DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

Prepared in cooperation with the
Appalachian Regional Commission

MISCELLANEOUS FIELD STUDIES
MAP MF 641 A

Summary of behavior of the hydrogeologic regime as related to environmental characteristics, Allegheny County, Pennsylvania

Introduction

During the past decade, there has been an increasing effort to apply earth-science data to land-use planning. By use of these data to describe the environmental controls determined by geology, hydrology, geomorphology, climate, soil, and vegetation, it is possible to delineate areas of adverse environmental problems that may result where the stress of change in land use exceeds the limiting constraints of those natural controls. Therefore, rational land-use decisions require knowledge of the land's physical characteristics, as defined by interrelated earth-science disciplines. In few areas of the United States is this knowledge adequate; however, land-use decisions cannot be postponed until such a knowledge base is available. Although integrated data are generally inadequate in Allegheny County for managing the environment, knowledge is adquate in some disciplines.

An innovative approach to link earth-science data to present land development and to future land-use planning in Allegheny County, Pa., was begun in July 1973 by the U.S. Geological Survey, sponsored by the Appalachian Regional Commission (ARC) under ARC contract 74-31. This approach attempts to integrate presently available data with new data generated by short-term studies and to identify those areas that require longer and more comprehensive studies. The role of the hydrogeologic regime in land-use planning in Allegheny County is one such effort. This study is an attempt to demonstrate the interaction of available knowledge of the shallow ground-water regime to mining and its related problems of mine drainage and mine subsidence; slope stability; and heavy-storm precipitation, and related mass movement.

Location and Physical Features

Allegheny County is located in southwestern Pennsylvania, as shown in figure 1. The county has an area of about 730 mi^2 (1,900 km^2) and lies in the most rugged, dissected part of the Pittsburgh Plateau section of the Appalachian Plateau Province. Stream erosion has shaped the present topography. Altitude ranges from about 1,400 feet (430m) above sea level in the extreme eastern part of the county to about 1,200 feet (370 m) in the southern part. The resultant topography is a complex series of hilltops and valley bottoms having as much as 650 feet (200 m) of relief. The major streams--the Ohio River and its larger tributaries, the Allegheny River from the northeast and the Monongahela and Youghiogheny Rivers from the south and southeast--have cut channels to a minimum altitude of about 650 feet (200 m) above sea level. However, later back filling by glacial outwash (?) and alluvium established the present day valley floor, which ranges from about 700 to 750 feet (210 to 230 m) above sea level.

Hydrogeologic Framework

The hydrogeology of Allegheny County was described by Piper (1933) in his study of the ground-water resources of Allegheny, Butler, Fayette, Green, Washington, and Westmoreland Counties in southwestern Pennsylvania. Gallaher (1973) summarized the hydrogeology of Allegheny County to aid users of water to develop and manage their water resources. Other studies emphasizing availability and use of water from valley-fill deposits, chiefly in the Pittsburgh area, were described by Adamson, Graham, and Klein (1949), Van Tuyl (1951), and Noecker, Greenman, and Beamer (1954). The above reports provide much data used in the present study.

The hydrogeologic framework is made up of bedrock units consisting of sandstone, limestone, silt, shale, claystone, coal, and coal underclay. The lithologic, structural, and hydrologic character of these units are given in table 1, and the hydrogeologic framework and general ground-water circulation system is described by Subitzky (1975b).

Environmental Characteristics

Environmental problems, such as acid mine drainage, landslides, ground-water drainage from wells, owing to mine subsidence, and land subsidence of the region generally result from some degree of interaction of the hydrogeologic regime and effects of mining and related problems, mass movement, and response to heavy-storm precipitation. Those problems may increase with the intensity of urbanization as it extends countywide from the Pittsburgh area and vicinity to areas underlain by abandoned and active mines.

The extensive underground and strip mining of coal in Allegheny County has contributed to different types of environmental problems. These include subsidence, acid-mine drainage, flooding of mined-out areas, and poorly drained, locally hazardous, derelict land. Mining and related problems of the shallow hydrogeologic regime are described by Subitzky (1975c). Subsidence can be defined as some degree of vertical displacement of the land surface resulting from mine roof collapse over some active mines and mined-out area, creating a hazard to structures, such as buildings, bridges, and highways. However, it is possible to have mine-roof collapse that does not cause subsidence problems. It has been recognized that subsidence increases the distribution and intensity of fractures in bedrock units and, in turn, generally enhances ground-water circulation.

Water accumulations in mines can be relatively large. Control of water inflow in mines is necessary to prevent mine abandonment. Temporary suspension of such control in wet mines also can result in flooding. Abandoned mines that remain unsealed and uncontrolled against the inflow of water are underground reservoirs that will continue to fill until the hydrostatic head in the mined-out part and in the overlying dewatered rock units is such as to result in near zero water inflow. Mine flooding creates new drainage problems generally resulting in an increase of acid-mine water discharge to streams. Seepage on slopes may also be increased as a result of mine flooding. These slopes may be more vulnerable to slippage than prior to mining because of increased loading from increased saturation.

The stability of natural and manmade (cut slopes) generally reflects the lithologic, hydrologic, and structural characteristics of the hydrogeologic framework of the region. It has been noted that slope failure most commonly occurs in weathered materials, chiefly of the Pittsburgh red beds of the Glenshaw Formation.

The impact of heavy-storm precipitation is largely a function of antecedent moisture conditions. Other factors that influence storm impact are soil type and drainage characteristics, soil cover, slope and land use. The season in which the storm occurs may also influence its impact. Moreover, recurring precipitation of low intensity may have the same result as a high intensity storm on flooding and mass movement, chiefly landslides and small mud flows from natural and manmade cut slopes. Slopes surcharged by landfill material may fail as they become supersaturated due to their high porosity and poor permeability (drainage) characteristics. The effects of heavy-storm precipitation and related mass movement are described by Subitzky (1975d).

The impact of land use in the county on water quality of the hydrogeologic regime is chiefly a function of mines and the extent and intensity of urban development. Some insight into such impact in two small basins fairly representative of land use is described by Subitzky, 1975e).

Results of this investigation are based chiefly on available data and provide only a preliminary appraisal. Longer term and more comprehensive studies would be necessary to evaluate specific problems. Such studies, ideally, would be directed to the following:

1. The occurrence and extent of increased hydraulic connection of joints and fractures of shallow bedrock aquifers due to mine subsidence. Locally, some induced subsurface drainage from wells has been reported in areas overlying shallow mining of the Upper Freeport coal bed of the Freeport Formation. (Subitzky, 1975c).
2. The effect of rising water levels owing to above -drainage mine-flooding on slope stability in areas of increasing urban development.

Acknowledgements

Many individuals and public agencies furnished information, and several individuals gave freely of their time to accompany the writer in the field; their help is gratefully acknowledged.

NOTE:

Stratigraphic nomenclature adapted from the following:

Allegheny Group (Kittanning and Freeport Formations)
Shaffner, M. N. 1963, Geology and mineral resources of the Donegal quadrangle: Pennsylvania Geol. Survey, 4th ser., Atlas A-48, 116 p.

Williams, E. G., 1960, Marine and fresh-water fossiliferous beds in Pottsville and Allegheny Groups of western Pennsylvania: Jour. Paleon., v. 34 n. 5, p. 908-922.

Conemaugh Group (Glenshaw and Casselman Formations)
Flint, N. K., 1965, Geology and mineral resources of southern Somerset County, Pennsylvania: Pennsylvania Geol. Survey County Rept. C-56A, 267 p.

Monongahela Group (Pittsburgh and Uniontown Formations)
Berryhill, H. L., Jr. and Swanson, V. E., 1962, Revised stratigraphic nomenclature for Late Pennsylvanian and Early Permian Rocks, Washington County, Pennsylvania, in Short papers in geology and hydrology: U.S. Geol. Survey Prof. Paper 450-C, p. C43-C46.

Dunkard Group (Washington and Waynesburg Formations, undivided)
Berryhill, H. L., Jr., Schweinfurth, S. P., and Kent, B. H., 1971, Coal-bearing Upper Pennsylvanian and Lower Permian Rocks, Washington area, Pennsylvania: U.S. Geol. Survey Prof. Paper 621, 47 p.

Deere, D. V., 1963, Technical description of rock cores for engineering purposes: Rock mechanics and engineering geology, v. 1, n. 1, p. 17-22.

Gallaher, J. T., 1973, Summary ground-water resources of Allegheny County, Pennsylvania: Pennsylvania Geol. Survey, 4th Ser., Water Resources Rept. 35, 71 p.

McGlade, Wm. G., Geyer, A. R., and Wilshusen, J. P., 1972, Engineering characteristics of the rocks of Pennsylvania: Pennsylvania Geol. Survey, 4th Ser., Bull. EG-1, 200 p.

Piper, A. M., 1933, Ground water in southwestern Pennsylvania: Pennsylvania Geol. Survey 4th Ser., Bull. W-1, 406 p.

EXPLANATION

Semi-Quantitative Terms 1/

Lithologic and Structural Characteristics: (after McGlade and others, 1972)

Bedding thickness: (0.08 in = 2mm; 4 ft = 1.2m)

Laminated	less than 0.08 in
Thin and flaggy	1/2 in to 2 in
Medium	2 in to 2 ft
Thick	2 ft to 4 ft
Very Thick	more than 4 ft

Fracturing - Joint Spacing: (after Deere, 1963)

Very widely spaced	more than 10 ft
Widely spaced	3 ft to 10 ft
Moderately spaced	2 ft to 3 ft
Closely spaced	2 in to 1 ft
Very closely spaced	less than 2 in

Approximate thickness, in feet: (mostly after Gallaher, J. T., 1973)

Relative Position to Pittsburgh coal, in feet: (after Gallaher, J.T., 1973)

+ Feet above Pittsburgh coal
- Feet below Pittsburgh coal

Environmental characteristics:

Natural Slope:

Weathering

Depth

Deep	greater than 4 ft
Moderate	1 to 4 ft
Shallow	less than 1 ft

Mantle - Thickness

Thick	greater than 30 ft
Moderate	5 to 30 ft
Thin	0 to 5 ft

Steepness of Natural Slope (percent)

Level or nearly level	0 to 3
Gentle	3 to 8
Moderate	8 to 15
Fairly steep	15 to 25
Steep	25 to 35
Very steep, Vertical	greater than 35

Cut slope:

Maximum stable cut-slope observed

Gentle	0° to 5°
Moderate	5° to 15°
Fairly steep	15° to 45°
Steep	45° to 80°
Near-vertical	80° to 89°
Vertical	90°

(Modified after McGlade and others, 1972)

1/ Conversion Table:
1 foot (ft) = 0.3048 metre (m)
1 inch (in) = 25.4 millimetres (mm)

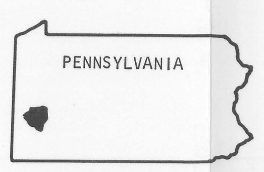

Figure 1
Location Map
Allegheny County

SYSTEM	SERIES	GROUP	FORMATION	GEOLOGIC UNITS	APPROXIMATE THICKNESS IN FEET	RELATIVE POSITION TO PITTSBURGH COALBED IN FEET
QUATERNARY	Holocene / Pleistocene			Undivided Alluvial and glacial outwash(?) deposits	0-65	
PENNSYLVANIAN and PERMIAN	Upper Pennsylvanian and Lower Permian	Dunkard		Washington Formation and Waynesburg Formation, undivided		+550 to 750
PENNSYLVANIAN	Upper Pennsylvanian	Monongahela		Uniontown Formation	30	
		Monongahela	Pittsburgh Formation	Upper Member ("Benwood Limestone" as used by Gallaher, 1973)	60-105	
		Monongahela	Pittsburgh Formation	Sewickley Member including Benwood Limestone Bed("Sewickley Sandstone" as used by Gallaher, 1973)	20-60	
		Monongahela	Pittsburgh Formation	Fishpot and Redstone Members, undivided ("Fishpot Limestone" as used by Gallaher, 1973)	0-20	
		Monongahela	Pittsburgh Formation, Lower Member	("Pittsburgh Sandstone" as used by Gallaher, 1973)	0-70	+75
		Monongahela	Pittsburgh Formation, Lower Member	Pittsburgh Coal bed		
		Conemaugh	Casselman Formation	Upper and Lower Pittsburgh Limestone Members	50	
		Conemaugh	Casselman Formation	Connellsville Sandstone Member	20-70	-30 to 60
		Conemaugh	Casselman Formation	Little Clarksburg Coal bed		-80 to 100
		Conemaugh	Casselman Formation	Clarksburg Limestone Member	0-3	
		Conemaugh	Casselman Formation	Morgantown Sandstone Member	90-120	-150 to 220
		Conemaugh	Casselman Formation	Birmingham Shale Member	50-60	
		Conemaugh	Casselman Formation	Duquesne Coal bed	0-4	
		Conemaugh	Glenshaw Formation	Ames Limestone Member	3-8	-230 to 350
		Conemaugh	Glenshaw Formation	Pittsburgh Red beds	5-15	
		Conemaugh	Glenshaw Formation	Saltsburg Sandstone Member	30-80	-300 to 500
		Conemaugh	Glenshaw Formation	Bakerstown Coal bed and Associated rocks	10-20	
		Conemaugh	Glenshaw Formation	Buffalo Sandstone Member	20-60	-450 to 510
		Conemaugh	Glenshaw Formation	Brush Creek Coal bed and associated rocks	30-40	
		Conemaugh	Glenshaw Formation	Mahoning Sandstone Member	20-100	-420 to 600
		Allegheny	Freeport Formation	Upper Freeport Coal bed and associated rocks		-500 to 750
		Allegheny	Freeport Formation	Butler Sandstone Member	10-40	
		Allegheny	Freeport Formation	Lower Sandstone Member ("Freeport Sandstone" as used by Gallaher, 1973)	30-70	
		Allegheny	Kittanning Formation	Upper Kittanning Coal bed and associated rocks		
		Allegheny	Kittanning Formation	Worthington Sandstone Member	15-100	

GEOLOGIC UNITS	LITHOLOGIC AND STRUCTURAL CHARACTERISTICS	HYDROLOGIC CHARACTERISTICS	MINING AND RELATED PROBLEMS	ENVIRONMENTAL CHARACTERISTICS — MASS MOVEMENT: NATURAL SLOPE	MASS MOVEMENT: CUT SLOPE	RESPONSE TO HEAVY STORM PRECIPITATION
Undivided Alluvial and glacial outwash(?) deposits (Quaternary)	Alluvium - An aggregate of interfingering beds of fine gravel and sand from reworked glacial valley train deposits and mised with locally derived deposits of silt, sand, and gravel. Upper glacial gravel Wisconsin Glaciation--well rounded cobbles as much as 3 inches (8 cm) in diameter, erratic boulders as much as 12 inches (30 cm) in diameter, and a matrix of sand and clay comprising the Allegheny-Ohio Valley glacial train deposits which extend from 100 to 50 feet (30 to 15 m) below low water. Lower terrace deposits - Sand, silt, clay and rounded pebbles of local derivation on low terraces grading into present flood plain. Chiefly confined to the Monongahela Valley and other tributaries of the Ohio and Allegheny River. Middle glacial gravel - Consists of reworked gravel, sand, and clay on sloping rock shelves below 820 feet (250 m) altitude in Ohio River Valley. Lower glacial gravel Illinoian Glaciation - Deeply-decayed gravel, sand, and silt of glacial and local material derived from sedimentary and crystalline rocks forming high terrace deposits in the Allegheny and Ohio River Valleys. Carmichaels Formation - High terraces in Monongahela River Valley and abandoned meanders consisting of sand, silt, clay, and deeply decayed partly rounded pebbles of local origin.	The variation of thickness, distribution, and texture of these units influences ground-water availability and circulation. Well yields range from 5 to 3,000 gal/min (0.3 to 190 l/s) depend in degree of sorting and grain size. High porosity and permeability occur in the coarse sand and gravel parts of the vallyfill and glacial outwash (?) deposits of the Allegheny, Monongahela, and Ohio River Valleys and their large tributaries. Whereas coarse deposits plastered with clay and containing admixtures of clay particles may have limited permeability. Deposits associated with the earlier Illinoian Glaciation and those forming high terraces on valley walls, generally are well drained and only show seepage following precipitation; however, locally, clay beds may be present to maintain a perched water body.	Locally where saturated, these units yield some water to mine overburden.	Generally deeply weathered and may be greatly altered by leaching and oxidation. Locally may have formed steep slopes now modified by slumping. Alluvium in stream-cut banks frequently stand temporarily that is, days, weeks, perhaps months, rarely years) on vertical slopes. Where sodded, alluvial and terrace mixtures of sand, gravel, and clay can stand at repose angles "forever." With these materials it is believed to be more a function of height of slope. Slopes 5 to 10 feet (1.5 to 3 m) high of 45° are fairly common, slopes higher than 10 feet (3 m) at such angles are rare.	Material chiefly unconsolidated, varying degree of sorted and unsorted soil, boulders, cobbles, and pebbles. Very low angle cut slopes are stable. Locally where sufficient thicknesses of water-bearing sand and gravel layers are present, special treatment to prevent slumping may be required.	Drainage is generally good in valley-fill deposits. Where other units occur, drainage may be generally poor locally resulting in ponds, lakes, and wetlands. In areas of high relief, some deep percolation of rainfall occurs.
Washington Formation and Waynesburg Formation, undivided (Dunkard)	In Allegheny County, the Dunkard Group consists almost entirely of the Waynesburg Formation (Berryhill and Swanson, 1962). The overlying basal beds of the Washington Formation (Berryhill and Swanson, 1962) crop out only on a few hilltops along the southeastern border. The Waynesburg and Washington Formations are grouped as the Washington Formation by Piper (1933). A complex sequence of sandstone and limestone with shale, claystone, and some thin coal beds and underclays. Bedding moderately well developed in limestone and shale; may be obscured by crossbedding in sandstone; beds of sandstone tend to be thick, whereas beds of limestone are flaggy. Fracturing is locally developed in claystone, shale, and limestone; joints are blocky closely spaced in finer-grained rocks, moderately spaced in sandstone and irregular. Joints are vertical and open.	Only capping some hills in the extreme southern part of the county, the Waynesburg Formation is too thin to yield sufficient quantities of water to wells. Beds of shale and sandstone, thin-bedded limestone, and coal have very limited primary porosity; however, joints provide a sufficient secondary porosity. Interconnection of joints and distribution of bedding planes permits limited ground-water circulation. Generally unit is dewatered partly due to stream erosion and partly from seepage along valley slopes.		Limestone and sandstone are moderately resistant and the depth of weathering of these rocks is shallow. The beds of claystone, shale, and coal weather readily and cause rock falls where they disintegrate rapidly under more resistant beds. The overlying mantle ranges in thickness from thin to moderate. Slopes generally 25 percent or less are stable.	Cuts of moderate slope are required; whereas decomposition and disintegration of the weaker rock units cause undercutting of the more resistant units resulting in rock falls, slumps, and landslides.	Drainage is generally fair to good. Some seepage occurs along slopes from heavy rainfall or from several periods of light or moderate rainfall.
Monongahela Group (Uniontown and Pittsburgh Formations)	Consists of alternating layers of shale, claystone, sandstone, siltstone, limestone, coal, and underclays; upper and lower parts sandstone, shale, and claystone; several prominent minable coals in lower part. Bedding is well developed thin beds in sandstone and siltstone, thicker beds in limestone; shale in laminated or very thin partings; claystone has very poor bedding. Joints vary from poorly to moderately well developed in limestone. Fracturing widely spaced in irregular intervals, generally blocky or platy patterns, and spacing closer in finer-grained rocks. Joints usually open and vertical. Subsidence fractures may be encountered in connection with underground coal mining.	These units yield limited quantities of water to wells. Yields range from 1 to 5 gal/min (0.06 to 0.3 l/s). Low yields are partly the result of coal mining dewatering some rocks such as the lower member of the Pittsburgh Formation("Pittsburgh Sandstone" as used by Gallaher, 1973) and partly the result of streams cutting through many formations of the unit. All these units have little primary porosity; porosity of sandstones is generally fair; well-developed joint systems have secondary porosity. Interconnection of joints and bedding planes permits ground-water circulation within a single unit and to some degree limited circulation into overlying and underlying units. Cleating in coal provides for some limited circulation.	The extensive mining of coal in the County has significantly changed the natural availability and circulation of ground water. Throughout much of the area, where the Pittsburgh coal bed has been extensively mined, subsequent collapse of the rock column over mined-out areas has completely drained the overlying lower member of the Pittsburgh Formation ("Pittsburgh Sandstone" as used by Gallaher, 1973).	The limestone and sandstone units are moderately resistant and show shallow deterioration. The shale, claystone, siltstone, and coal units show deeper deterioration and weather more rapidly. The mantle cover is of variable thickness--ranging from thin to moderate. Slopes of 25 percent and locally steeper are relatively stable where mantle is thin; where mantle is moderatly thick slopes less than 25 percent may have limited stability. Slopes less than 15 percent in general are stable.	Stable cuts, generally, are obtained on moderate slopes except where excessive undercutting of the resistant limestone and sandstone units occur.	Drainage is generally fair to good; some deep percolation into limestone may occur.
Conemaugh Group (Casselman and Glenshaw Formations)	Composed of alternating layers of shale, sandstone, siltstone, limestone, coal, underclay and claystone. It includes a large number of shaly, gray limestones and numerous thin discontinuous coals, Red beds occur locally throughout but are most persistent in the middle and upper parts of the unit; lower part consists of marine gray shale, limestone, and fine to coarse-grained, locally conglomeratic sandstone; upper part consists of numerous coal beds and fresh-water gray-limestone. The unit is usually well bedded; thickness of beds varies with lithology, ranging from a fraction of an inch (less than a centimeter) to several feet (a meter or more);very poorly developed in claystone. Sandstone may be very thick locally, shales are thin and laminated, and limestones are thin. Joints are poorly to moderately well formed and are open and vertical. Subsidence fractures may be encountered in connection with underground coal and clay mining.	Several units, in descending order, the Connellsville, Morgantown, Saltsburg, Buffalo, and Mahoning Sandstone Members generally yield from 1 or 2 gal/min (0.06 to 0.13 l/s) to as much as 100 gal/min (6.3 l/s)of water to wells. Shale and limestone often yield sufficient supplies for household use. Primary porosity of sandstones and where present conglomeratic sandstones is usually good. Secondary porosity created by well-developed joint systems and their interconnection with bedding planes permits varying degrees of ground-water circulation in limestone and other rock types.	In those areas where Upper Freeport coal has been extensively mined the overlying units of the Conemaugh Group have been dewatered as a result of collapse of mined-out areas.	Sandstone, siltstone, and limestone are moderately resistant; claystone, underclay and coals weather deeply. Disintergration forms rubble of very small plates and small irregular blocks. The overlying mantle is thin. These materials have exceedingly variable slope stability. Slopes over the Morgantown and Mahoning Sandstone Members probably are quite stable if well vegetated; over gray shales slopes up to 25 percent in general may be stable; on red beds stability of slopes is exceedingly variable. Where red beds weather to a thin mantle, slopes of 45° or more may stand depending on drainage. A thick weathered red bed mantle can fail at less than 15 percent.	Most cuts generally require a moderate slope. The disintegration of claystone and shale underlying resistant limestone and sandstone units cause rockfalls, slumps, and landslides; whereas cuts in massive sandstone units can be nearly vertical. Cuts in red-bed colluvium can fail at very low cut angles.	Drainage is generally good; locally, percolation may be very limited where limestone occurs near the surface.
Allegheny Group (Freeport and Kittanning Formations)	Composed of alternating layers of sandstone, shale, silstone, claystone, limestone coal, and underclay. Contains several minable coal beds. Sandstone units are medium to coarse-grained and sometimes conglomeratic; no red beds present. Bedding is variable in thickness, depending on rock type. Joint spacing and density are dependent on rock type; more widely spaced in sandstones and closer-spaced in finer grained rocks and coal; patterns often regular but locally may be very complex and irregular. Joint sets are usually open and vertical. Subsidence fractures may be encountered in connection with underground coal and clay mining.	Wells obtaining water from sandstone yield from 2 to 75 gal/min (0.13 to 4.7 l/s). The porosity of the sandstone units is usually moderate to good; in other rock units, fair to poor. Water is often available above claystones, underclays, and coals; locally, where joint systems interconnect with bedding planes, limited circulation to other units may occur. Generally geologic units more than 100 feet (30 m) below drainage level contain brackish or salty water. Within Allegheny County, units below the Worthington Sandstone Member contain salt water.		The claystone and coal weather rapidly and more deeply than do siltstone and sandstone and to a lesser degree than (?) limestone. The thickness of the mantle is variable, dependent on rock type and depth of weathering, but usually less than 25 feet (7.6 m).	Most cuts should be of moderate slope; undercutting of resistant sandstone and limestone causes rock falls, slumps, and landslides. Sandstone of homogeneous character can be cut to steep slope angles.	Drainage is generally good.

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By Seymour Subitzky 1975

Interior—Geological Survey, Reston, Va.—1976—L26068