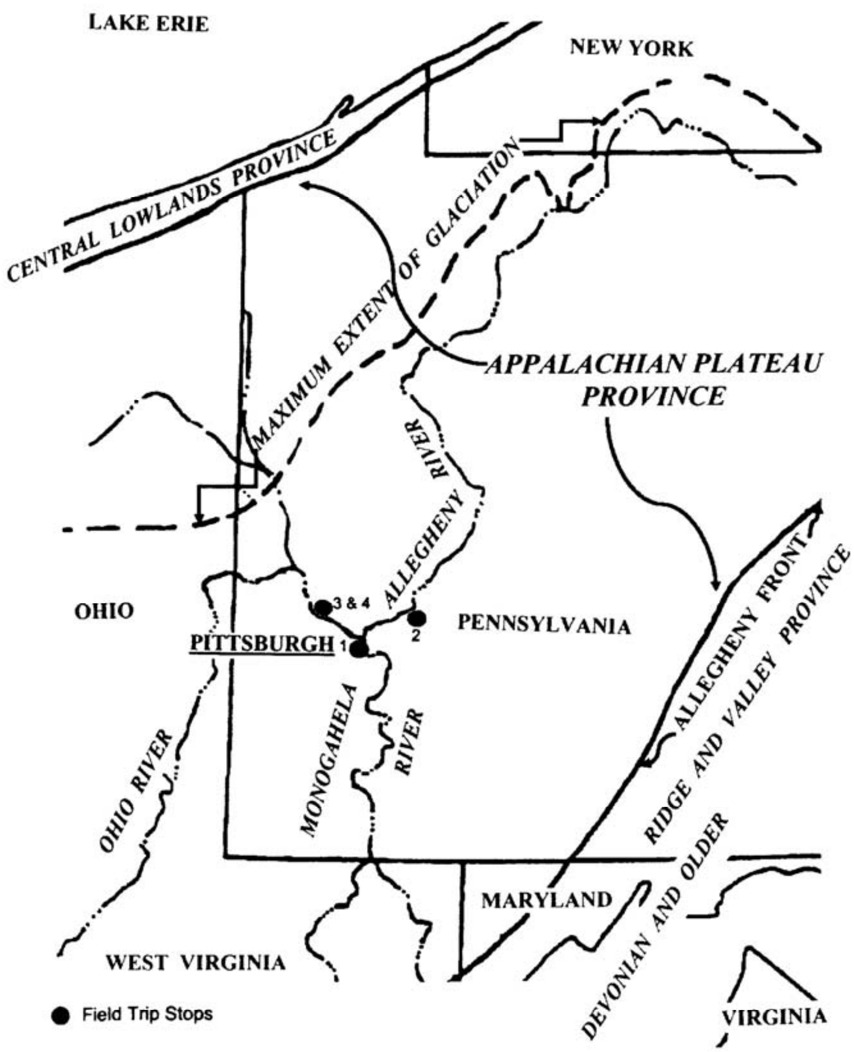


Figure 1. Field trip stops, Appalachian Plateau, Western Pennsylvania. Modified from Gray et al. (1979).

PHYSIOGRAPHY AND GEOLOGY

The Appalachian Plateau is a naturally dissected upland surface developed on gently folded but essentially flat-lying sedimentary rocks. In Pennsylvania and West Virginia, the Appalachian Plateaus Province trends northeast to southwest. It is bounded on the southeast by the Ridge and Valley Province and on the northwest by the Central Lowlands Province. Elevations range from 180 m (600 ft) along the Ohio River to ~1100 m (3700 ft) along the Allegheny Front, an escarpment forming the eastern boundary of the province. Erosion by streams and rivers has been intense and deep valleys and moderate to steep slopes form hilly to mountainous terrain. Along the major streams, local relief of 120–150 m (400–500 ft) is common.

A small portion of the northwest section of the Appalachian Plateau was glaciated during the Pleistocene Epoch (Fig. 1). Glaciation subdued the previously existing topography, which was likely similar to the present topography in unglaciated sections, by infilling valleys and mantling upland surfaces with ice contact and other drift deposits. The Pittsburgh area has not been glaciated (Fig. 1). Although not directly affected by the ice sheets, unglaciated portions of the plateau were influenced in an important way by the periglacial climate. With regard to slope stability, the most significant periglacial effects were the greater rates of weathering, soil formation, and mass wasting (Denny, 1956; Philbrick, 1961; Rapp, 1967).

Rock strata in the Appalachian Plateau are Devonian, Mississippian, Pennsylvanian, and Permian in age (Fig. 2). Rocks of Pennsylvanian age form the preponderance of surface strata. Pittsburgh is located within the portion of the Plateau underlain by Pennsylvanian rocks. Due to limitations on travel time for a one-day trip, all of our stops are in Pennsylvanian age rocks or soils derived from them. A thick band of Mississippian age rocks outcrops between the Pennsylvanian and Devonian rocks in the northerly portion of the area (Fig. 2) and Permian age rocks outcrop in the south-central portion.

The structural trend of the region has a northeasterly direction and several anticlines and synclines extend for long distances. The dip angles associated with the fold structures are negligible to at most only a few degrees. On the east side of the plateau, adjacent to the Ridge and Valley Province, the dip of the strata increases to a maximum of 10° and Mississippian and Devonian strata are exposed on the higher ridges (Fig. 2). A detailed summary of the structure of the Appalachian Plateaus Province has been given by Rodgers (1970, p. 12–30). Mississippian and Devonian strata are predominantly shale, sandstone, and limestone (Fig. 3). The Permian and Pennsylvanian strata are characterized by thin cyclic sequences of sandstone, shale, claystone, coal, and limestone (Philbrick, 1953, 1959, 1960).

SLOPE FORMATION

Current slope development in the unglaciated portion of the Appalachian Plateau is consistent with flat-lying sedimentary rocks in a temperate, humid climate. The occurrence of alternating weak and resistant rock strata is reflected topographically by breaks in slope and somewhat subdued to well-developed erosional benches. Hillside benches produced by landsliding exist at many locations; see Stops 3 and 4.

Existing and past climatic conditions have resulted in substantial mechanical and chemical weathering which produced a residual or colluvial soil mantle over almost the entire rock surface. The sedimentary rock strata are normally not exposed. There is considerable evidence that rocks of this region remain highly stressed (Ferguson, 1967, 1974; Dahl and Parsons, 1971; Voight, 1974), except where stresses have been relieved near-surface in the valley walls and floors (Ferguson, 1967, 1974; Ferguson and Hamel, 1981). Stress relief fracturing is associated with many types of mass-wasting; see Stops 1–4. Joints caused by the local release of residual stress are closely spaced (2–3 m) in sandstone and limestone, whereas joints caused by tectonic stresses exhibit a spacing of many meters (Nickelsen and Hough, 1967). The finer-grained rocks have closely spaced joints. Nickelsen and Hough (1967) presented details of tectonic joint patterns, trends and spacing in the Appalachian Plateau of Pennsylvania.

Except locally where sandstone may be abundant, the predominance of fine-grained rock (shale and claystone) within the geologic section results in soils typically being silty clay or clayey silt with rock fragments. Residual soils are characteristic of the flat upland surfaces and flat surfaces of larger erosional benches, with colluvial soils formed on slopes.

Creep and sliding results in downslope movement of the soil and its accumulation on slopes and at the toes of slopes in colluvial masses. Colluvial soils tend to be 1.5–9 m (5–30 ft) thick on slopes and generally increase in thickness (to a maximum of ~30 m or 100 ft) near the toes of slopes unless there is active stream erosion. Colluvial soils are generally stiff to hard, and individual samples have relatively high shear strengths. However, creep or sliding processes (or both) during slope development have generally reduced the shear strength along movement surfaces to residual or near-residual levels. These low strength movement surfaces may occur at several levels within the colluvial mass but there is always a low strength movement surface at the soil-rock interface (Deere and Patton, 1971; Hamel, 1980). As the slope materials seek equilibrium between stress and strength, the soil mantle moves downslope and the mean slope angle decreases until a relatively flat slope angle, compatible with a state of marginal equilibrium, is achieved. This natural slope-flattening process accounts for the relatively thick soil cover on mature colluvial slopes, particularly at the base of slopes. Deere and Patton (1971) have suggested that there are no stable natural slopes in the Appalachian Plateau where the inclination exceeds 12°–14°. Terzaghi and Peck (1948, p. 357) reported movements on slopes as flat as 10°, whereas Gray and Donovan (1971) demonstrated that several mature colluvial slopes, with evidence of preexisting failure surfaces, had slope angles ranging from 7° to 10°. Hamel (1980) presents additional information on colluvial slope inclinations.

We do not have any documented data on rates of creep of colluvial slopes in the area. Observations suggest, however, that colluvial slopes may creep at rates of a few centimeters per year. With the exception of creep, large colluvial masses appear stable unless disturbed by cutting, filling, drainage changes, or extreme precipitation events.

LANDSLIDING

The Appalachian Plateaus Province is among the most severe for landsliding within the United States (Ladd, 1927, 1928; Sharpe and Dosch, 1942; Ackenheil, 1954; Eckel, 1958; Baker and Chieruzzi, 1959). Most landslides are in soil, the most

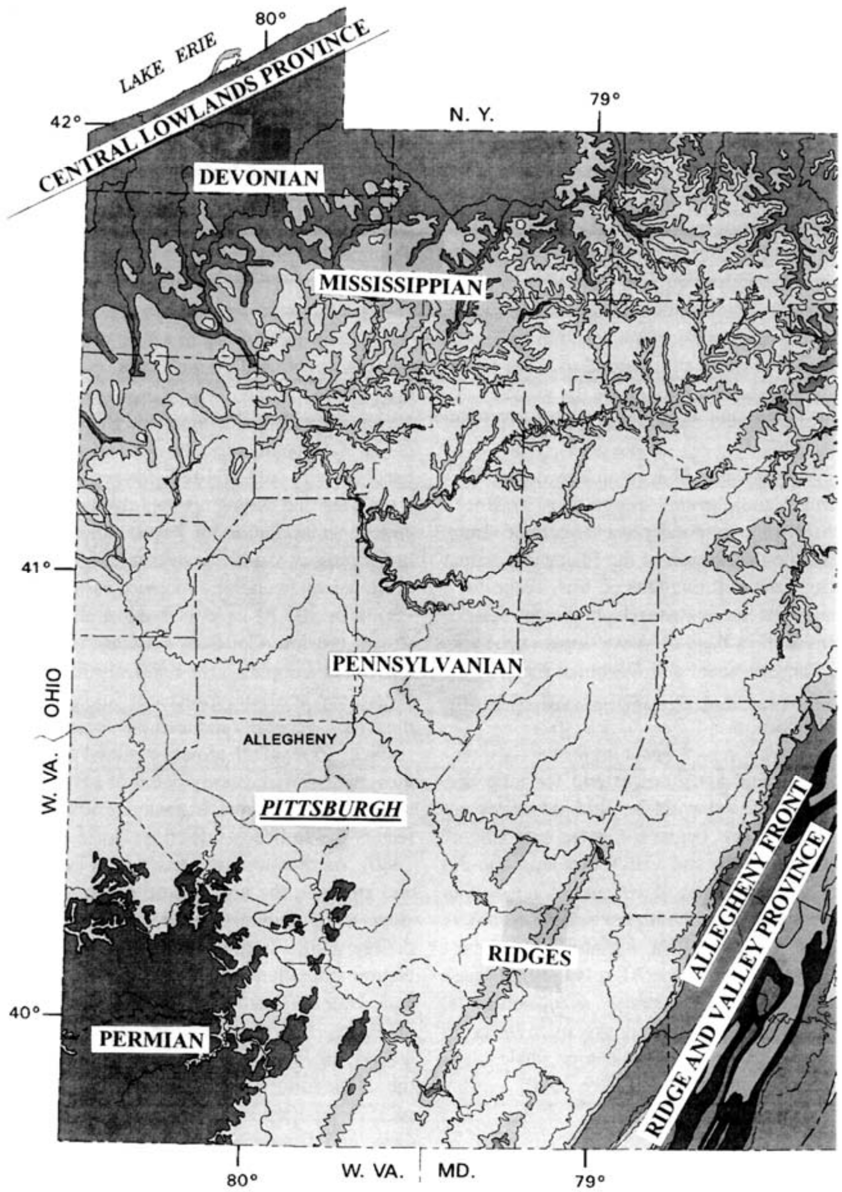


Figure 2. Regional geology. Modified from Gray et al. (1979).

common being slump-type slides or slow earth flows which range in size up to several million cubic meters. Rockfalls, the next most common type of slide, are typically much smaller with maximum volumes on the order of a few hundred cubic meters. Other types of slide movements do occur, however; see Stop 1.

Numerous small slump or slow earthflow slides occur during seasonal wet periods or due to local stream erosion, with catastrophic hydrological events being of major significance. For example, the great amount of precipitation associated with Hurricane Agnes in June 1972 caused a significant number of

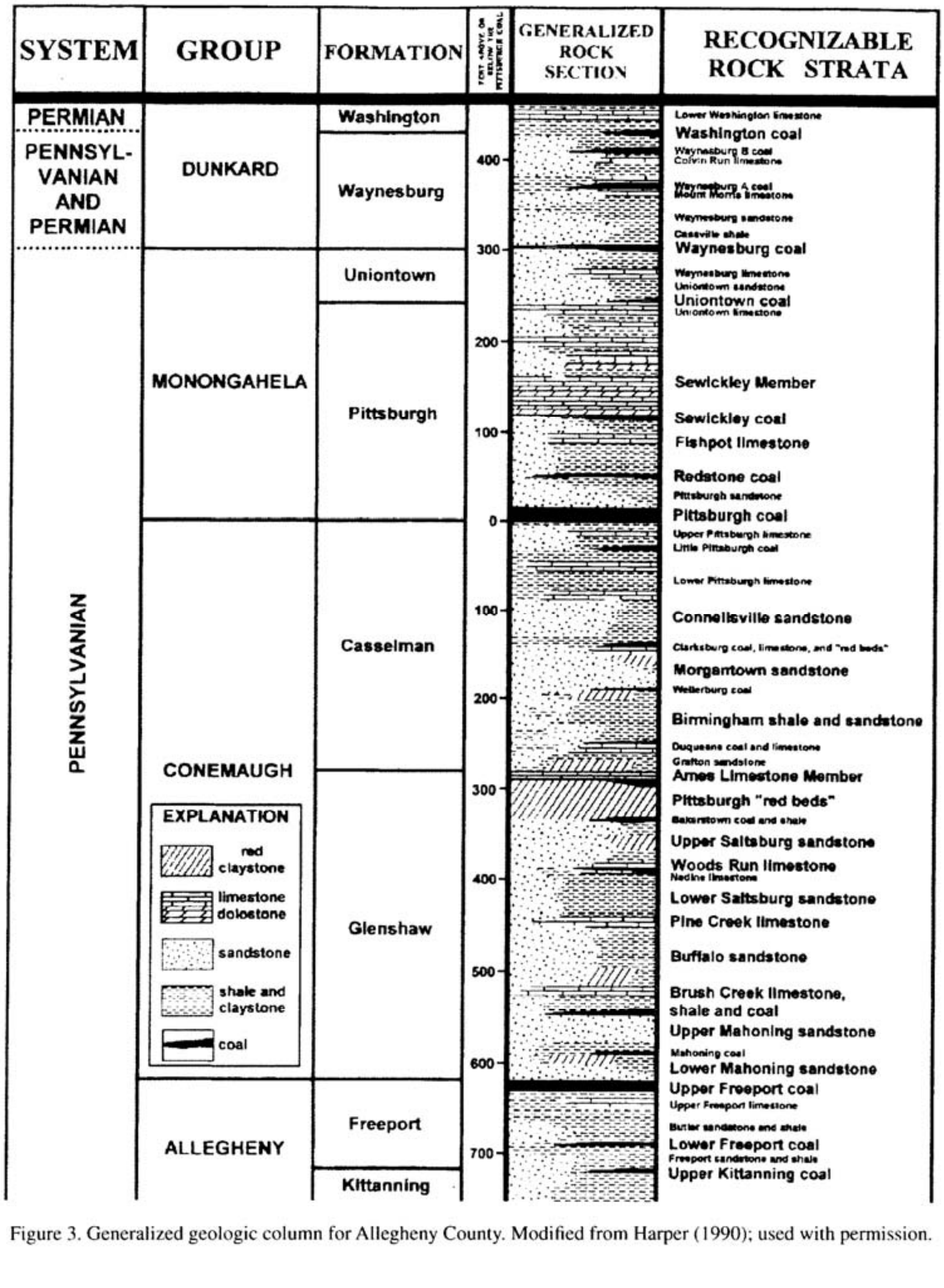


Figure 3. Generalized geologic column for Allegheny County. Modified from Harper (1990); used with permission.

such slides. However, most slides are a direct result of man's disturbance of natural conditions. Frequent causes of sliding are (1) removal of toe support, (2) surcharging slopes by the placing of fill embankments, or (3) a change in surface and subsurface water flow. The largest slides usually result from disturbance of ancient landslide masses in soils and/or rock. These ancient landslides appear to have occurred in the main under periglacial conditions. Limited radiocarbon dating (Philbrick, 1961; D'Appolonia et al., 1967) suggests a Pleistocene age for some of these deposits. Peltier (1950) and Denny (1956) found fossil periglacial features close to the front of the maximum advance of the Wisconsinan glaciation in Pennsylvania and strongly supported the influence of Pleistocene periglacial processes on slopes. In a study of a portion of central Pennsylvania just east of the Appalachian Plateau, Rapp (1967), concurred with the above authors. In a review the effect of periglacial processes on slope profiles in areas currently experiencing humid temperate climates, Carson and Kirkby (1972) concluded the effect is not as great as indicated by the above studies.

Where interbedded strong and weak rock strata are exposed, differential weathering and erosion result in the weaker rock being removed, leaving the more resistant rock as overhanging ledges. The result of this process is small but often dangerous rockfalls. Cuts containing hard sandstone or limestone beds underlain by relatively low-strength shale or claystone are common throughout the Pittsburgh area. Weathering causes relatively rapid decomposition and spalling of the softer rock, leaving unsupported ledges of limestone and sandstone. Rates of undercutting of ~60–180 mm (2–7 in) per year have been reported by Philbrick (1959), based on observations over a period of several years for a highway cut with claystone underlying massive Morgantown Sandstone. Average rates of undercutting of 13–38 mm (0.5–1.5 in) per year (over a period of two years) were measured by Bonk (1964) at two carefully prepared test sites in excavated slopes in Pittsburgh red beds claystone. Average rates of undercutting of 30–150 mm (1–6 in.) per year were reported by Bonk (1964) for Pittsburgh red beds exposed for periods of two to ten years in highway cuts. In relatively short periods of time, weathering can progress to the point where a resistant rock ledge can no longer sustain its cantilevered weight and the ledge falls. Vertical to subvertical stress relief joints often form the backs of rock fall blocks.

Deep-seated rock slides are relatively rare under present climatic conditions, but many are believed to have occurred under the more severe climatic conditions of Pleistocene time; see Stops 1, 3, and 4. Recent deep-seated rock slides have typically involved excavated slopes in which large wedges of rock, separated from the valley walls by near-vertical stress relief joints, slide along or through weak claystone or shale beds. Water pressures in the slopes are usually significant contributing factors in such slides (see Case History 3 in Gray et al., 1979; Hamel, 1998; and introductory material for Stops 3 and 4).

GEOTECHNICAL DATA

The engineering properties of intact rock materials of the northern Appalachian Plateau vary widely with lithology and degree of weathering. Almost no data on the permeability and deformability of these rocks have been published and relatively few strength data are available in the literature. Most of the rocks of the Appalachian Plateau are of very low to medium strength and low to medium modulus ratio according to the classification system of Deere (1968).

As with most rocks, the engineering behavior of the sedimentary rocks of the Appalachian Plateau is controlled largely by geologic discontinuities; e.g., faults, joints, bedding contacts, weak beds or beds affected by fluid pressure conditions, and old sliding surfaces, rather than by properties of intact rock materials. Even the engineering behavior of colluvium derived from these rocks is governed mainly by old failure surfaces. Due to a history of previous shearing, these old failure surfaces generally have much lower shear strengths and much higher permeabilities and deformabilties than other portions of the colluvium or the rocks from which the colluvium was derived.

Index properties and strength data on colluvium derived from claystones of the Appalachian Plateau have been given by D'Appolonia et al. (1967), Hooper (1969), Hamel (1969), Hamel and Flint (1969, 1972). This colluvium ranges from massive blocks of relatively intact claystone to silty or sandy clay soil with rock fragments. Dry unit weights typically range from ~1.9–2.2 Mg/m^3 (118–137 pcf).

A recent paper by Nakamura et al. (2010) identified three groups of soils. In the first group of soils, sliding appeared to be controlled by minerals such as quartz, feldspar, calcite, dolomite and layer silicate minerals other than smectite, vermiculite, chlorite, and mica and their residual strength was almost constant at ~32°. In the second group of soils, the controlling mineralogical factor for sliding shifted from non-preferred–orientation minerals to preferred-orientation minerals and residual strength decreased from 30° to 10°. In the third group of soils, sliding is well controlled by preferred-orientation layer silicate minerals and residual strength gradually decreased from 10° to 5°. They concluded that the total content of layer silicate minerals prone to preferred orientation (smectite, vermiculites, chlorite, and mica) in the sub–425 μm soil fraction is a suitable mineralogical parameter for predicting the magnitude of residual strength.

The colluvium generally exhibits strain-softening behavior (Skempton, 1964) and its residual (large displacement) shear strength is generally less than half its peak (small displacement) strength at a given effective normal stress. For effective normal stresses of less than ~350 kN/m^2, the peak strength of claystone colluvium is commonly characterized by cohesion intercepts of 7–35 kN/m^2 and friction angles of 20–25° while the residual strength is usually characterized by negligible cohesion intercepts and friction angles of 8–20°. Measured residual friction angles for most claystone-derived colluvium are on the order of 11–16°. Experience in calculation of strength data from colluvial slide masses (Hamel, 1969; Hamel and Flint, 1969, 1972; Gray and Donovan, 1971; Hamel, 1980, 2004) indicates that shear strengths characterized by residual level friction angles of 13–16°, with zero cohesion intercept, are commonly mobilized in place.

STOP 1. MOUNT WASHINGTON

By Richard E. Gray

(Permission to use this amended text was granted by the Pennsylvania Geologic Survey, sponsor of the Annual Field Conference of Pennsylvanian Geologists, and by the author [Gardner, 1980].)

Pittsburgh is located in a moderately dissected portion of the Appalachian Plateau where a relatively flat plateau surface is cut by streams producing steep sided valleys having a vertical relief of 425–560 ft (130–170 m). Here on Mount Washington, we are at approximately elevation 1140 ft. The normal pool level of the rivers below is elevation 710 ft.

Pittsburgh is located at the confluence of the three largest rivers in the region, the Allegheny, Monongahela, and the Ohio. The Allegheny River, flows from the north originating in northern Pennsylvania and southern New York. The Monongahela River flows from the south, originating in east-central West Virginia. The Allegheny and Monongahela Rivers meet to form the Ohio. The Ohio River is a major artery of drainage that flows west and joins the Mississippi River at Cairo, Illinois, ~930 mi (1500 km) downstream from Pittsburgh.

While Pittsburgh was not directly glaciated during the Pleistocene, the closest approach of Wisconsinan ice was ~30 mi (50 km) north of the city; the Allegheny and Ohio Rivers served as channels for glacial meltwaters. The heavy sediment load in the glacial outwash caused river aggradation that is now represented by coarse sand and gravel deposits and low lying terraces along the Allegheny and Ohio Rivers. Much older alluvial sediments, possibly of nonglacial origin, occur in high terraces and old alluvial channels that occur ~325 ft (100 m) above the present channels. The age of the high level deposits is thought to be Illinoian.

The Monongahela River flows north through predominantly shales so that its alluvial deposits consist mainly of silt and clay.

It was the strategic location at the confluence of the rivers that first attracted the attention of Europeans to the "Forks of the Ohio" at what is now Pittsburgh. The conflicts between the British and French in Europe in the early and mid-1700s were extended to North America as both nations struggled for domination of the continent. The French claimed the area west of the Allegheny Mountains as theirs, including the combined Ohio and Allegheny Rivers; the English did not recognize these claims. Ensuing clashes between the French and English trading in the area prompted Governor Dinwiddie to send a 21-year-old major of the Virginia Militia, George Washington, to deliver a protest to the French. En route, Major Washington traveled by the Forks and noted:

> ...I spent some time viewing the rivers, and the land in the Fork; which I think extremely well situated for a fort, as it has absolute command of both rivers...the Land at the point is 20 to 25 feet above the common surface of the water; and a considerable bottom of flat, well-timbered land all around it, very convenient for building.... (from Washington's Chronicle, in Lorant, 1975)

The confrontations with the French prompted the Virginians to build a fort at the Forks as suggested by Washington. Construction of Fort Prince George was initiated in March 1754, and was the first recorded Euro-American construction on the land that is now Pittsburgh. The unfinished colonial fort was abandoned one month later when a superior force of French and Indians threatened attack. The French then erected their own fort, Fort Duquesne, at the Forks. The French controlled the forks for four years, repelling several English attempts to regain control. In November of 1758, the French burned and abandoned Fort Duquesne in the face of imminent attack by British forces led by General John Forbes and Colonel George Washington. The English erected their own fort (now partially reconstructed in Point State Park) on the ruins of Fort Duquesne, and Forbes named it Fort Pitt in honor of the English Prime Minister. Fort Pitt received no attacks from the French, although it suffered a siege by Indians in 1763 during "Pontiac's War." The end of the Indian uprising reduced the need for Fort Pitt, and it was gradually dismantled in the mid-1760s.

The community that developed around Fort Pitt continued to grow as a center of trade for the ever increasing travel from east to west. When the community was incorporated as a city in 1816, it was the major center for commerce in the west since most travel from the east coast to the west went through Pittsburgh. Pittsburgh's economy was primarily based on commerce in the late 1700s and early 1800s. As Pittsburgh grew, it required an ever-increasing supply of goods, most of which were manufactured in the east. However, transporting large quantities of goods was incredibly difficult and expensive because rugged mountains were a formidable barrier between Pittsburgh and the east. This led to Pittsburgh developing a manufacturing industry. By 1830, the commerce aspect of Pittsburgh's economy was eclipsed by manufacturing. Thus, Pittsburgh was founded and began to flourish as a center of commerce and manufacturing because of its geography. But Pittsburgh was only born of its geography; it owes most of its growth and eventual status as a leading industrial center to its geology.

Although less than two percent of the local rock stratigraphy is coal, it was coal that made Pittsburgh an industrial giant—the Iron and Steel Center of the World.

Other industries developed in the region as a result of the exploitation of the local geologic resources. The Pittsburgh glass industry began about the same time as the iron industry, because the resources for making glass (sand and lime) were available, and it was difficult to import glass over the rugged mountains from the eastern manufacturing centers. Glass manufacturing first occurred in Pittsburgh in 1797. The first cheap aluminum ($2.00/pound) was produced in Pittsburgh on 25 November 1888, in a factory developed by Martin Hall, the inventor of the process. A large brick, pipe, and refractory manufacturing industry was fostered in the region by the occurrence of abundant clay (fireclay) and shale.

One of the most significant resources, other than coal, to affect the development of the Pittsburgh area was oil and gas. In 1859, the Drake Well was drilled near Titusville, ~90 mi (145 km) north of Pittsburgh, and major oil production was born. By 1871, 60 oil refineries were operating in Pittsburgh producing 36,000 barrels of oil per day. Natural gas was developed about the same time, with the first gas well near Pittsburgh being drilled in 1878 in Murrysville, 12 mi (20 km) east of the city. In 1883, a gas pipeline was completed from Murrysville to Pittsburgh to feed, among other things, the gas street lights of the city.

Pittsburgh's strategic location as a "Gateway to the West" necessitated use of the rivers as the chief avenue of haulage. Railroads did not enter the area until the 1850s, and the rivers provided the quickest, easiest avenue for transporting large loads, as they still do today. Boatbuilding was an important industry of Pittsburgh from its earliest days. The first steamboat on western waters was the *New Orleans*, which was built in Pittsburgh in 1811. Although the Ohio River was a major pathway to the interior of the continent, traveling from Pittsburgh to the Mississippi in anything much larger than a canoe was usually restricted to the wetter seasons because the Ohio River was often too shallow for navigation during the summer and fall. In addition, transporting goods prior to the 1820s was usually unidirectional, downstream, because the current was too strong for upstream trips by larger boats. The advent of the steamboat on the Ohio River eliminated this problem, but the problem of seasonal navigation still remained. It wasn't until 1929, when a series of 50 locks, dams, and canalization had been completed, that the Ohio River was totally free of seasonal restrictions to navigation.

The Pittsburgh Coal is located ~100 ft below us. In 1759, British soldiers developed a coal mine on "Coal Hill," now Mount Washington. Coal was mined on a small scale until industrialization created greater demand in the mid-1800s. The Pittsburgh coal is considered to be one of the richest economic deposits in the world. The U.S. Geological Survey estimated that the Pittsburgh coal alone yielded eight billion tons from the early 1900s to 1965, comprising 35 percent of all bituminous coal in the Appalachian Basin and 21 percent of the cumulative production for the entire United States. The Pittsburgh coal is essentially "worked-out" and no longer deep mined in Pittsburgh. The principal user of coal in the Pittsburgh region was the iron and steel industry.

With this background of mining, mineral extraction, and heavy industry, along with its three rivers, topography, and geology, it is not surprising that Pittsburgh became a major center for practice in engineering geology and geotechnical engineering. A decade ago, Hamel and Adams (2000; see GSA Data Repository[1]) presented an update on engineering geology problems, challenges, and practices in the Pittsburgh area. The material in that paper is still relevant today. Landsliding, of course, presents significant challenges at many locations in the Pittsburgh area, including the slope below, as described in the following guidebook section.

LANDSLIDING ALONG SLOPE BELOW MOUNT WASHINGTON

By James V. Hamel

Observation areas along Grandview Avenue on Mount Washington indeed provide a "grand view" of the Allegheny and Monongahela Rivers joining to form the Ohio River at the "Point" of downtown Pittsburgh. The slope below Mount Washington, along the downstream end of the Monongahela Valley and the upstream end of the Ohio Valley (Fig. 4), has a long history of mass-wasting, including various landslide and rockfall processes (Ackenheil, 1954, 1958; Hamel, 1998; Hamel et al., 1998; Pomeroy, 1974). The following information is summarized mainly from Hamel (2000; see GSA Data Repository[2].) Permission to use this material was granted by the Pennsylvania Geologic Survey, sponsor of the Annual Field Conference of Pennsylvania Geologists.

The three major rivers here now have nominal elevation (El.) 710 ft maintained as normal pool of the navigation dam at Emsworth, 6 mi down the Ohio River from the "Point." The Mount Washington Slope extends from this river level up to approximately El. 1150 ft along Grandview Avenue (Figures. 4–7). Rocks here are flat-lying sedimentary strata of the Pennsylvanian age Conemaugh and Monongahela Groups. The Ames Limestone marking the top of the Lower Conemaugh Glenshaw Formation is ~40 ft above river level at nominal El. 750 ft. The Pittsburgh Coal marking the base of the Monongahela Group is ~100 ft below Grandview Avenue at nominal El. 1050 ft. The first known mining of the Pittsburgh Coal was done here on Mount Washington, then called "Coal Hill," ca. 1760; see the Historical Marker on Grandview Avenue.

This area is generally considered to have been eroded to Mount Washington ridgetop El. 1200 ft (south of Grandview Avenue) by the end of the Tertiary. During the Pleistocene, continental glaciers advanced to a line ~30 mi northwest of Pittsburgh on at least two occasions—at least once during the Illinoian period and at least once during the Wisconsinan period.

Erosion of the three main river valleys down to the Parker Strath, nominal El. 900 ft at Pittsburgh, is generally thought to have been done by the Illinoian period when glacial outwash was deposited here up to nominal El. 1000 ft (Fig. 6). The three main rivers then eroded their channels deeper into bedrock, down to nominal El. 660 ft beneath the Pittsburgh "Point," during late Illinoian time (Figs. 6 and 7). During the subsequent

[1]GSA Data Repository item 2011160, "Update on Engineering Geology in the Pittsburgh Area" is available at www.geosociety.org/pubs/ft2011.htm or on request from editing@geosociety.org.

[2]GSA Data Depository item 2011161, "Mt. Washington Slope—Duquesne Incline to Smithfield Street Bridge," is available at www.geosociety.org/pubs/ft2011.htm or on request from editing@geosociety.org.

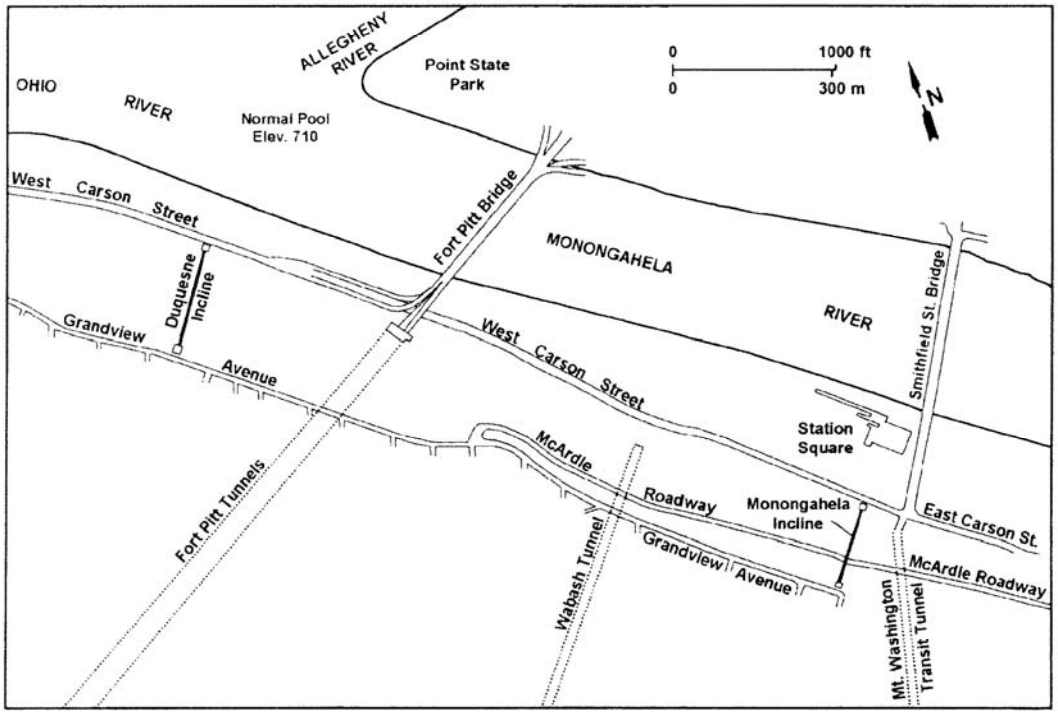


Figure 4. Map of Mount Washington Slope, Duquesne Incline to Smithfield Street Bridge.

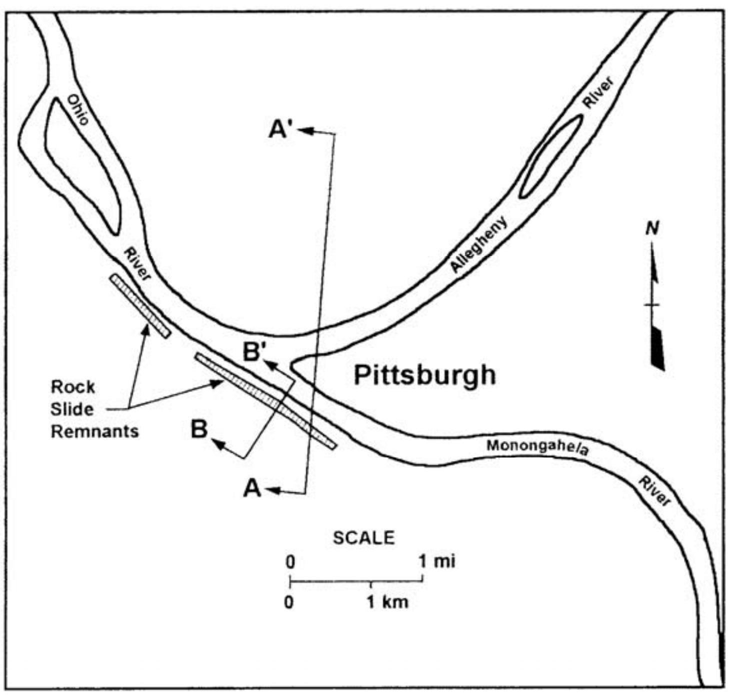


Figure 5. Map of Pittsburgh with cross sections A–A′ and B–B′ (after Hamel, 1998)

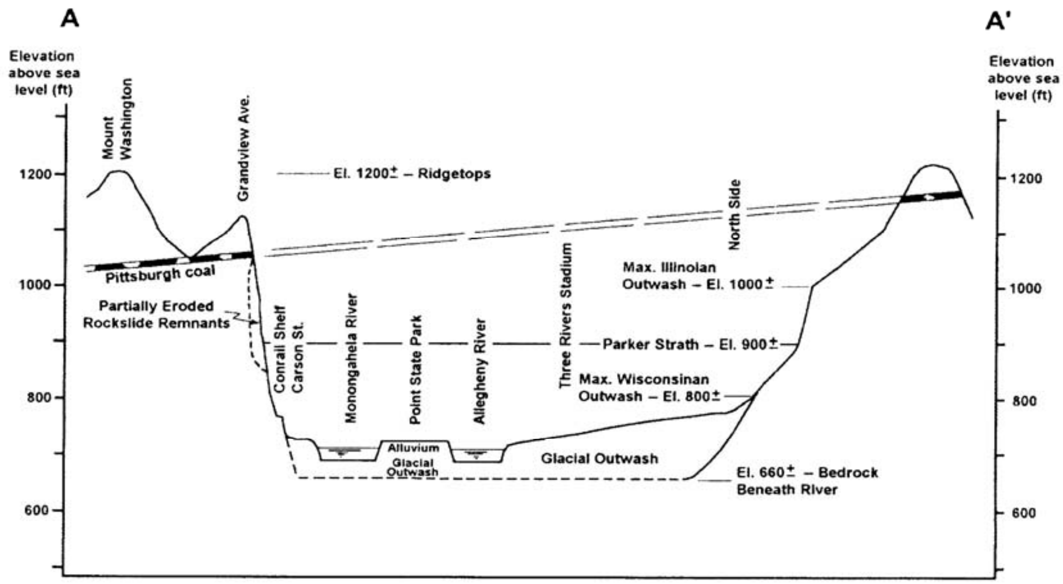


Figure 6. Cross section A–A′ (after Hamel, 1998).

Wisconsinan period, little, if any, additional downward erosion of the bedrock channels is thought to have occurred. Extensive Wisconsinan outwash was deposited and reworked in the river valleys, with remnants existing up to nominal El. 800 ft at and near Pittsburgh (Fig. 6).

During the Illinoian and Wisconsinan periods, the southerly flowing Allegheny River carried huge quantities of meltwater and outwash. Glacial outwash is thought to have dammed the Allegheny and Monongahela Rivers at Pittsburgh on several occasions, producing significant ponding events with extensive sediment deposition in slackwater. Ice jams from the Allegheny River may have caused additional ponding events.

Valley stress relief (Ferguson, 1967; Ferguson and Hamel, 1981) during the relatively rapid (on a geologic time scale)

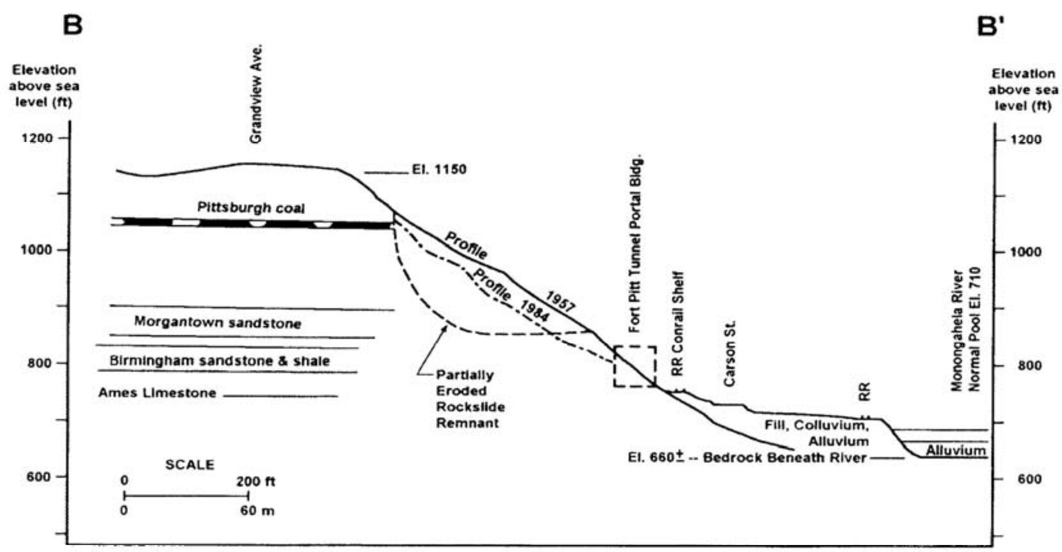


Figure 7. Cross section B–B′ (after Hamel, 1998).

Pleistocene erosion of bedrock valleys loosened rock masses in the valley walls. The severe periglacial climate and vigorous hydraulic activity during Pleistocene time caused rock sliding in the valley walls and accelerated weathering of rock slide debris. Over time, these produced the marginally stable colluvial rock and soil masses currently existing on many slopes in the Pittsburgh area, including the Mount Washington Slope.

As Pittsburgh grew over the past 250 years, extensive development occurred in flatter areas along the top and bottom of the Mount Washington Slope. Circa 1850, the first railroad was constructed along the toe of this slope. As Pittsburgh industries grew, additional railroad tracks were constructed ca. 1900 on a bench locally excavated into the slope toe (Fig. 7). The slope itself, with a height of 300–400 ft and an overall inclination of 1.5H:1V (34°) with some steeper segments, remained essentially undeveloped. This resulted mainly from difficult access and extensive slope instability. Numerous landslides and rockfalls have come down onto the railroad over the past 160 years.

In the early 1990s, a Busway to Pittsburgh International Airport was considered for the railroad shelf along the toe of the Mount Washington Slope (Hamel et al., 1998). Preliminary geotechnical investigations from 1991 to 1993 identified considerable rockfall potential. Detailed geotechnical investigations in 1994 and 1995 provided further information on slope geology, historic slope instability along the railroad, and landslide and rockfall hazards along the proposed Busway. Construction of various stabilization measures along the Mount Washington Slope began in late 1996 and was terminated in early 1997 prior to completion. This portion of the Busway was deleted at that time when the overall project was considerably reduced in scope and length due to cost and political considerations. Given present economic conditions, it seems unlikely that the Busway segment along the toe of the Mount Washington Slope will ever be constructed.

Busway slope investigations in 1994 and 1995 included review of historical vertical aerial photographs as well as large scale low-level oblique aerial photographs taken in April 1994. Extremely difficult access, along with safety and environmental concerns, precluded drilling on the slope. Field work mainly involved detailed reconnaissance and mapping on large scale (1:360) oblique aerial mosaics (Hamel et al., 1998).

This field work disclosed many of the slope failure types and processes of Varnes (1978). Rockfalls and rock topples are abundant here. Many, if not most, of these failures are related to lateral rock spreads, rock slides, and rock slumps associated with valley stress relief (Ferguson, 1967; Ferguson and Hamel, 1981; Hamel, 1998). Debris slumps, debris slides, and slump-earthflows, all typical colluvial slope failure processes of the region (Hamel and Ferguson, 1999) are common along the Mount Washington Slope. Debris slides, debris flows, and debris avalanches, all of which involve movement of colluvium and/or talus down ravines or chutes, are also common here (Hamel et al., 1998).

The most important geologic finding along the Mount Washington Slope was the previously hypothesized (Ferguson and Hamel, 1981; Hamel and Adams, 1981; Hamel and Ferguson, 1999) but seldom reported existence of numerous partially eroded and/or partially excavated remnants of deep-seated slumps and translational block slides in bedrock (Fig. 7).

These rock slides are thought to have occurred during the Pleistocene (probably Illinoian) when the rivers were actively entrenching their valleys in bedrock and climatic and hydraulic conditions (involving both surface and subsurface waters) were much more severe than those during the Holocene (Hamel, 1998). Portions of these rock slide masses were eroded during the Late Pleistocene and some additional portions were excavated during the two major phases of railroad construction ca. 1850 and 1900.

Discovery and documentation of numerous rock slide remnants along the Mount Washington Slope lead to review of previously observed but widely scattered rock slides in the region (Hamel, 1998). These rock slides have significant geologic implications regarding the Pleistocene history of the region, i.e., processes of valley formation and colluvial slope development. They also have significant engineering implications related to continuing rockfalls and rock slides along railroads and highways.

STOP 2. WEBSTER ROAD

By William R. Adams Jr.

State Route 2090, Landslides

Stop 2 provides several examples of the type of slope movements that typically impact the highways in southwestern Pennsylvania. There are numerous landslides visible along and causing distress to Webster Road, a roadway owned and maintained by the Commonwealth of Pennsylvania. Webster Road is designated by the Commonwealth as State Route (SR) 2090 and it is located in eastern Allegheny County ~16 mi east northeast of Downtown Pittsburgh (see Fig. 1) in the municipality of Plum Borough.

Webster Road is ~10,800 ft in length with most of the eastern end of the roadway, ~3400 ft, barricaded by concrete Jersey Barriers prohibiting travel by the public as a result of the many landslides along the roadway. There are 6 larger slope movements identified along Webster Road and their locations can be seen in Figure 8. We will travel past Landslide No. 1 and then stop at the western barricade before walking to slope movements 2 through 4. Of the 6 slope movements, 5 fall within the section of the roadway that is closed. Landslide No. 1 was left outside the barricade to enable access by property owners to certain portions of their property.

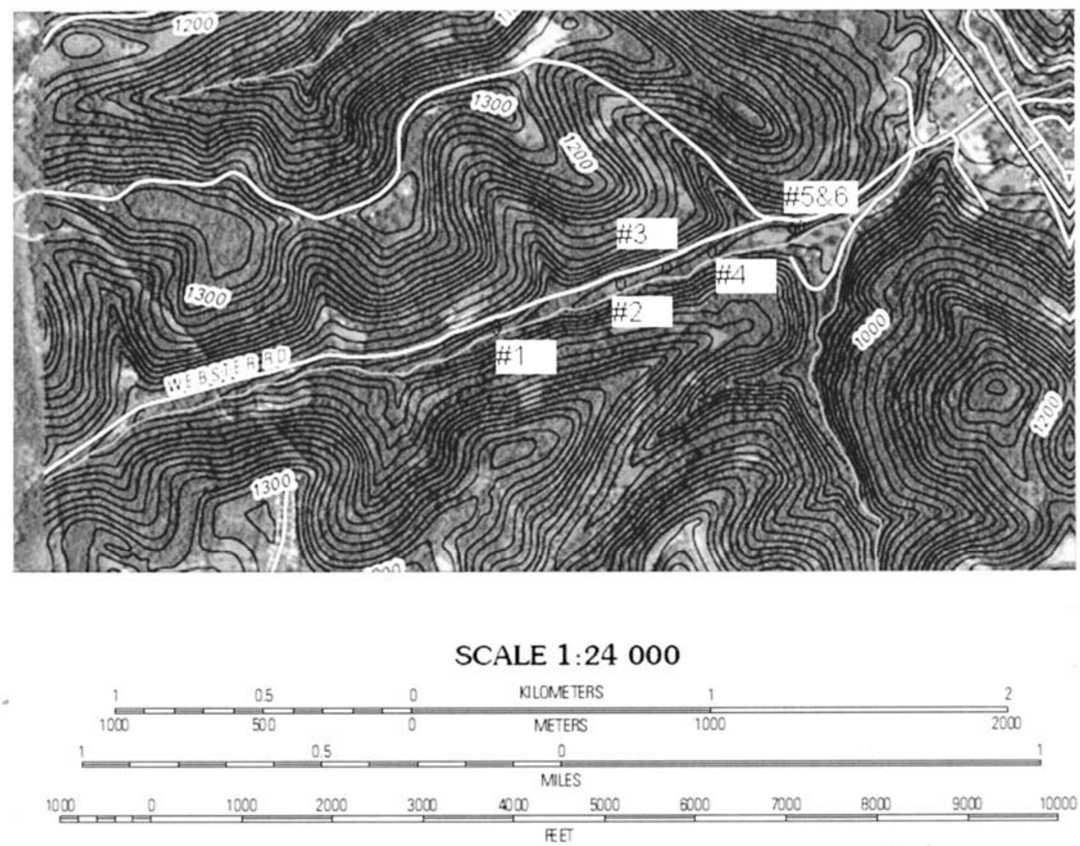
Webster Road trends along the lower portions of northern valley walls of a tributary stream to Pucketa Creek. Pucketa Creek then flows toward the northwest into the Allegheny River. The general topography of the area is shown in Figure 9. The relief of the valley walls in the vicinity of the slope movements is slightly more than 400 ft with the top of the valley walls reaching elevations of ~1250 ft to1350 ft above mean sea level (msl). The portion of the roadway most affected by the slope movements varies in surface elevations from ~900 ft to approximately elevation 1020 ft above msl.

Stratigraphically the valley wall slopes are underlain by the Casselman Formation and upper part of the Glenshaw Formation (see Fig. 3). The bedrock is composed of cyclothems made up of primarily shales, sandstones, claystones, limestones, and coal. These cyclic deposits are well described by Philbrick (1959). The well-known mineable coal seam of our region, the Pittsburgh coal, is present in some of the hill tops in the area.

Based on available published mapping, the Ames limestone (see Fig. 3) should be present above most of the roadway. Blocks of the Ames limestone have been observed ~10 ft above Webster Road in the vicinity of Slope Movements numbered 5 and 6 at approximately elevation 920. It is unknown if these blocks are in place or are float blocks in a colluvial mass; however, based on regional geologic information the blocks are very near the expected elevation of the Ames limestone. This places the roadway on the slope at or just below most of the thicker red bed units in the local bedrock including the Pittsburgh red beds, a claystone well known for slope instability.

The rapid weathering of the underlying red beds (claystones) have been well reported and documented (Adams, 1986; Hamel, 1969). Some investigators have, also, measured the rate of weathering (Bonk, 1964). These claystones weather to a very weak soil which is very susceptible to landsliding.

Structurally, the regional dip of the underlying bedrock is in a south southeastern direction at a slope of approximate 1.2 ft per 100 ft. This is basically perpendicular to and out of the valley walls along which Webster Road trends. The regional dip continues into the southern or north-facing valley walls. This regional



CONTOUR INTERVAL 20 FEET
NORTH AMERICAN VERTICAL DATUM OF 1988

Figure 8. Location of landslides. Base map produced of the New Kensington East 7-1/2 min Quadrangle by the U.S. Geological Survey, 2010.

dip would cause the groundwater to flow out of the south-facing slopes along which Webster Road is constructed. This increase in groundwater could be a contributing factor to the numerous failures along the roadway. While there are typically a number of contributing factors to the occurrence of a landslide, there is usually one triggering factor and it frequently is associated with increased groundwater levels and/or the introduction of water into the soils on the slopes (Adams, 1986).

Figure 10 is a map of the active or recently active landslides; soil, and rock susceptible to landsliding; and ancient landslides in the vicinity of Webster Road. This mapping was conducted as part of a regional study in southwestern Pennsylvania by the U.S. Geological Survey in the mid-1970s. The ancient or prehistoric landslides frequently leave large amphitheaters or large arcuate shapes in areas on the slope that represent the upper reaches of these ancient landslides. Depending on the vegetation cover during our site visit, some of these amphitheaters that are present on the valley walls may or may not be readily visible. Very large examples of these amphitheaters are present and will be visible in and around Stops 3 and 4.

From the mapping illustrated in Figure 10, it appears that there is more evidence of ancient and recent movement on the northern valley wall which again may be reflective of the regional dip and probable increase in groundwater flow out of the south facing valley walls. The contribution of these ancient failure masses to the increased likelihood of historic landsliding is well documented (D'Appolonia et al., 1967; Hamel and Flint, 1969; Adams, 1986). Inability to recognize these failures has resulted in many recent/present day failures (Hamel and Flint, 1969; Hamel and Adams, 1981).

The District Geotechnical Unit was first called out in the spring of 2007 to investigate the slope movements impacting the roadway. Because of the rapid development of the slope movements and the number of them, little actual geotechnical/geological investigation was performed at the slope failures before the roadway was closed. By late May 2007, the roadway was officially closed for a length of 3400 ft. I first became involved with the project in the fall of 2009 when I returned to the Geotechnical Unit. As a result of the anticipated direction for addressing these failures, that is, to abandon the roadway and, also, the likely cost of the remediations, it was decided not to perform a detailed subsurface investigation.

Some borings were drilled at Landslide No. 1 and Landslide No. 2; however, due to a lack of funding and staff, the

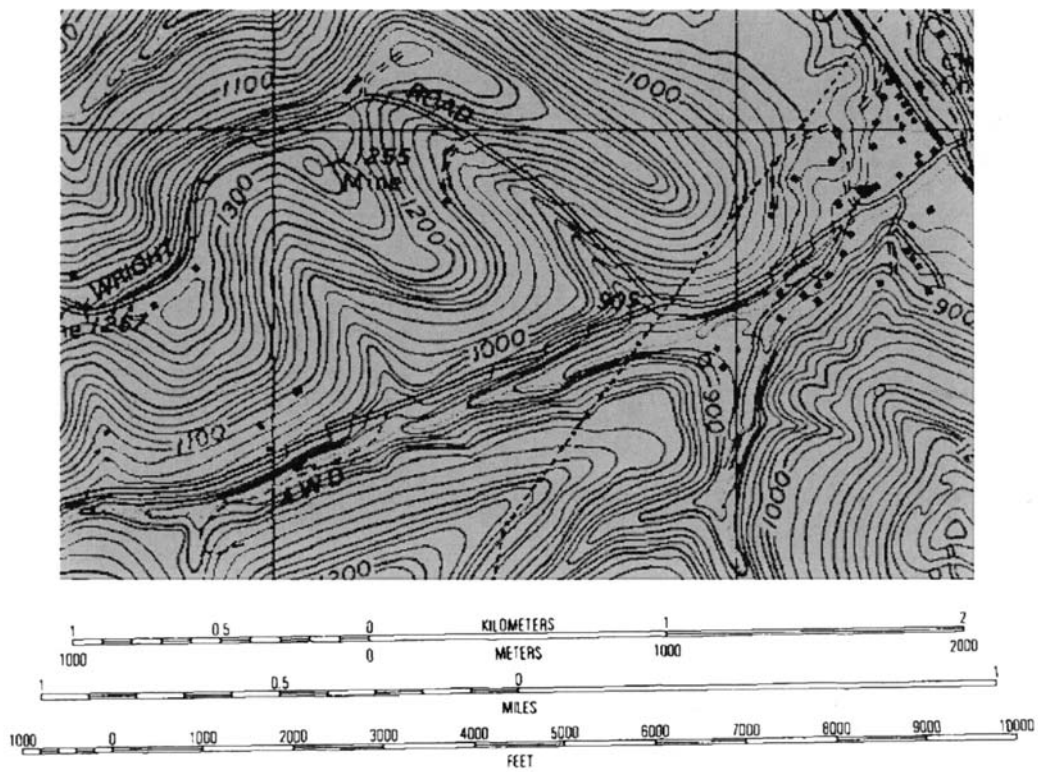


Figure 9. Topographic setting. Base map from the New Kensington East 7.5-minute Quadrangle, 1998 NIMA 5056 II SW-SERIES V831.

borings were not logged by a geologist or geotechnical engineer. Again because the investigation was terminated and no funds were available, the locations and surface elevations of the borings were not surveyed, so it was difficult to correlate them with the underlying stratigraphy. The closure of the roadway and the drilling of these borings all occurred prior to my returning to the Geotechnical Unit.

The slope movements are in various stages of development with Landslides No. 1 (see Fig. 11) and 4 (see Fig. 14) most severely impacting the roadway. Landslide No. 2 (see Fig. 12) and Landslide No.3 (see Fig. 13) while slightly smaller than Landslides No.1 and 4, they are still large enough to restrict travel to 1 lane or less. In total, there are 6 relatively larger slope movements. Besides these 6 there are numerous locations along the roadway where smaller slope movements are starting to develop. About 4 locations can be seen just east of Landslide No. 1, where smaller slope movements are starting to impact the roadway including an area where the guiderail has been completely undermined and is suspended in air over a portion of its length.

While no detailed investigation has been conducted on these slope movements, they have the general appearance of one of the most common types of failures impacting roadways in this region, that is, complex type landslides. These typically have a slump type movement near the heads or upper portions of the

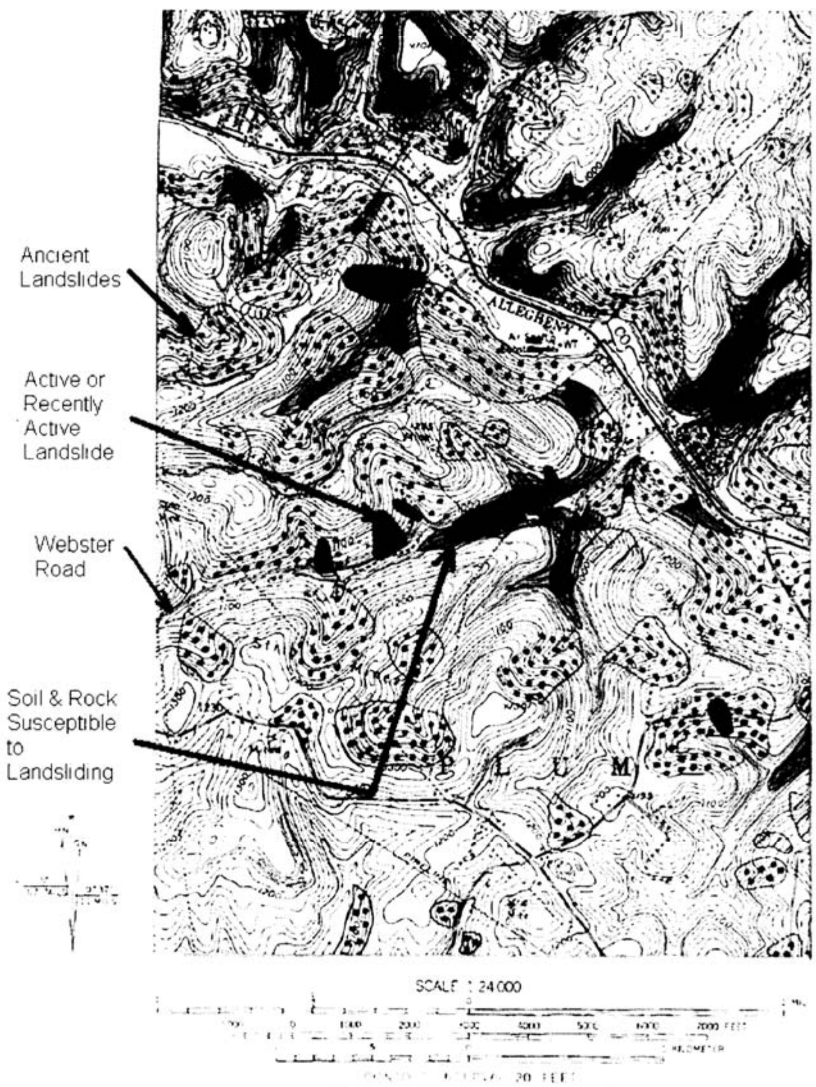


Figure 10. Slope Movement Features. Modified from Landslide Susceptibility Map of the New Kensington East 7-1/2′ Quadrangle, Allegheny County and Vicinity, Pennsylvania, Open File Map 74-283 by William E. Davies (Davies, 1974).

Figure 11. View of Landslide No. 1 looking west.

Figure 12. View of Landslide No. 2 looking east.

landslides with the lower or toe areas turning into flow type movements (Eckel, 1958; Varnes, 1978).

Landslides 5 and 6 are shown in Figures 15 and 16. They appear to be in the early stages of development at least at the roadway level. They also appear to be coalescing into one large landslide.

The Pennsylvania Department of Transportation (PennDOT) is presently evaluating the permanent closing and possible abandonment of a portion of Webster Road. Preliminary cul-de-sac designs are under way to determine the most effective locations to permit turning around where the roadway is closed by barriers. Additionally, consideration must be given to possible relocation of property owners and land locking of property which may have permanent residents on it.

STOPS 3 AND 4. LANDSLIDES ALONG INTERSTATE ROUTE 79

By James V. Hamel

Introduction

Stops 3 and 4 on this field trip are along Interstate Route 79 (I-79) about 9 mi northwest of Pittsburgh (Fig. 17). Along this section of I-79, deep-seated ancient landslide masses high on the valley walls were not recognized during investigation and design of the highway in the early to mid-1960s. Sidehill excavations for highway construction in 1968 and 1969 removed the toes of marginally stable landslide masses and initiated progressive failures which propagated upslope. By mid-1969, reactivated ancient

Figure 13. View of Landslide No. 3 looking east.

Figure 14. View of Landslide No. 4 looking east.

Figure 15. View of Landslide 5 looking east.

Figure 16. View of Landslide 6 looking east.

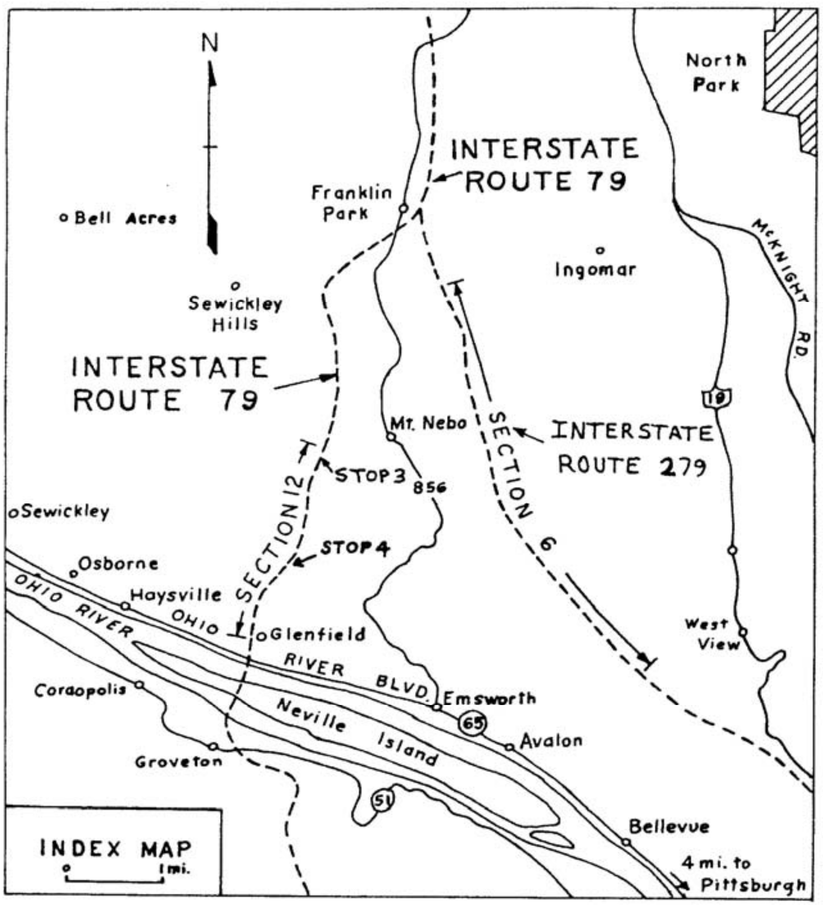


Figure 17. Location map for Stops 3 and 4 along Interstate 79 (after Flint and Hamel, 1971).

landslide masses extended discontinuously along the east valley wall from approximate highway Station (Sta.) 900–955.

Stop 3, near the north end of this landslide zone, is at approximate Sta. 975–985 where partially excavated remnants of some of the smaller landslides remain. Stop 4 is near the south end of the landslide zone at approximate Sta. 900–910, where partially excavated remnants of the largest landslide mass remain. Before describing Stops 3 and 4, it is appropriate to present some background on the landslide situation along this highway segment.

Initial Work, 1968–1969

Dr. Norman K. Flint (now deceased) and I had a rock slope research project under way with the Pennsylvania Department of Highways (predecessor of the Pennsylvania Department of Transportation) at the University of Pittsburgh in the fall of 1968. At that time, extensive landsliding occurred along this segment of I-79 which was then under construction. Because of their magnitude, proximity, and importance to the Department of Highways, the I-79 landslides became the focus of our research project. These landslides were located high on the east valley wall and they had basal failure surfaces at or near the base of a thick zone of weak claystone (Pittsburgh red beds) and/or colluvium derived from this claystone and overlying rock units (Fig. 18).

Slope excavation and related landsliding proceeded rapidly from the summer of 1968 through the summer of 1969. By December 1968, there was a mile-long active landslide laboratory, mainly along the east side of Kilbuck Run Valley. I spent about three days there each week from December 1968 through May 1969 trying to keep up with the continuing development and progression of landslides along this active construction corridor. Field observations, notes, sketches, and photographs were all I could manage initially. In early 1969, I began taking samples of failure surface clay seams for laboratory testing. By May 1969, Bill Adams (one of the leaders of the present field trip) and I were obtaining high-quality block samples from fresh failure surfaces. Most of the laboratory shear strength tests on these samples were done by Bill Adams. Results of our work on the I-79 landslides were presented in several reports and papers from 1969 to 1972 (Hamel, 1969; Hamel and Flint, 1969, 1972; Flint and Hamel, 1971). Portions of the report by Hamel and Flint (1969) and the entire field trip guidebook section by Flint and Hamel (1971) are available from the GSA Data Repository.[3,4] Note that the Interstate Route numbers were later changed from those in these early publications. I-279 in these early publications is now I-79 and I-79 in these early publications is now I-279.

[3]GSA Data Depository item 2011162, "A Slope Stability Study on Interstate Routes 279 and 79 near Pittsburgh, Pennsylvania" is available at www.geosociety.org/pubs/ft2011.htm or on request from editing@geosociety.org.

[4]GSA Data Depository item 2011163, "Engineering Geology at Two Sites on Interstate 279 and Interstate Route 79 Northwest of Pittsburgh, Pennsylvania" is available at www.geosociety.org/pubs/ft2011.htm or on request from editing@geosociety.org.

Subsequent Work, 1972–2010

I was away from the Pittsburgh area from 1969 to 1972. Since returning in 1972, I have continued to intermittently observe, consider, and evaluate the I-79 slopes. Most of the interpretations, conclusions, and recommendations presented from 1969 to 1972 are still considered valid. A few items, however, require clarification and/or amplification. Some of these items were mentioned, but not fully treated, in two later papers (Ferguson and Hamel, 1981; Hamel and Adams, 1981). Other items were addressed in a recent discussion (Hamel, 2004).

At the time the work on I-79 was done in 1969, my focus was on residual strength (Skempton, 1964), progressive failure (Bjerrum, 1967), back-calculation of shear strength (Hamel, 1969), and the only published case history of a near-by colluvial slope in Weirton, West Virginia (D'Appolonia et al., 1967). I recognized that the I-79 colluvial slopes were similar in some ways to the Weirton slope, but that the rear (upslope) portions were more like old rock slide masses. Subsequent observations along I-79 (Hamel and Adams, 1981), along with experience elsewhere, indicated that this was indeed the case.

Briefly, the connecting links between rock slides and colluvial slopes in the Upper Ohio River drainage basin (and probably elsewhere), which I had not yet recognized ca. 1970, are (1) the theory of valley stress relief in flat-lying sedimentary rocks (Ferguson 1967; Ferguson and Hamel, 1981) and (2) the Pleistocene history of the region (Leverett, 1902, 1934; Jacobson et al., 1988; Harper, 1997, 2002). These concepts are discussed further by Hamel (1998).

The original rock slides, extending up to ridge-top level along the east wall of Kilbuck Run valley, probably occurred in the Early to Middle Pleistocene (Pre-Illinoian or Illinoian) on the order of 500,000–1,000,000 years ago (Harper, 1997, 2002). Lateral stress relief accompanying valley down-cutting, probably in conjunction with high pore and joint water pressures in valley wall rock due to periglacial precipitation (glacial ice front some 20 mi to northwest) and perhaps rapid drawdown of glacially ponded water, caused rock sliding along the valley wall. Subsequent sliding, creep, and weathering broke down the outer portion of the original rock slide masses into more typical colluvium.

Along the I-79 corridor, bedrock strata dip westerly (out of the east valley wall) at ~2% (Fig. 19). Groundwater flow down these strata and down through stress relief fractured rock, rock slide masses, and colluvium contributed to both ancient and recent sliding of these materials, especially where groundwater discharge zones were blocked (covered or confined) by ice formations and/or clayey colluvium.

X-ray diffraction analyses showed concentrations of expandable lattice clay minerals (vermiculite, smectite) along the failure surface clays of the I-79 slides. These secondary minerals were hypothesized to result from groundwater flow and weathering or alteration effects along the failure surfaces and to be at least partially responsible for the low measured residual shear strengths of the failure surface clays (Hamel, 1969; Hamel and Flint, 1969).

Subsequent mineralogical and geochemical investigations of the claystone-derived shear zone at the base of a similar ancient rock slide located along present I-279 some 3 mi east of the I-79 slides showed an accumulation of randomly interstratified clay minerals (illite, chlorite, vermiculite, kaolinite) precipitated from colloidal solution as a result of groundwater interactions in overlying fissured claystone (Elnaggar and Flint, 1976). Chigira (1989) noted oxidation of pyrite in mudstones transforming chlorite to smectite as a potential cause of landslides in Japan. Anson and Hawkins (1999, 2002) also noted implications of geochemical processes in residual strength reductions along landslide failure surfaces in England. This is a potentially fruitful area for further research (Hamel, 2004; Nakamura et al., 2010).

Hamel (1969) and Hamel and Flint (1969) plotted residual friction angles from multiple reversal direct shear tests on I-79 failure surface clays versus clay size fraction in the manner of Skempton (1964). The I-79 data (with clay size fractions of 10%–29%) fell well below Skempton's band. They attributed this

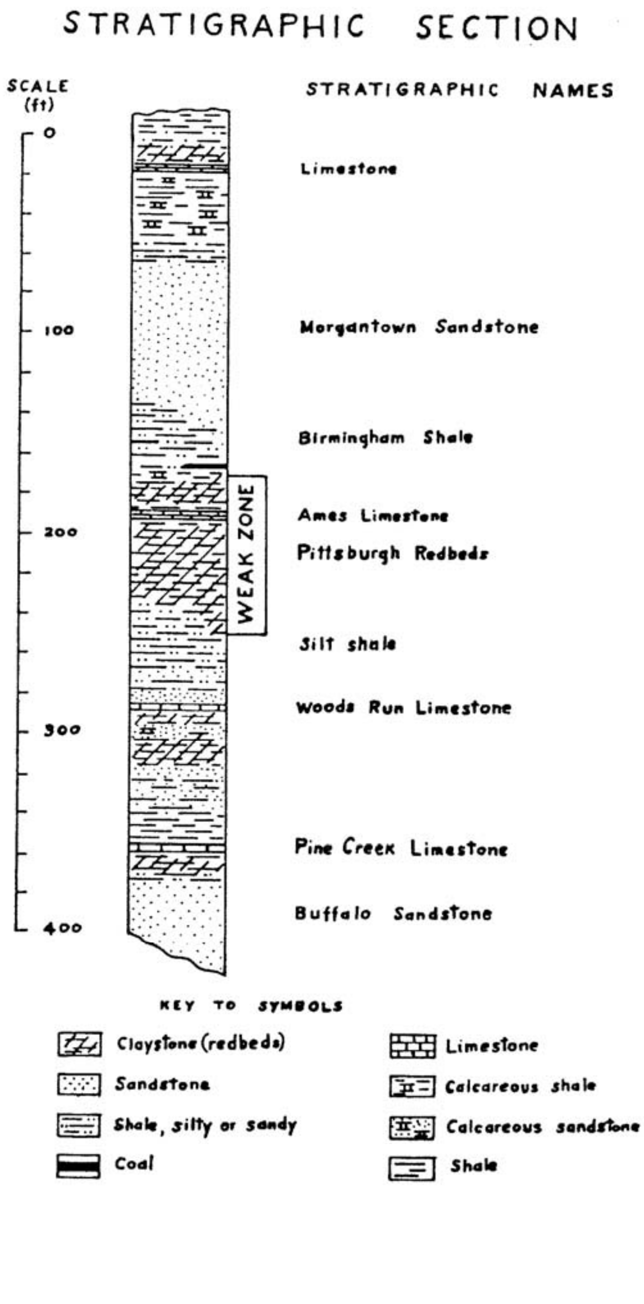
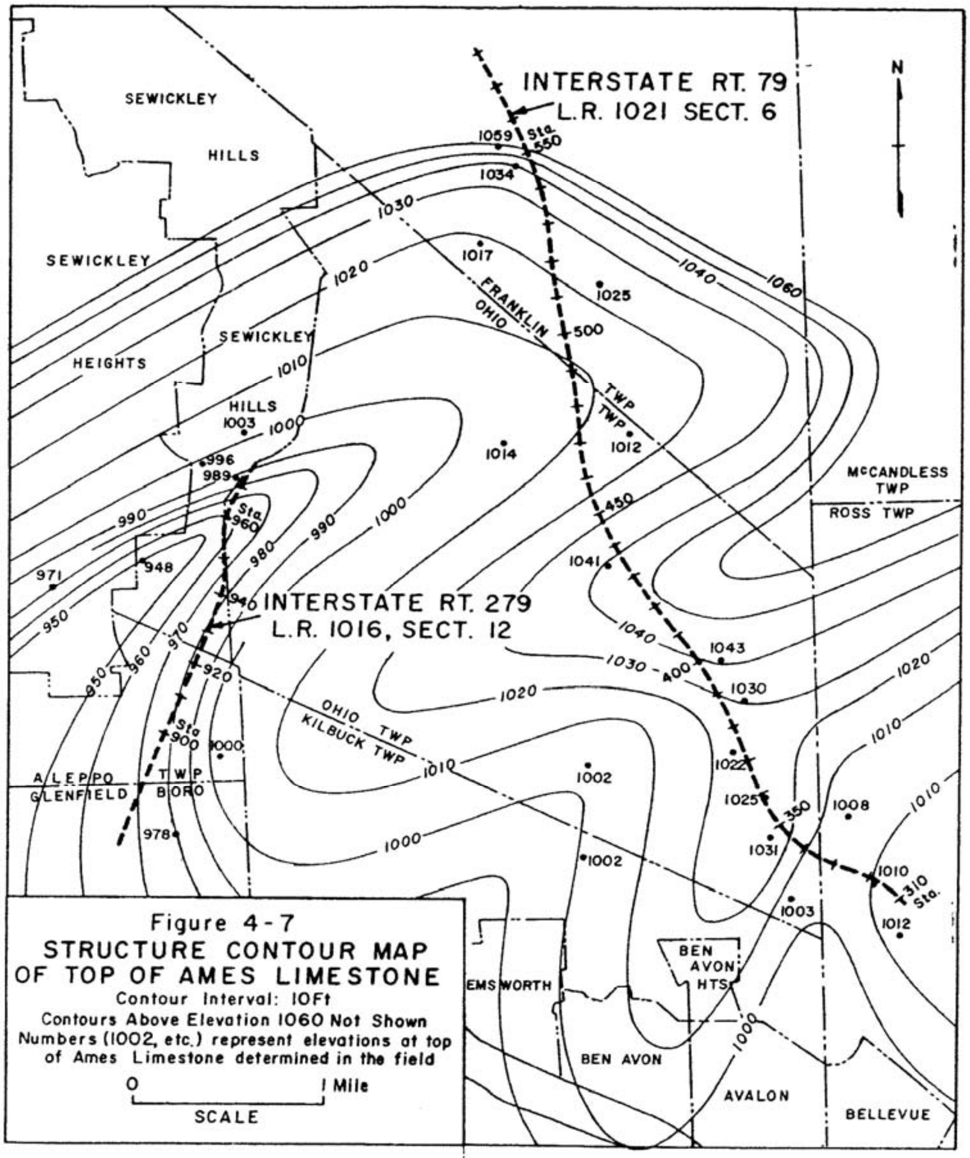


Figure 18. Stratigraphic section for Stops 3 and 4 (after Flint and Hamel, 1971).



Map by N.K. Flint - from Hamel and Flint (1969)

"Analysis and Design of Highway Cuts in Rock:
A Slope Stability Study on Interstate Routes
279 and 79 Near Pittsburgh, Pennsylvania"

Figure 19. Structure contour map on top of Ames limestone (by N.K. Flint) for Stops 3 and 4 (from Hamel and Flint, 1969).

to platy shaped aggregates of clay minerals (claystone and shale fragments of fine sand and silt size) becoming oriented parallel to the failure surface so that the measured residual friction angle was close to that of their mineral constituents.

Hamel (2004) showed that residual friction angles measured and back-calculated for claystone and claystone-derived colluvium of Western Pennsylvania plotted versus plasticity index also fell below empirical strength correlation bands given by Mesri and Shahien (2003). He recommended that these strength correlation bands be used with caution, particularly for low to moderate plasticity materials like Western Pennsylvania claystone and claystone-derived colluvium.

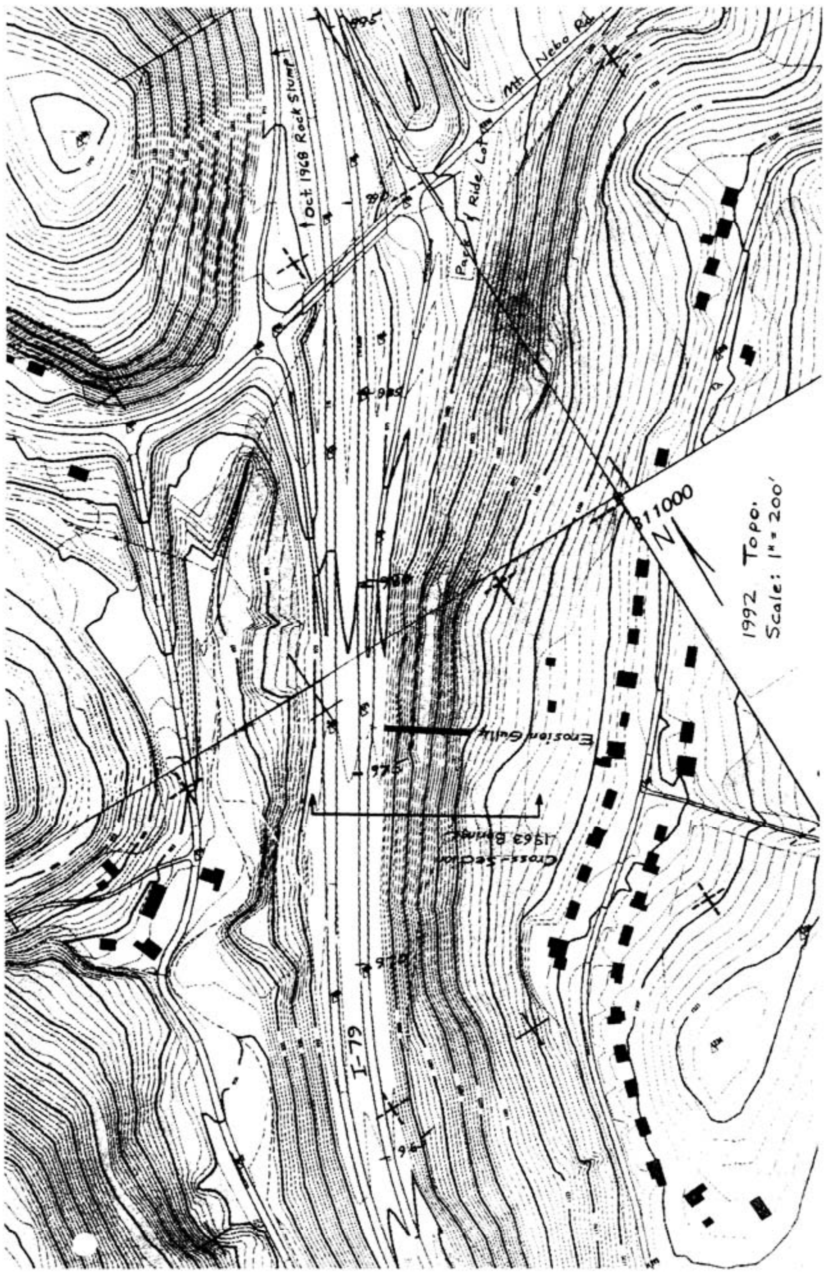


Figure 20. Plan, Stop 3 (on portion of Allegheny County Topographic Map, 1992).

Reflection on these concepts over the past 40 years, along with reconsideration of failure surface clays from I-79 and elsewhere observed in the field as well as the laboratory, suggests that the low (relative to index properties) residual friction angles measured and back-calculated for these clays may also result in part from thin films of (generally pale gray and slippery) clay coating platy shaped sand and gravel size (and presumably smaller) rock fragments along the failure surfaces. This inference is supported by the work of Elnaggar and Flint (1976) regarding clay mineral accumulation in a landslide shear zone and by the more recent work of Nakamura et al. (2010).

STOP 3

Stop 3 includes a length of ~1500 ft along the east side of I-79 from approximate Sta. 973–988 (Fig. 20). Figure 21 is a

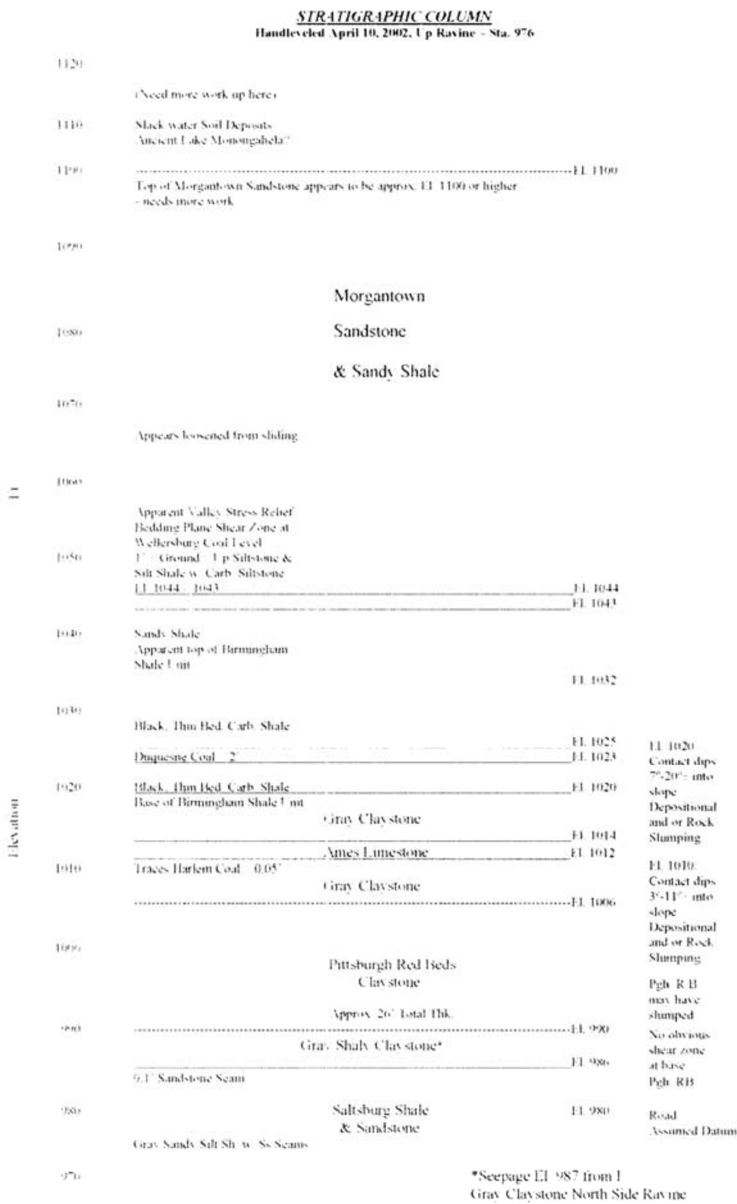


Figure 21. Stratigraphic column, Stop 3.

stratigraphic column measured up the erosion gully at Sta. 976 and Figure 22 is a slope cross section at Sta. 974. This cross section was developed from pre-construction topography and the logs of borings drilled in 1963.

For Stop 3, we leave the vehicle(s) at the Mount Nebo Road Park and Ride lot near Sta. 988 (Fig. 20). We walk south along the east side of the northbound exit ramp and the east side of I-79 to approximate Sta. 973. Along the way, we observe landslide features including colluvial soil masses, bent trees, and spring discharge zones in the slope above and discuss the stratigraphic column in Figure 21. At or near Sta. 974, we see slumped rock masses in the slope above and discuss the pre-construction cross section in Figure 22.

Then, we walk north to the erosion gully at Sta. 976 (Fig. 20). Just south of this gully, we climb the slope on a zigzag path. Along the way, we observe rocks exposed in the gully (Fig. 21) and, south of the gully, a slumped mass of carbonaceous shale of the Birmingham Shale Unit (Figs. 21 and 22). On a bench at approximately elevation (El.) 1040, we see an apparent valley stress relief bedding plane shear zone at the base of the Morgantown Sandstone Unit (Fig. 21).

We continue upslope to a relatively level area at or near the top of the Morgantown Sandstone at approximately El. 1100 (Fig. 21). From there, we follow a highway construction access road northerly and downslope to the northbound exit ramp at or near Sta. 985 (Fig. 20). Along the way, we see typical colluvial landslide features including hummocky topography, bent trees, spring discharge zones, and closed depressions with ponded water.

We then walk back to the Park and Ride Lot, board the vehicle(s), cross over I-79 to the southbound entrance ramp (Fig. 20), and drive ~1.5 mi south on I-79 to the next exit where we cross under I-79 to a northbound entrance ramp and Stop 4.

STOP 4

Stop 4 includes a length of ~1000 ft along the east side of I-79 from approximate Sta. 900 to Sta. 910 (Fig. 23). This is the largest and most spectacular landslide area along this section of I-79 and it was the main one investigated by Hamel (1969) and Hamel and Flint (1969). They investigated two separate landslides which were reactivated by highway slope excavation: Slide A from approximate Sta. 906–910 and Slide B from approximate Sta. 899–904. Plans of Slides B and A are shown in figures 5-2 and 5-3, respectively, of Hamel and Flint (1969). Cross sections through Slide B at Sta. 899 + 00, 901 + 50, and 903 + 50 are shown in figures 5-6, 5-7, and 5-8, respectively, of Hamel and Flint (1969). A cross section through Slide A at Sta. 908 + 00 is shown in figure 5-9 of Hamel and Flint (1969). All of these figures show conditions as they existed in the spring of 1969.

Later in 1969 and 1970, Slides A and B coalesced and the northern part of the coalesced landslide propagated several hundred feet easterly to form the huge landslide amphitheater extending from approximate Sta. 904-910 on Figure 23.

In 1969, the Department of Highways acquired additional right-of-way to contain the enlarging landslide area. The magnitude of this landslide problem occurring during a large

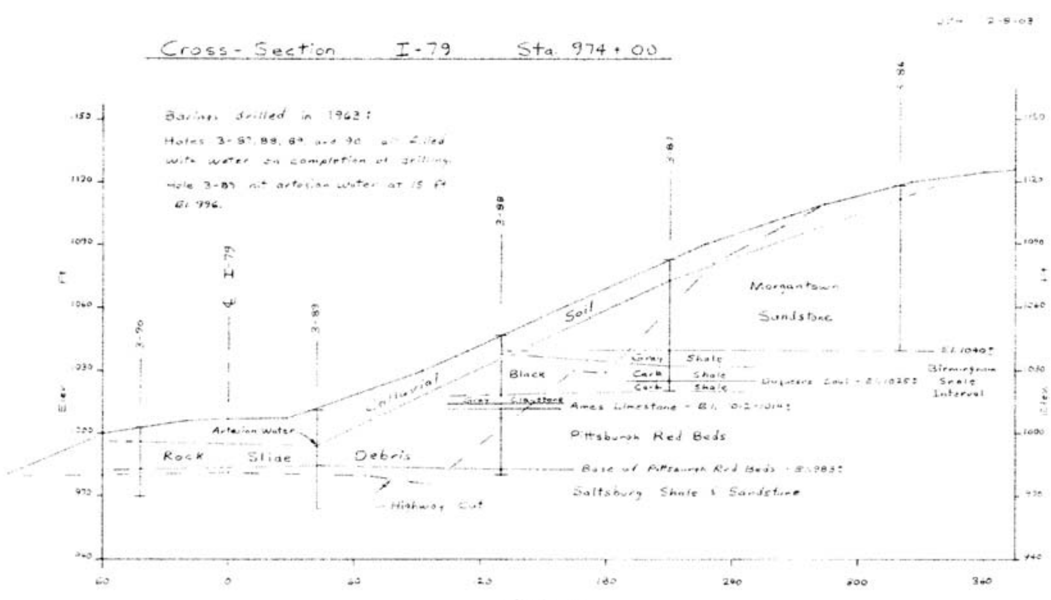


Figure 22. Cross section, I-79, Sta. 974+00, Stop 3.

construction project, along with the low residual strengths of clay seams along basal failure surfaces (Hamel and Flint, 1969), indicated that the most economical solution here involved removal of a substantial portion of the landslide mass. A bench was excavated at or below the base of the landslide along the outer part of the slope to catch landslide debris and the landslide debris further upslope was excavated to a nominal inclination of 5H:1V, producing the topography shown in Figure 23.

Slope excavation was completed in 1970. Since then, movements have propagated further upslope, opening preexisting stress relief joints in Morgantown Sandstone. Some of these joints at the rear of the slide area were open to depths on the order

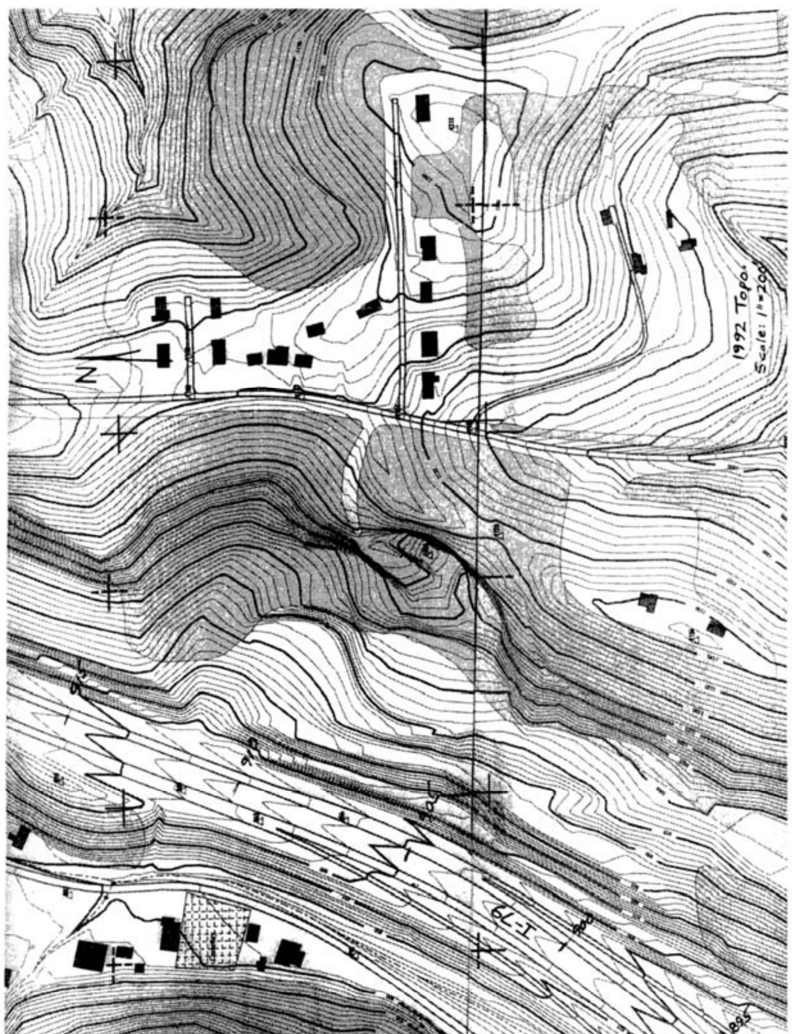


Figure 23. Plan, Stop 4 (on portion of Allegheny County Topographic Map, 1992).

of 100 ft by 1981. Large sandstone blocks have been detaching from the valley wall and creeping and/or intermittently sliding downslope on underlying claystone. These movements pose no threat to the highway.

For Stop 4, we leave the vehicle(s) on the road shoulder at approximate Sta. 908 and walk up the slope at approximate Sta. 910 (Fig. 23). We walk south along the excavated bench to approximate Sta. 905, then northerly along the partially excavated landslide mass to approximate Sta. 909. On this partially excavated surface, we see numerous sandstone stress relief joints opened by the continuing slide movements.

We then walk south along the partially excavated surface to approximate Sta. 904 where we turn northeast and walk into the amphitheater at the rear of the landslide area (Fig. 23). There we see the slide scarp along stress relief joints in Morgantown Sandstone, a graben-like canyon where rock moved away from the scarp, and huge sandstone blocks separated by various fissures and openings. Some of the latter are several feet wide with depths of 100 ft or more. All of this block movement and separation at the rear of the landslide mass has occurred since 1969.

From the rear of the amphitheater, we walk north along the inside of the right-of-way fence to approximate Sta. 910, then proceed westerly and downslope along the south side of the valley at approximate Sta. 911. Along the way we see various landslide features, e.g., rock debris and spring discharge areas. One of the springs has an abandoned Appalachian livestock watering trough—spring water formerly carried by a pipe to an overflowing cast iron bathtub.

We return to the vehicle(s) on the road shoulder at approximate Sta. 908 and then leave for Pittsburgh.

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Appendix B

Selected Photographs of Field Trip Stops

Stop 1
Interstate Route 79 - Station 973-988

Mary Ann Gross, Barb Dunst, and Jim Hamel in the upper part of the ravine (Birmingham shale level) Interstate Route 79, Station 976, Stop 1.

Photo by Brian Dunst – March 21, 2021

Jim Hamel, Barb Dunst, Mary Ann Gross climbing the slope at Sta 975.

Photo by Brian Dunst – March 21, 2021

Overall view northeast at the eroded ravine Sta 976.

Photo by Mary Ann Gross – March 8, 2020

Closer view northeast at the eroded ravine at Sta 976.

Photo by Mary Ann Gross - March 8, 2020

View north at the upper part of the eroded ravine, Ames Limestone up to Duquesne coal – strata dip 7^{o} into the slope – apparently slumped.

Photo by Mary Ann Gross – March 8, 2020

Slumped carbonaceous shale above the Duquesne coal level at approximately 50 ft. south of the eroded ravine.

April 18, 2019

Base of the Morgantown sandstone in the upper part of the eroded ravine. The stick with the orange flag is at the ½ in. thick Wellersburg coal.

Photo by Brian Dunst – March 21, 2021

Sta 975 upslope of the eroded ravine – overall of slackwater soil at approximate el. 1116 ft.

April 16, 2002

Close-up of the above-mentioned soil.

April 16, 2002

Jim Hamel at bent trees along the right of way fence just north of the eroded ravine.

Photo by Mary Ann Gross – March 8, 2020

Jim Hamel at a spring discharge on the colluvial slope north of the above bent tree.

Photo by Brian Dunst – March 21, 2021

Mike Forth at a depression pond in colluvium above the Mt. Nebo exit ramp.

April 1, 2002

Stop 2
Toms Run Nature Reserve

Jim Hamel at the confluence of third and second order tributaries of the Ohio River. Saltsburg shale and sandstone are exposed in the far bank of the second order tributary.

Photo by Mary Ann Gross – March 8, 2020

Jim Hamel at a lobe of slide debris on the south side of the third order tributary valley.

Photo by Mary Ann Gross - March 8, 2020

An Ames Limestone cobble in the stream at approximate el. 930 ft.

January 27, 2020

Ames Limestone boulders in the stream at approximate el. 940 ft.

January 27, 2020

Jim Hamel at a slumped Ames Limestone boulder on the slope on the north side of the stream.

Photo by Mary Ann Gross – March 8, 2020

Closer view of the above-mentioned Ames Limestone boulder.

January 29, 2020

Close-up of the above-mentioned Ames Limestone boulder.

January 29, 2020

Overall view of slumped Pittsburgh red beds shaly claystone on the slope on the north side of the stream at approximate el. 980 ft.

January 29, 2020

Close-up view of the above-mentioned Pittsburgh red beds.

January 29, 2020

View south at the Ames Limestone boulder and orange discharge in the head of the valley at approximate el. 980 ft.
January 29, 2020

View east down the valley at the above-referenced location.

January 29, 2020

Overall view of a ridge of slumped Morgantown sand-stone on the south side of the valley.

February 26, 2021

Closer view of the above-mentioned Morgantown sandstone.

February 26, 2021

Overall view of a huge Morgantown sandstone slump block on the north side of the valley at approximate el. 1000 ft.

February 24, 2020

Closer view of the above-mentioned slump block.

February 24, 2020

The above slump block is on the left; a closed depression is on the right.

February 24, 2020

The above-mentioned closed depression.

February 24, 2020

Stop 3
Ohio Township Community Park

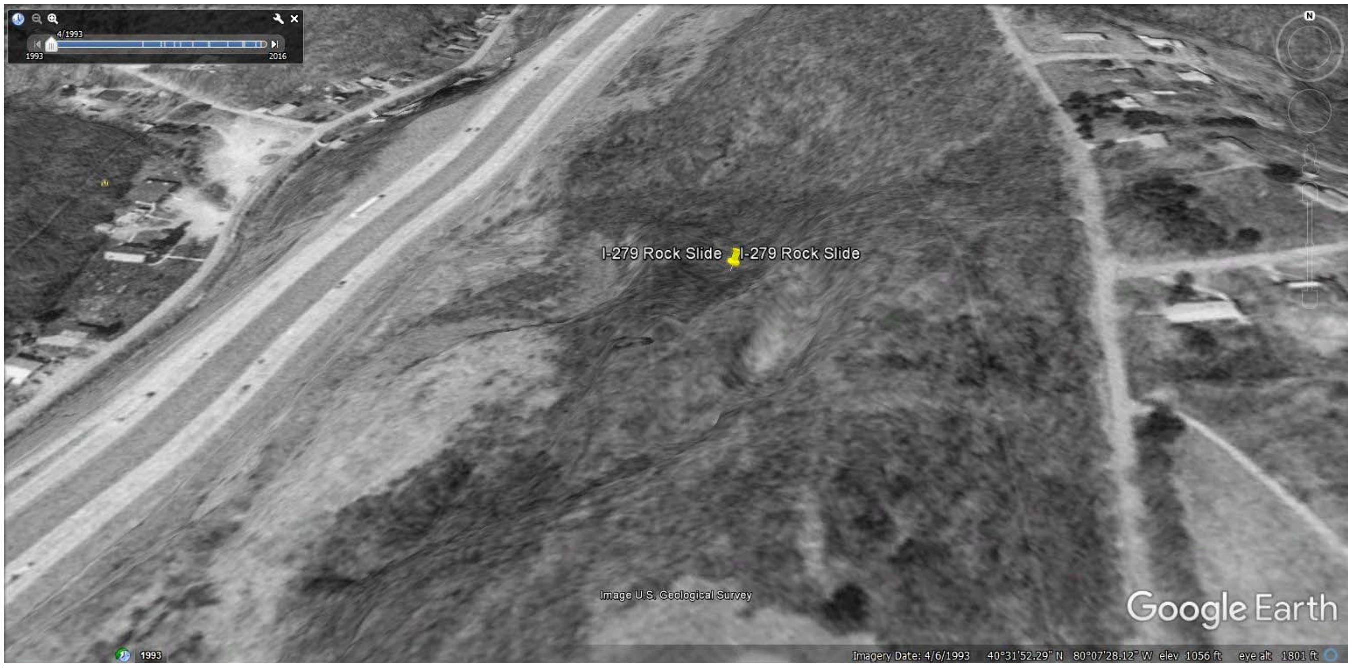
Ohio Township Community Park picnic pavilion and restroom building.

January 29, 2020

Stop 4
Interstate Route 79 - Station 900-910

View north from approximate Sta 895 at the excavated slide debris above the lower excavated bench on top of the Saltsburg shale and sandstone.

June 17, 1972



Google Earth photo looking north at the slide area, approximate Sta 902-910. The graben is on the right and below the yellow tack.

April 6, 1993

More recent, full color Google Earth photo looking north at the slide area, approximate Sta 904-910. The graben is on the right and below the yellow tack.

April 19, 2014

View southwest at the cracks between sandstone slide blocks. Clipboard for scale. Approximate Sta 907.

April 6, 2019

View southeast at the above cracks. Clipboard and 6 foot rule for scale.

April 6, 2019

View southwest at the cracks in the slide debris. Clipboard and 6 foot rule for scale. Approximate Sta 904.

April 10, 2019

View north at the above-mentioned cracks. Clipboard and 6 foot rule for scale.

April 10, 2019

View north along the slide scarp from approximate Sta 904. The graben is at the top left.

April 6, 2019

Closer view north along the scarp and graben.

April 20, 2016

Calcite joint filling in the right center of the previous photo.

April 20, 2016

View south along the scarp and graben from approximate Sta 908.

April 20, 2016

View west at sandstone slide blocks west of the graben at approximate Sta 907.

March 31, 2019

View west just north of the above photo.

March 31, 2019

View south at the intermediate scarp in the previous photos.

March 31, 2019

View north at an area in the above photo.

March 31, 2019

View south at the slide fissure at approximate Sta 906.

April 6, 2019

View east at the front face of the sandstone slide blocks (intermediate scarp) at approximate Sta 905.

March 31, 2019