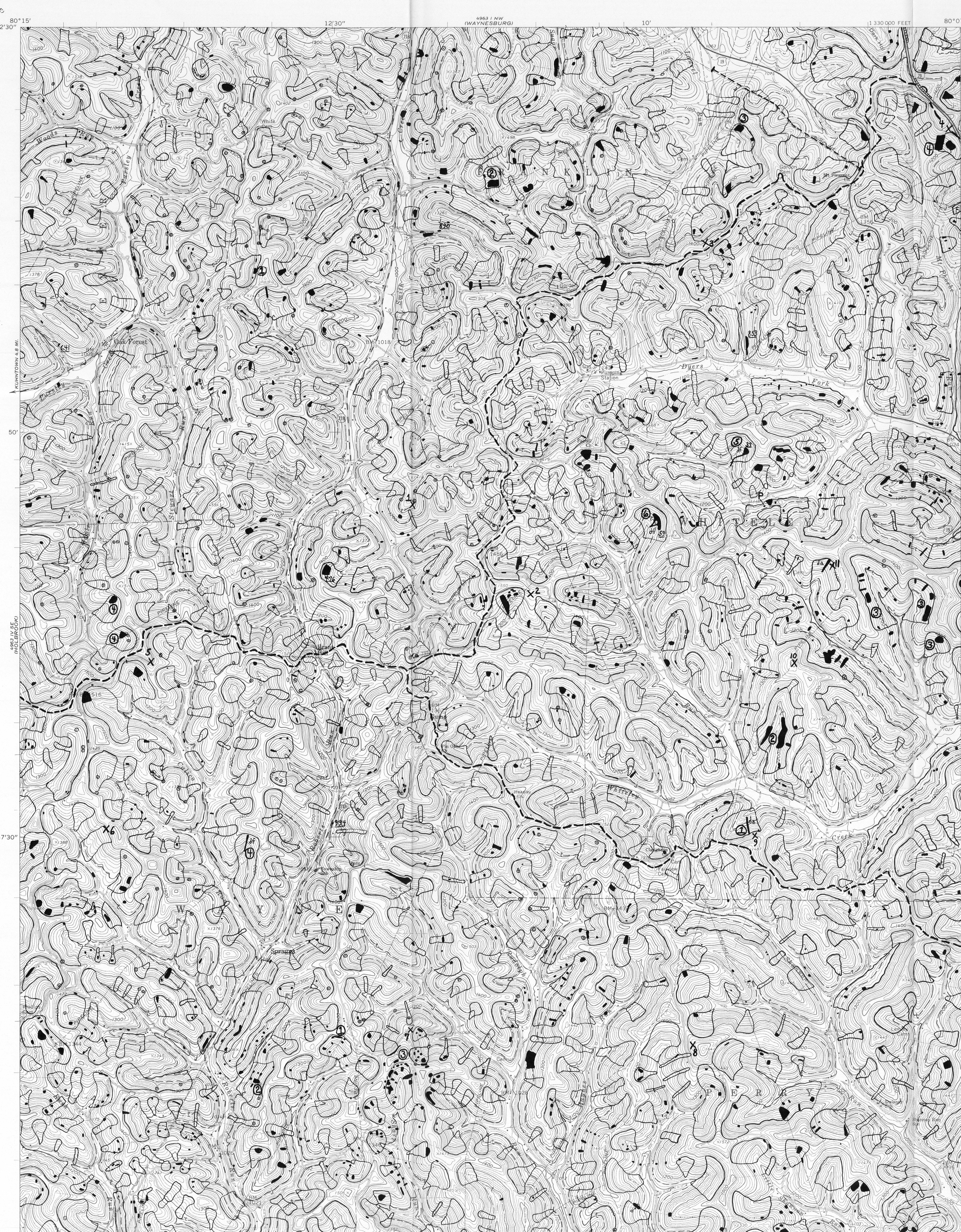

Base from U.S. Geological Survey, 1977

UTM GRID AND 1973 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

MN GN 5° 89 MILS 0°31' 9 MILS

SCALE 1:24 000

1 ½ 0 1 MILE

1 .5 0 1 KILOMETERS

CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

PENNSYLVANIA
QUADRANGLE LOCATION

EXPLANATION

(NOTE: This map and accompanying text contain data usable in the identification of areas involving slope stability, but this data cannot be used as a substitute for detailed geologic engineering investigations of specific sites.)

Active or recently active slope movements--Debris slide, slump, earthflow, or complex type; less common debris flow (indicated by df) and debris avalanche (da). Earthflow is most common. Includes scarp and deposit. Boundaries are approximate

Area of extensive older, mostly prehistoric, slope movement which may represent coalescing slope movements of varying ages and types; small area may represent single event. Colluvium is thickest in areas of laterally concave slopes where incidence of recently active slope movement is most severe. Outcrops are rare to nonexistent. Includes scarp and deposit. Boundaries are approximate

Spring (seep) observed in field. Documentation dependent upon time of year (spring or fall) which accounts for unequal distribution shown on map

④ Described slope movement (see table 1)

$\times^2$ Approximate location of cored drill hole (see fig. 7)

— — — Drainage divide (see fig. 2)

P Site of backhoe-generated trench

⊢ — ⊣ Site of pipeline trench study (northeast corner)

853 Sample location (see table 2)

Coal beds as mapped by Roen (1972)

— — t — — t - Ten Mile
— — j — — j - Jollytown
— — w — — w - Washington

NOTE:

1) All slopes in quadrangle are moderately to highly susceptible to sliding and (or) flowage of colluvial material based on distribution of slope movements.

2) Unspecified slopes may show evidence of poorly defined old movements. These slopes generally bear less colluvium than slopes with "area of extensive older slope movement" and locally show discontinuous outcrops commonly of sandstone.

INTRODUCTION

This map is the first example in the eastern United States of a 1:24,000-scale 7.5-minute quadrangle map that identifies areas with slope-stability problems in detail. Such a map enables the user to make a rapid evaluation of the potential for mass movement. Furthermore, detailed slope movement inventory of this type can serve as a framework for statistical analyses of several factors that cause slope failures, such as the effects of bedrock lithology, soil and slope characteristics, and precipitation. Planners, engineers, soil scientists, geologists, and elected officials should find the map useful in the assessment of slope hazards and planning for future land use. Final evaluation of any site within the quadrangle should be based on an examination by a soils engineer or an engineering geologist.

Field investigations in the springs of 1981 and 1982 and the fall of 1981 involved nearly 60 days of traverses. The foot traverses were supplemented by the interpretation of the land surface on vertical black-and-white aerial photography flown in January and February of 1973 at a scale of nearly 1:24,000. Earlier aerial photography flown in June and July 1939 at a scale of 1:20,000 and more recent but significantly smaller scale photography (1:80,000) flown in June 1977 supplied additional documentation. More than 1,200 active or recently active and 900 older slope movements were identified.

The geologic map of the Oak Forest quadrangle (Roen, 1972) is one of several geologic maps at a scale of 1:24,000 in eastern and central Greene County. Stone (1932) wrote an earlier report of the geology and mineral resources of Greene County. A series of reconnaissance landslide maps at 1:24,000 scale based mainly on aerial photographic interpretation included Greene and adjacent counties (Hackman and Thomas, 1978).

Selection of the Oak Forest quadrangle for a more comprehensive study of the slope movements was based on the existence of a recent geologic map (Roen, 1972), sizeable tracts of both forested and non-forested land, nearby precipitation record stations, a large number of pipelines which could offer pertinent data, and good accessibility of terrain from secondary roads. Finally, Hackman and Thomas (1978) showed that the area was representative of any quadrangle in the northern part of the Dunkard basin in its distribution and density of slope movements.

The quadrangle is located about 65 km southwest of Pittsburgh, Penn. (fig. 1). Three distinct drainage systems (north, east, and south trending) are represented within the quadrangle (fig. 2).

TERMINOLOGY

The term "soil" is used in this report in the engineering sense; it includes material that has resulted from rock weathered in place (residuum) as well as weathered material that has moved downslope and accumulated at the base of slopes (colluvium).

The term "mudstone" is extensively used in this report rather than "clay-shale" or "shale" as used by previous workers in southwestern Pennsylvania and in southeastern Ohio. Earlier investigators did not differentiate between bedded shale and nonbedded mudstone. Berryhill and others (1971) state that mudstone is a more appropriate term than shale for these fine-grained clastic rocks because the rocks commonly lack fissility. Mudstone contains equal proportions of clay and silt, is essentially nonbedded, and breaks with an irregular fracture (Collins and Smith, 1977). Only where the rocks are bedded or fissile should it be called shale. A claystone is a clay-rich mudstone. The definitions of rock types are according to Gary and others (1972).

The term "landslide" has been widely used as an all-inclusive term for almost all types of slope movements including some that involve little or no sliding (Varnes, 1978, p. 11). In this report, I have used the general term "slope movement" rather than "landslide" except for movements that involve only sliding.

Four types of slope movements (Varnes, 1978, fig. 2.1) are present in the Oak Forest quadrangle. They include falls (rock falls), slides (earth slumps, debris slides), flows (debris and earth flows, debris avalanches, creep), and complex movements (slump-earthflows, debris slide-earthflows).

Rockfalls are free falls of bedrock. Alternating competent and incompetent lithologies, in addition to closely-spaced vertical joints commonly parallel to drainage, are contributing factors to the process. No major rockfall hazard is present in the quadrangle. Slides are either earth slumps involving rotational movement with an upward curving rupture surface or are debris slides which take place along planar or mildly undulatory surfaces. Debris slides are also called translational movements. Both types of slide movements can be very slow to rapid. Flows are of four types ranging in movement from extremely rapid (debris avalanche) to very rapid (debris flow) to rapid to very slow (earthflow) to extremely slow (creep). Earthflow is ubiquitous throughout the area. Soil creep is the imperceptible downslope movement of soil and rock material. Accelerated creep often precedes sliding. Creep is common on many slopes where ground breakage is scant or absent. Many slope movements are complex in that features of two or more basic slope movements are represented (fig. 3). What starts out as rotational-type sliding (slumping) sometimes develops into a translational (or planar) movement which becomes a flowage feature in the lower part. Not only are sliding and flowage combined, but the sliding itself consists of both rotational and planar movements.

ACTIVE OR RECENTLY ACTIVE SLOPE MOVEMENTS

More than 90 percent of the active or recently active slope movements in the Oak Forest quadrangle are small, generally less than 30 m in maximum dimension. Small slides and flows having a maximum dimension of less than 9 m are not shown because of the map scale. Slope movements in the quadrangle are generally less than 2.5 m thick. No deep-seated slope movements extending into unweathered bedrock have been documented.

More than 1,200 slides and flows are shown on the map; their density is about 8.2/km^2. Most slides and flows shown with this designation are less than 20 years old, determined primarily from conversations with landowners and SCS officials; few probably exceed 40 years in age. Table 1 is a guide to selected localities. Figure 4 illustrates the debris flow at locality 5, region 2.

Most of the slope movements have been triggered by natural causes such as unusually high amounts of rainfall either during an intense storm or over a longer period of time. Man's modification of sensitive slopes is a less important factor in the quadrangle. Man-generated causes include excavating at the base of a slope so that the slope becomes oversteepened, overloading a slope with fill causing instability, altering drainage conditions that affect not only the surface water but ground water as well, and vibrations stemming from increased heavy construction (blasting and pile driving). Any one of these actions can reduce the shearing strength of the earth material and cause slippage.

Active slides and flows are distinguished by obvious frontal movement with a steep, rounded nose and by fresh scars, not only at the head but throughout the entire displaced mass. A poorly drained, hummocky surface characterizes a recent slope movement. Many slides and flows become stabilized, at least temporarily, after movement occurs.

OLDER SLOPE MOVEMENTS

More than 900 older movements have been identified in the quadrangle. Older slope movements are less apparent than the more recent movements, but the recognition criteria are similar (Pomeroy, 1982a). Most of these movements have well-defined geomorphic features such as hummocky ground and bowl- or amphitheater-shaped upper slope areas. They are shown on the map as either individual movements or as a series of coalesced movements that are mapped together as one unit. Some of the latter are up to 2.2 km in width and do not represent a single event in the history of the area, but they are part of a continuing process during and after the Wisconsin glaciation.

Although the quadrangle lies within the unglaciated part of the Appalachian Plateau, it is believed to have been influenced by the periglacial climate. Ancient landslides on the Appalachian Plateau largely have formed under periglacial conditions (Gray and others, 1978). The rate of movements was no doubt greater at this time and shortly thereafter because of increased rainfall. Radiocarbon dating of slide planes at construction sites in West Virginia indicate a minimum age of 40,000 years at Wierton (D'Appolonia and others, 1967), and about 8,940 and 9,750 years at Morgantown and Wheeling respectively (Philbrick, 1962).

In many places, the resultant slope of an older movement deposit has attained equilibrium, and because of its now stable configuration, the slope is not susceptible to further sliding and (or) flowage. The toe and foot areas are relatively stable, and many dwellings built on them decades ago have not been damaged. However, excavations on the surface can reactivate sliding.

Unspecified slopes on the map commonly are sites of poorly defined old movements. The head scarp and hummocky lower slope are not always apparent because of erosion. Locally, discontinuous sandstone outcrops can be found.

All slopes in the quadrangle are moderately to highly susceptible to movement. Although unmarked slopes generally bear less colluvium than slopes with extensive older movements, renewed activity can occur anywhere.

GEOLOGY AND SOILS AND THEIR RELATION TO SLOPE MOVEMENTS

Exposed bedrock in the Oak Forest quadrangle consists of flat-lying to subhorizontal, cyclothemic sedimentary rocks of Pennsylvanian and Permian age and includes, from oldest to youngest, the Waynesburg, Washington, and Greene Formations all of the Dunkard Group (fig. 5; Roen, 1972). Outcrops are abundant only along drainages and road cuts; except for scattered sandstone ledges, they are rare along hillsides. Lithologies generally are inferred based on microtopographic expression.

All observed slope movements (exclusive of rockfalls) in the quadrangle occur in colluvial or residual clayey to clayey-silty soil and weathered rock derived from mudstone, claystone, shale, siltstone, and sandstone. Soils derived from the generally nonbedded mudstones, claystones, and shales of the Dunkard Group are particularly prone to sliding and flowage.

In order to more fully evaluate the causes for the observed distribution of the slope movements, a mylar sheet with contacts and key beds traced on it from Roen (1972) was registered to the slope movement map. Not all of these lines were transferred to this map because of the density of the line work.

Slope movement heads commonly occur at or just below a sandstone (or siltstone) bed in contact with a weaker (mudstone or shale) sequence. Seeps are common at contacts between permeable and impermeable lithologies.

Slope movements can occur anywhere in the stratigraphic section when favorable conditions for movement (slope configuration, lithology, precipitation, etc.) are present. However, the weathered material from some rock units has a slightly greater potential for movement than other units. Table 2 shows the relative susceptibility of the weathered material to slope movement. Figure 6 indicates the heterogeneity and relative thinness of lithologic types in the Washington and Greene Formations. No description of the lithologies encountered in a schematic columnar section on a geologic map is as meaningful to the reader as the actual depiction of lithologies at specific locations. Facies changes in the geologic section are numerous (fig. 6). Individual lithologies (except for some coals which serve as marker beds) are seldom traceable for distances greater than 1.5 to 2.0 km. Slope movements can originate in the vicinity of any of a number of contacts separating permeable and impermeable horizons within the 100 meters or more of section.

Areas underlain by the finer grained clastic rocks (mudstone, claystone, shale) of the Dunkard Group, particularly that part of the section lying above the Washington coal (Washington and Greene Formations) are the most sensitive to movement. In the Washington Formation, a sandstone which commonly occurs at the approximate position of the Jollytown coal bed lies above an unstable zone underlain by mostly mudstone (about 30 m thick) in a large part of the northeast quadrant. That part of the Greene Formation highly prone to movement occurs above the Ten Mile coal bed extending upwards about 30 m in some places and as much as 90 m in other areas.

Intervals less prone to being sources of slope movement in the Greene Formation seem to occur 90 m to 140 m above the Ten Mile coal bed, or when an approximately 30-m or less thick zone overlying the Ten Mile coal bed caps the hilltop or ridge. However, the relative position of the less competent horizons on a slope is possibly a more significant factor, at least locally, than its lithologic makeup (Pomeroy, 1982, p. 19) because the lower the position of the weaker horizon along the hillslope, the greater the volume of water available to the unit.

The only area with few recent slope movements is the valley in the northeastern part of the quadrangle where the Waynesburg Formation underlies the slopes. Slopes in this area are more moderate than elsewhere. A higher proportion of sandstone and siltstone, compared to weaker rock as seen in the pipeline trench (see map), is another factor in accounting for fewer slope movements.

Soils mapped as Dormont-Culleoka silt loam (Siebert and others, 1983) are found on all slopes in the Oak Forest quadrangle. The soils show a moderate plasticity index ranging from 9 to 25 and a moderate shrink-swell potential (USSCS, 1983, p. 87, 89). On the basis of USSCS data, the soil permeability is generally slow to moderately slow. Because of its low strength, wetness, and tendency to slip, the Dormont-Culleoka soil poses severe limitations as a use for foundation base in road and dwelling construction.

Clayey material from several recently active slope movements was collected. The samples contain two suites of clay minerals similar to each other (table 3). The predominant suite contains illite, kaolinite, and a clay component which may be vermiculite; the other suite contains illite, kaolinite, and a more smectite-type expandable clay (Virginia Gonzalez, U.S. Geological Survey, unpub. data). The illite is potassium-deficient, which is a condition prevalent elsewhere in unstable shales and mudstone of Devonian to Permian age in western Pennsylvania. Fisher and others (1968, p. 79) in Ohio concluded that degraded illites behave similarly to montmorillonites in the presence of water, with the exception that expandability is not as great.

PRECIPITATION

Precipitation is the most significant factor in the frequency of slope movements.

Data (NOAA, 1970-82) show that precipitation at Waynesburg (1.5 km north of the Oak Forest quadrangle border) between 1970 and 1982 was above normal except for three years (fig. 7). The three drier years were less than 10 percent below normal whereas eight of the 10 above normal years were more than 10 percent above the norm. Earlier data (NOAA, 1962-69) indicate a marked period of well below normal precipitation.

The increase in frequency of slope movements was probably caused by greater than normal precipitation in the 1970-1982 period. During and immediately following any intense rainstorm or period of persistent rainfall, pore-water pressures in the soil are built up accompanied by a decrease in shear resistance of the regolith and weathered rock. This combination initiated the slope failures.

Many slope failures observed in the quadrangle are less than 10 years old. Diagnostic features include exposures of fresh soil in the head scarp and along lateral margins, abrupt termination of vegetation, appearance of transverse and (or) radial cracks, and identification of basal shear surfaces in the head area.

One precipitation station was maintained from 1980 to early 1982 by the U.S. Geological Survey Water Resources Division along Whiteley Creek (Don Williams, 1983, written commun.). Despite the proximity to the Waynesburg station (12 km), the annual precipitation at the two stations shows a noticeable difference (fig. 7). Such findings indicate that when one applies the figure for a precipitation station nearest to a specific slope movement, that figure might bear little relation to the precipitation that actually occurred at that locality.

Many landowners in the quadrangle remarked to the author that "sliding" has been increasing along the slopes in recent years. Long-time residents claimed that "slides" or "slips" were not as numerous when they were younger. Several property owners recognized the relationship between rainfall and "sliding".

ORIENTATION (ASPECT)

A study of recent slope movements versus orientation in the quadrangle indicates a slight preference for NW-, N-, NE-, and E-facing slopes (53.6 percent) over SE-, S-, SW-, and W-facing slopes (46.4 percent). Older, mostly prehistoric, slope movements show a slight partiality that is only fractional. However, 80 percent of the large older slope movements greater than 1 km in width face some component of north.

The combination of steeper slopes and greater soil moisture in addition to a thicker colluvial cover probably account for the slightly higher incidence of mass movement on north-facing slopes. Earlier studies in parts of nearby southern Washington County (Pomeroy, 1978, 1982b) showed more notable relationships wherever an east-west asymmetrical drainage system was present.

East-west drainages in this part of southwestern Pennsylvania are asymmetrical in that drainages such as Dyers Fork and Whiteley Creek are not at the centers of their respective basins. The shortness of tributaries flowing off north-facing slopes is in marked contrast with the significantly longer streams flowing from the north. This situation is not related to either lithology or structure.

Analysis of slope movements in the eastern part of the quadrangle shows that nearly 60 percent of recent mass movements favor NW-, N-, NE-, and E-facing slopes. The Dyers Fork and Whiteley Creek areas show a higher concentration of mass movements on slopes receiving the least sunlight during the colder part of the year. The map shows large (generally coalescent) areas of old movements on these slopes.

One type of slope movement, a debris flow (fig. 4), is dependent on a channel and, thus favors slopes with a preexisting drainage. Only three debris flows were observed in the quadrangle; all have a SSW to SW orientation. Most other types of movement (translational or rotational slide-earthflows) do not follow any preexisting drainage.

CONFIGURATION OF SLOPES

In an analysis of over 1,100 recently active mass movements in the quadrangle, about 60 percent occur along concave slopes (showing contour concavity), 26 percent along planar slopes, and 14 percent along convex slopes. Similar relationships have been cited by Pomeroy (1982a, b) and Lessing (1983).

Concave slopes are sites for extensive recent and older movements because these slopes collect large quantities of water. Increased soil weathering and consequent loss of shear resistance lead to instability.

The siting of pipelines with relation to slope configuration has improved in recent years. Earlier pipelines (as indicated on the base map) trend with little or no deviation in alignment. Replacement sections of pipelines and abandonment of original lines are in evidence within several concave slopes. In contrast, new pipelines commonly follow noses of slopes and utilize the crests of hills resulting in a zig-zag rather then a direct line. Areas affected by slope movements and moderate to strong creep are largely avoided.

RELATIONSHIPS OF STRUCTURE, SEEPS, WOODLAND COVER, AND SLOPE MOVEMENTS

The maximum degree of dip is slightly greater than 1 in the northern part of the quadrangle. However, no relationship exists between the structure contours (Roen, 1972) and the slope movements nor between the structure contours and seeps. About 80 percent of the encountered seeps lie within an area of extensive older slope movements. About 57 percent of the seeps are found along NW-, N-, NE- and E-facing slopes.

Maps were prepared at the scale of 1:24,000 of the extent of woodland for 1939, 1958, and 1977 based on aerial photographic interpretation. An attempt was made to correlate slope movement with forest cover (or lack of it). The percentage of the quadrangle covered by woodland as of 1977 has more than tripled since 1939. Deforestation has taken place in only one area which is less than one percent of the quadrangle. Coal waste development along Whiteley Creek has involved deforestation in a tributary valley, but extensive slope failures there are not believed to be wholly due to forest removal.

No pronounced relationships between slope movements and forest cover could be established. Recent movements are just as likely to occur along long-standing forested slopes (seen on 1939 aerial photographs) as on grassland slopes. Also, grasslands that existed in 1939 and whose vegetative cover has not changed since then are sites for continued movement.

SUBSURFACE STUDIES

Backhoe trench.--Trenching operations at recent earthflows have been undertaken in the Appalachian Plateaus in order to learn more about subsurface slippage. These studies (Stephen F. Obermeier, 1980, unpub. data) began in this quadrangle in 1980. One locality is in the northeast quadrant (Pitcock property) and is shown on the map as P.

A 3.5- to 4.0-m-deep trench at location P was excavated downslope from slightly above the crown area of a small earthflow to slightly below the toe. The earthflow occurs along the lower part of a north-facing slope underlain by the Washington Formation (below the Jollytown coal bed and within the 15-m-thick, weak zone of mudstone, shale, etc.) as indicated by Roen (1972).

Colluvium is 2.7 m thick above weathered bedrock. Multiple blue-gray shear zones occur above the weathered bedrock with a major shear zone (<1 cm thick) at the top of the weathered bedrock. The shear surfaces are roughly parallel to the 21° (37 percent) angle of the slope. The topmost shear surface is 1.8 m below the surface and is the slippage plane for the recent scarp. This surface continues upslope beyond the head scarp.

Pipeline trench.-- A 2-km-long, nearly 2-m-deep open pipeline trench a few m north of and parallel to an existing pipeline was investigated in September 1981 in the extreme northeast part of the quadrangle. Observations of colluvial thickness and shear plane identification were noted. A shear plane was found to occur on the average of one for every 11.5 m of stratigraphic section. About 56 percent of these shear surfaces occur between colluvium and bedrock; the balance occurs equally within colluvium or weathered bedrock.

Summary of subsurface investigations.--Trenches in this quadrangle and in adjacent areas show that:

1.) the zone at the base of the movement consists of blue-gray clay of variable thickness (2 mm to several cm) and slickenslided surfaces. Multiple slippage zones of blue-gray clay are common;
2.) the clay acts as an impermeable barrier with permeable material (commonly colluvium) above it. Movement is translational (planar) or roughly parallel; and
3.) the toe of the movement, where colluvium is thicker than upslope, shows an array of convoluted shear surfaces, only a few of which can be traced for more than a few meters.

SUMMARY

More than 1200 active or recently active and more than 900 older slope movements have been identified in this quadrangle at the north end of the Dunkard basin. Slope movements, mostly earthflows, occur in colluvial or residual clayey to clayey silty soil derived from mudstone, claystone, shale, siltstone, and sandstone of the Dunkard Group. Sliding and flowage of the regolith take place close to contacts of permeable and impermeable horizons which are numerous throughout the stratigraphic section especially in the Washington and Greene Formations. Prediction of slope movement occurrence is hampered by poor exposures, thinness of lithologic units, and abrupt facies changes within short distances as revealed by subsurface data.

Most of the slope movements have been triggered by natural causes such as precipitation. Greater than normal precipitation in the 1970-1982 period probably accounts for the increase in slope movements as shown by fresh appearance of the failures. The combination of steeper slopes, greater soil moisture, and thicker colluvial cover account for the slightly higher incidence of movements along north-facing slopes. Most mass movements take place along concave slopes where soil wetness is common throughout much of the year. These concave slopes contain soils where high pore-water pressure is easily reached and include some of the most extensive areas of slope movements.

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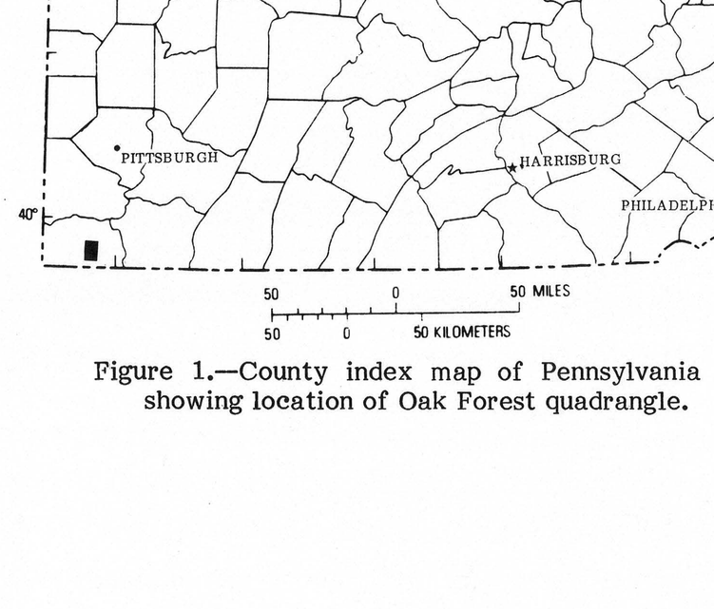


Figure 1.--County index map of Pennsylvania showing location of Oak Forest quadrangle.

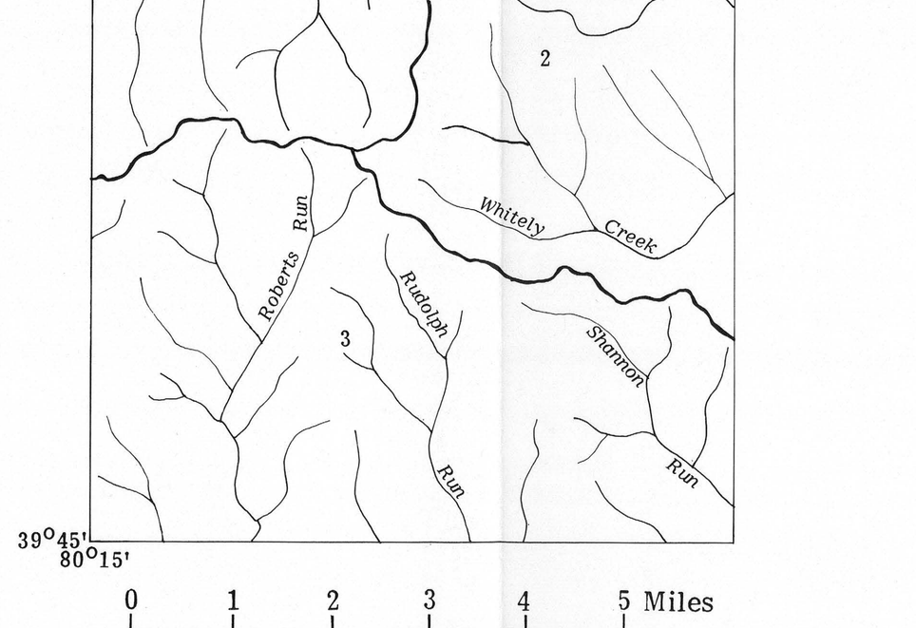


Figure 2.--Drainage systems, Oak Forest quadrangle. 1, Pursley-Smith Creeks; 2, Dyers Fork-Whiteley Creek; 3, Roberts-Rudolph-Shannon Runs. Drainage divides shown by heavy lines.

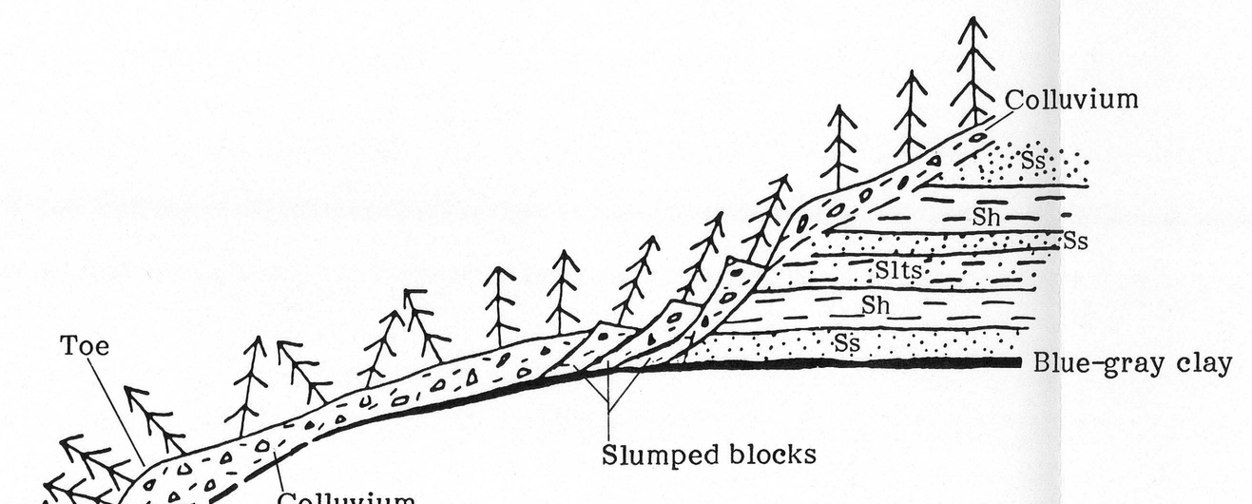
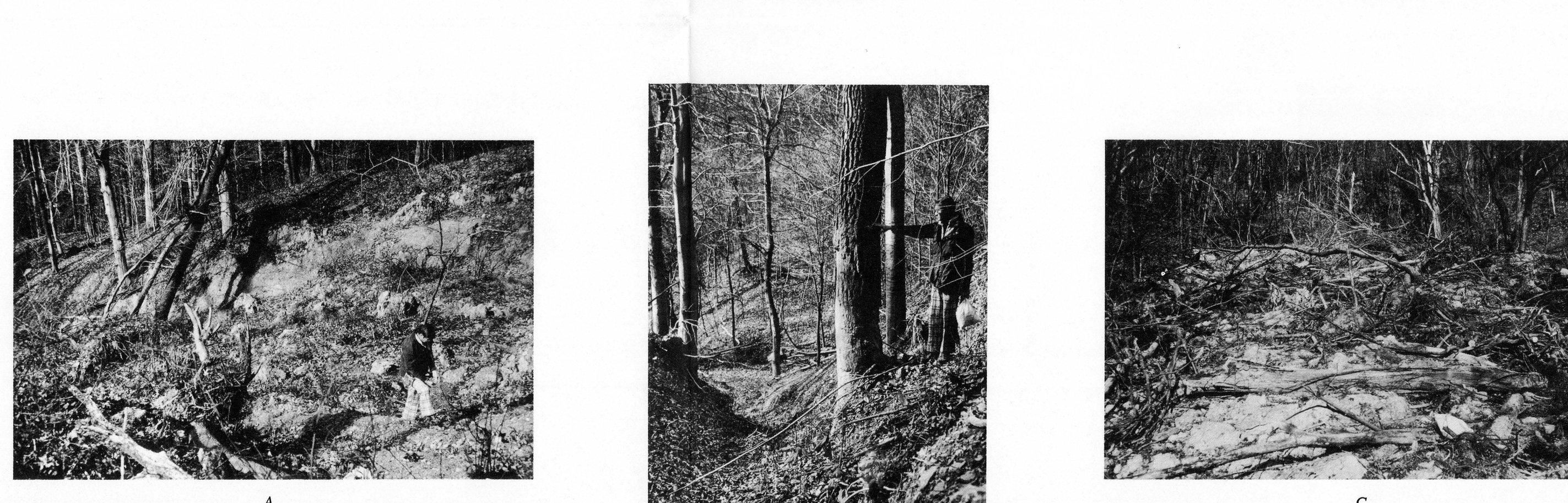


Figure 3.--Diagrammatic representation of a generalized complex slope movement. Ss, sandstone; Sh, shale; slts, siltstone. Tilted trees show influence of movement.



A *B* *C*

Figure 4.--Debris flow (table 1, region 2, locality no. 5). *A*, Head area; *B*, Chute (between head and toe). Note height of mud-encrusted bark; *C*, Toe area.

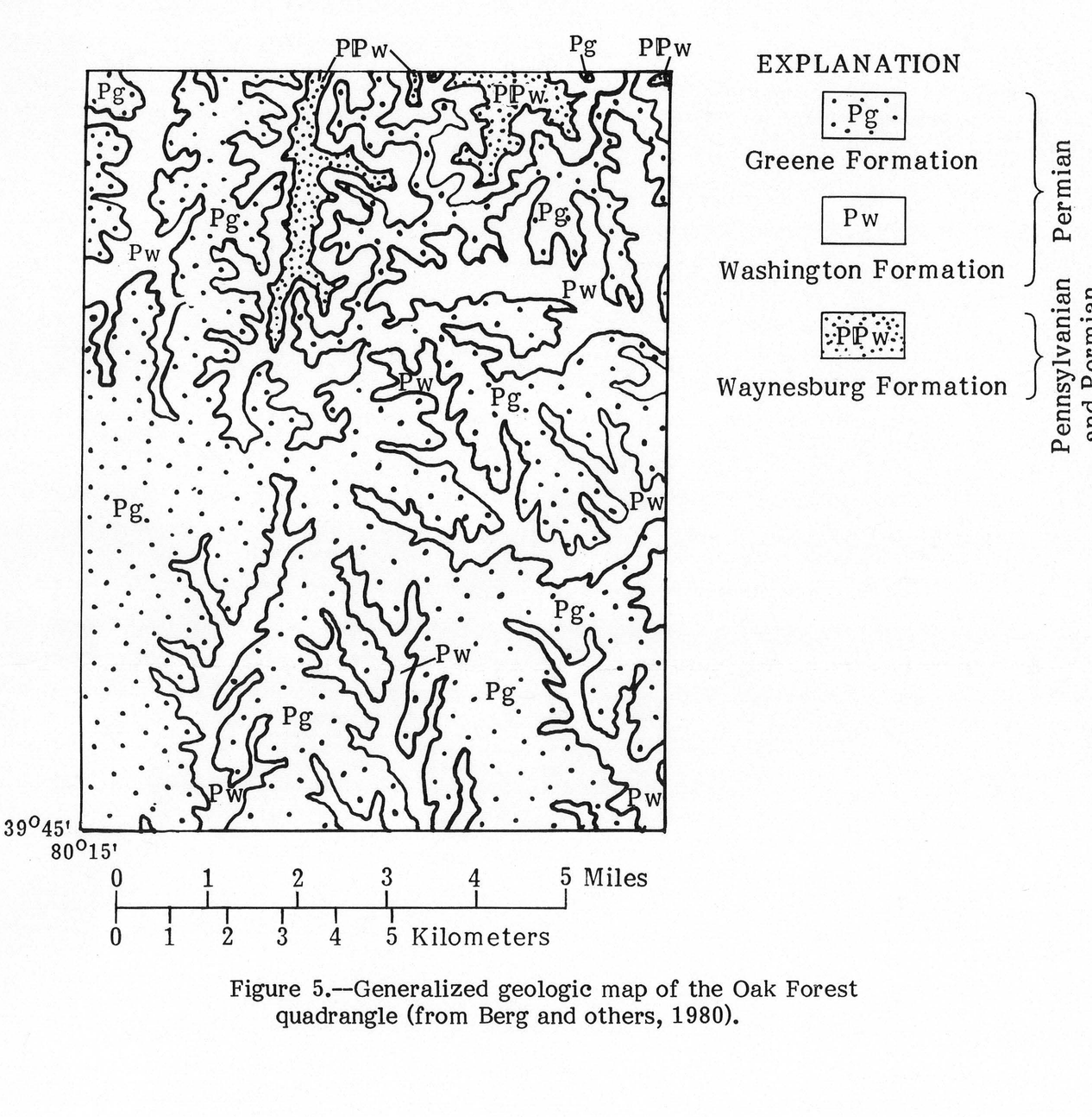


Figure 5.--Generalized geologic map of the Oak Forest quadrangle (from Berg and others, 1980).

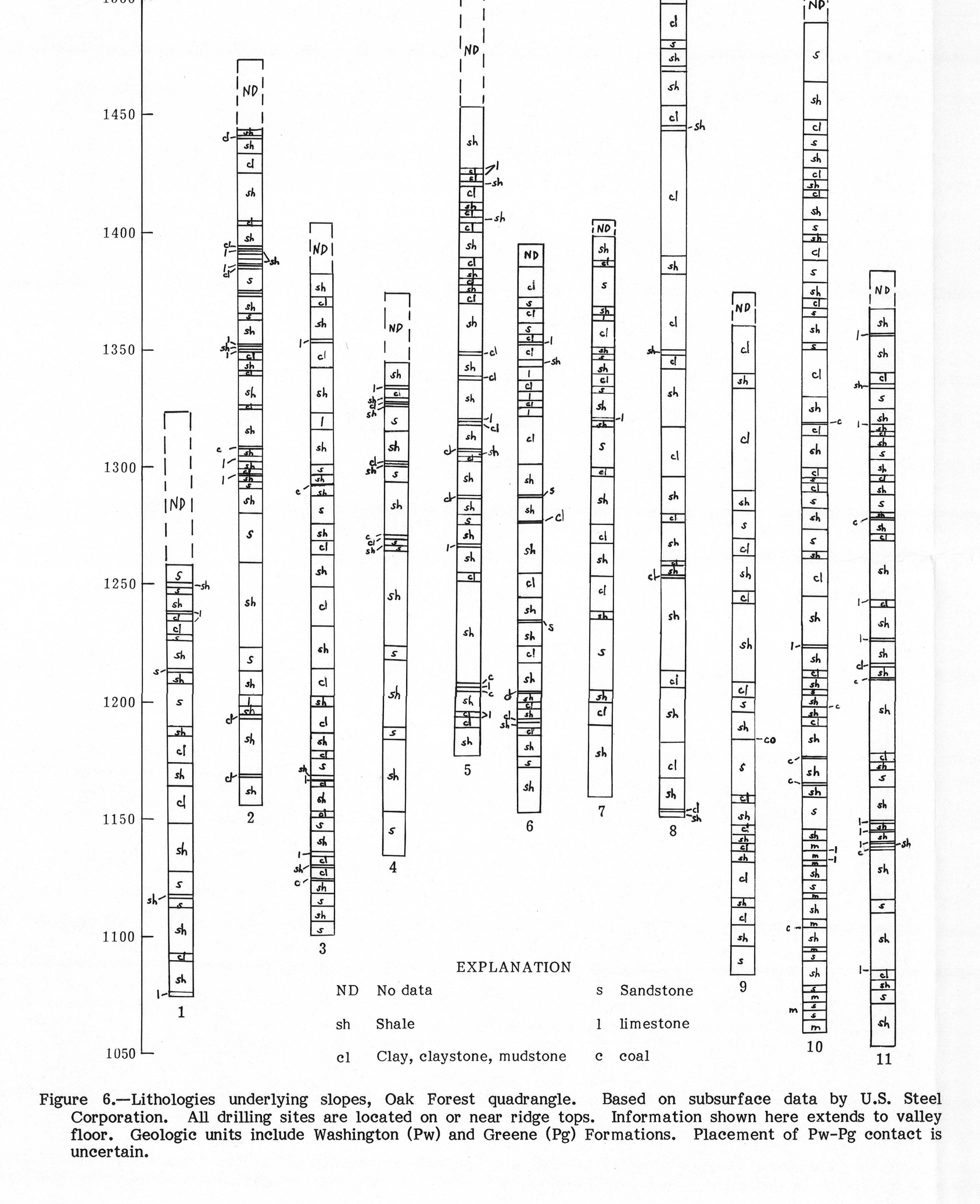


Figure 6.--Lithologies underlying slopes, Oak Forest quadrangle. Based on subsurface data by U.S. Steel Corporation. All drilling sites are located on or near ridge tops. Information shown here extends to valley floor. Geologic units include Washington (Pw) and Greene (Pg) Formations. Placement of Pw-Pg contact is uncertain.

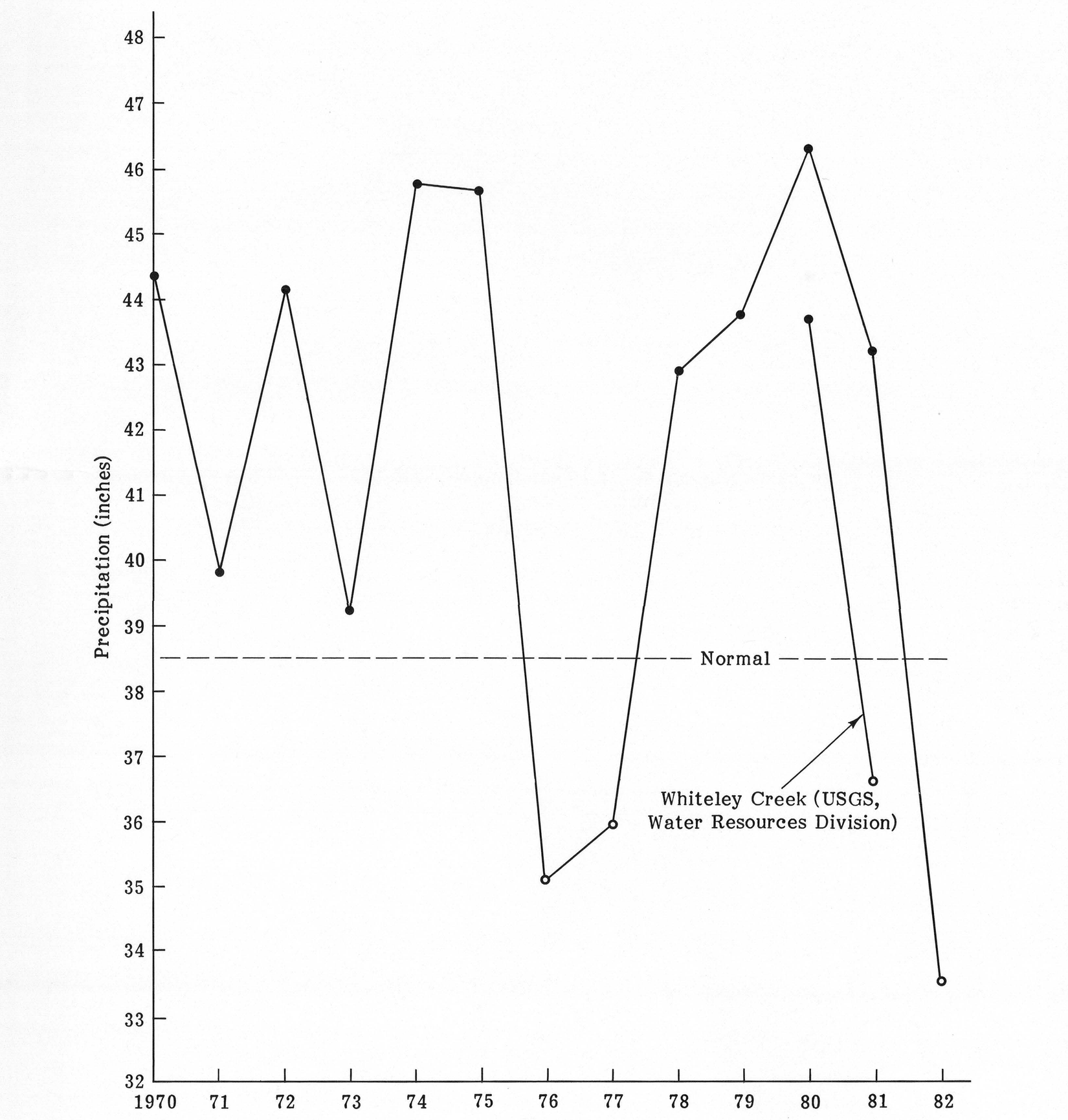


Figure 7.--Precipitation data, Waynesburg, Penn., 1970-1982 (data from National Oceanic and Atmospheric Administration, 1971-1983).

Table 3.--*Clay mineralogy.*[1]

Sample	Material	Location	Mineralogy
37	blue-gray clay	floor of head area of debris flow	Illite, 85 percent; kaolinite, 15 percent; trace of mixed-layer clay (vermiculite?)
59	blue-gray clay	floor of head area of debris flow	Illite, 85 percent; kaolinite, 12 percent; trace of mixed-layer clay (vermiculite?)
476	reddish-blue gray clay	head area of fresh movement	Very degraded illite with mixed-layer clay (vermiculite?), kaolinite, trace of quartz
641	blue-gray clay	excavated ditch in front of movement	Random mixed-layer clay with illite, kaolinite, possible quartz
853	blue-gray clay	slickensided surface of movement	Random mixed-layer clay with very degraded illite and possibly vermiculite component, kaolinite, some quartz
890	blue-gray clay	head of movement	Partially degraded illite with some random mixed-layer clay, kaolinite, trace of quartz
994	blue-gray clay	probable shear surface of movement	Very degraded illite with mixed-layer clay component, kaolinite, some quartz

[1] X-ray diffraction analysis by Virginia Gonzalez, U.S. Geological Survey

Table 1.--*Guide to selected slope movements.*

Region Number (fig. 2)	Locality Number	Location	Geologic Unit (head of slope movement)	Comments
1	1	East side of road about 2 km ENE of Oak Forest	Greene Fm., about 51 m above Ten Mile coal	Two planar movements (earthflows) flanked newly constructed house in front and in rear. Front movement--19 m wide, 21 m long, along 20° (37 percent) slope. Head close to undamaged concrete block foundation. Toe covered road. Rear movement--31-m-wide toe, 10 m from rear wall of house. Cut slope above toe is 21° (39 percent) in contrast to adjacent natural slope of 12° (20 percent). At head, slide is 20 m wide and extends downslope 21 m. Head scarp is as high as 1.5 m. Steeper slope (20° or 38 percent) above head scarp. Seepage at slope break.
1	2	W-facing forested slope 1 km east of Pa. 218	Washington Fm., middle member, 15 m below Jollytown coal	60-m-wide complex movement (mostly planar) to drainage. Influence of pipeline cutting across slope is possible. Red but mostly buff- to brown-weathering shale in head area at scarp.
1	3	North side of old US 19 east of Laurel Run	Washington Fm., middle member, slightly below Jollytown coal	73-m-wide front of complex slope movement with 1.5- to 2.5-m-high toe. Difference in elevation between head and toe is 24 m. Occupies northwest part of larger old slope movement which continues below road and is revealed by extensive hummocky surface. To southeast is a 24-m-wide slope movement. Brownish-red sandstone ledge slightly above head. Seepage noted below sandstone.
1	4	SW-facing hillside 3 km south of Oak Forest	Greene Fm., 73 m above Ten Mile coal	Mostly earthflows as wide as 90 m in two pipeline areas (one on map). Widespread wetness in head areas because of large number of springs. Several sequences of historic movements occur at slope break. Pipeline broke because of slope movements.
2	1	0.6 km south of Patterson Run-Whiteley Creek roads; forested	Greene Fm., approximately 39 m above Ten Mile coal	Debris avalanche, 240 m long, 21 m wide, fresh, facing NNW. Toe stands 1.2 m in relief near base of slope 60 m below head. Toe subjected to slumping which extends nearly to creek. Head area is red to grayish-green silty clay, slumped, as much as 1.2 m removed in zone of depletion
2	2	Tributary valley north of Whiteley Creek 0.5 km east of U.S. Steel office	Uppermost Washington Fm. and lower Greene Fm.	Man-modified valley has been filled with rock waste from underground mining (coal). Thickness of rock waste is probably more than 15 m at south end; average thickness about 4.5 m. Active 300-m-wide complex sliding zone (rotational and translational) along both sides of valley caused either by tensional forces along the slopes resulting from valley-floor loading and (or) rise of ground-water table because of increased thickness of valley fill. Slumping (30-50 m wide) in four localities above new access road induced by construction along sensitive slopes.
2	3	NNW-trending valley north of Whiteley Creek; partially forested	Greene Fm., approximately 36 m above Ten Mile coal	Major zone of historic activity (commonly earthflows) along ENE-facing planar slope and two generally SW-facing concave slopes. Movements begin at or slightly below slope break where seeps are abundant.
2	4	Extreme northeast border of quad west of Interstate 79	Uppermost Washington Fm.	Large slump-earthflows generated by surface and drainage modification. Excessive pore-water pressure has increased along slope below highway because of culvert outflow surcharging slope.
2	5	SW-trending concave forested slope 1.5 km WSW of US 19 and Dyers Fork road intersection (fig. 4)	Greene Fm., 21 m above Ten Mile coal bed	Mainly debris flow (fig. 4). May 1980 occurrence. Part of larger old slope movement. Head is 90 m wide and 60 m long to chute. Adjacent slope is 16° (27 percent). Head scarp is reactivated older 3-m-high scarp (1330 ft elevation) with slumped area in front of it (fig. 4*A*). Sandstone ledge with underlying shale locally appears in head scarp. Above, head scarp is slightly obscured benching backed by steeper slope to top of ridge. Incised drainage in lower part of head shows 3 m of light-bluish-gray mudstone, claystone (most common), very thinly bedded sandstone, and minor carbonaceous shale. Sliding surface in weathered mudstone. Chute is 52 m long and begins at 1260 ft elevation. Maximum height of debris flow on tree is 3 m above bottom of drainage (fig. 4*B*). Levee development of loose detrital material is on east side. Flow blocked drainage from major tributary to west causing ponding in that drainage. Toe is 1-2 m high above the drainage (fig. 4*C*). Flow stopped at rear of backyard (George Morris residence) at 1140 ft elevation. Exact date of event in May is unknown.
2	6	SW-trending concave forested slope 3.2 km NW of Whiteley Creek-Patterson Run road intersection	Greene Fm., 21 m above Ten Mile coal bed (same as above)	Mainly debris flow. May have occurred at time of preceding flow which lies 1.3 km to northeast. Head scarp (25 m wide) is at base of steeper slope. Hummocky ponded area lies in front of head scarp. Adjacent slope is 10° (18 percent). Flow is 15 m long and travelled existing drainage below head area. It stopped at about 1200 ft (elevation) at junction with pre-1960 debris flow in another drainage. Oldest tree on older flow is at least 22 years old. Bare earth and rock fragments on surface of younger flow attest to its age. Drainage has incised flanks of both flows. Older debris-flow levee is only 6 m northwest of levee of more recent one. Head scarp is less than 3 m lower than head scarp of fresher debris flow. Nearest resident (Mooney household) 0.5 km to southwest did not know date of activity.
3	1	South-facing slope west of ridge road 1.3 km southeast of Spraggs; grassland and forest	Greene Fm., 60 m above Ten Mile coal	Earthflow, 147 m wide, 17.5 m long, slow-moving, unusually wide but short, largely formed during 1979-1980. Head scarp 0.7 m high with difference in elevation of 5.5 m from head scarp to toe; newly created slope between scarp and toe is only 8° (14 percent); head scarp is at same elevation as sandstone ledge on west side of cove; seepage at base of sandstone. Partial graben development at east end with several transverse cracks. Below foot on right side is more recent earthflow (30 m wide) in woodland. Movement has broken northwest-trending pipeline. Offset amounts to 18 cm.
3	2	WNW-facing forested slope 1.5 km south of Spraggs	Greene Fm., 12 m above Ten Mile coal	Earthflow, fresh, 30 m wide, 70 m long. Head area lies below thick-bedded sandstone ledge. Toe is 2 m high. Adjacent slope is hummocky on both sides. Sliding plane is red to tannish-gray, wet clay within 1 m of surface in head area.
3	3	Ridge area 2.0 m southeast of Spraggs	Greene Fm., 30 m to 90 m above Ten Mile coal	Profusion of earthflows and debris slides at various horizons. Landowner (resident for almost 50 years) says that hillsides have become more difficult to mow in recent years because of creep and other movements.
3	4	SSW-facing slope 1.3 km north of Spraggs	Greene Fm., 60 m above Ten Mile coal	Debris flow, head scarp is 12 m wide at about 1400 ft elevation. Slope above is hummocky attesting to colluvial material involved in older slope movement. Additional scarps resembling head scarp at elevations of 1370 ft and 1340 ft. Toe is 1.2 m to 1.5 m high and fills 7.5-m-wide channel. Flow stopped slightly below 1200 ft elevation where gradient of channel moderates (<9° or 17 percent).

Table 2.--*Generalized stratigraphic section in Oak Forest 7.5-minute quadrangle (modified from Roen, 1972) and relative susceptibility of weathered material to slope movements (Mu-mudstone, Sh-shale, Sl-siltstone, Ss-sandstone, Ls-limestone, Cl-claystone, Cs-carbonaceous shale, C-coal). Lithologies are listed in order of decreasing abundance.*

System	Group	Formation	Approximate thickness in meters	Lithology	Relative susceptibility of derivative soils and weathered rocks to slope movements
Quaternary	Alluvium		0-6	Unconsolidated clay to cobble-sized particles	None
Permian	Dunkard	Greene	150+	Mu (Sh), Sl, Ss, Ls, Cl, Cs, C (cyclic repetition) Ten Mile coal bed in lower part	Moderately high to severe
"	"	Washington	57-94	Mu (Sh), Sl, Ss, Ls, Cl, Cs, C (cyclic repetition). Washington coal bed at base. Jollytown coal bed in upper part	Moderately high to severe
Permian and Pennsylvanian	"	Waynesburg	42-73	Sl, Ss, Mu (Sh) Ls, Cl, Cs, C (cyclic repetition)	Moderate

MAP SHOWING SLOPE MOVEMENTS IN THE OAK FOREST QUADRANGLE, GREENE COUNTY, SOUTHWESTERN PENNSYLVANIA

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