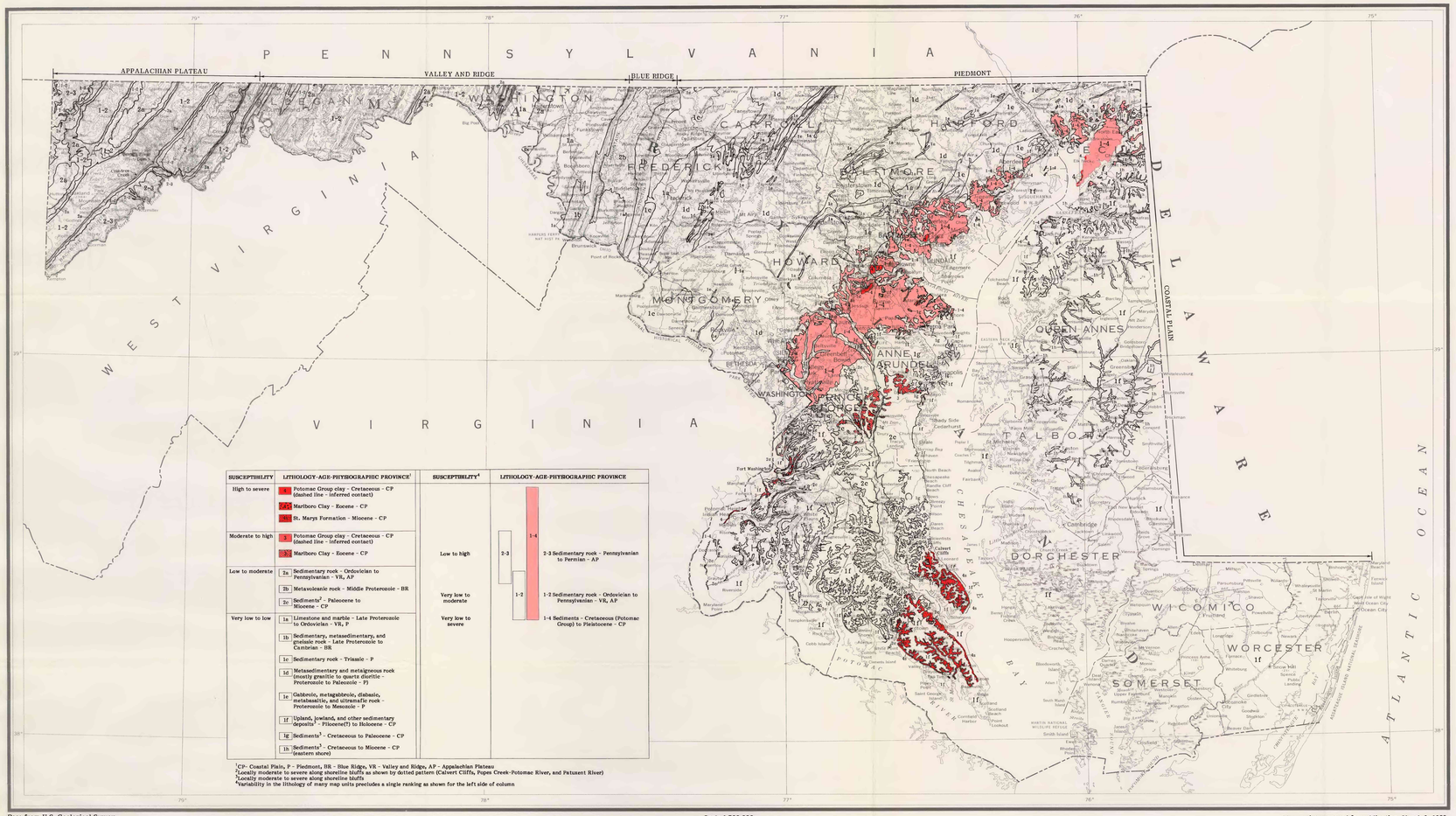
DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

MISCELLANEOUS FIELD STUDIES
MAP MF—2048
PAMPHLET ACCOMPANIES MAP



SUSCEPTIBILITY	LITHOLOGY-AGE-PHYSIOGRAPHIC PROVINCE[1]
High to severe	Potomac Group clay - Cretaceous - CP (dashed line - inferred contact)
	Marlboro Clay - Eocene - CP
	St. Marys Formation - Miocene - CP
Moderate to high	Potomac Group clay - Cretaceous - CP (dashed line - inferred contact)
	Marlboro Clay - Eocene - CP
Low to moderate	2a Sedimentary rock - Ordovician to Pennsylvanian - VR, AP
	2b Metavolcanic rock - Middle Proterozoic - BR
	2c Sediments[2] - Paleocene to Miocene - CP
Very low to low	1a Limestone and marble - Late Proterozoic to Ordovician - VR, P
	1b Sedimentary, metasedimentary, and gneisic rock - Late Proterozoic to Cambrian - BR
	1c Sedimentary rock - Triassic - P
	1d Metasedimentary and metaigneous rock (mostly granitic to quartz diorite - Proterozoic to Paleozoic - P)
	1e Gabbroic, metagabbroic, diabasic, metabasaltic, and ultramafic rock - Proterozoic to Mesozoic - P
	1f Upland, lowland, and other sedimentary deposits[3] - Pliocene(?) to Holocene - CP
	1g Sediments[3] - Cretaceous to Paleocene - CP
	1h Sediments[3] - Cretaceous to Miocene - CP (eastern shore)

SUSCEPTIBILITY[4]	LITHOLOGY-AGE-PHYSIOGRAPHIC PROVINCE
Low to high	2-3 Sedimentary rock - Pennsylvanian to Permian - AP
Very low to moderate	1-2 Sedimentary rock - Ordovician to Pennsylvanian - VR, AP
Very low to severe	1-4 Sediments - Cretaceous (Potomac Group) to Pleistocene - CP

[1]CP- Coastal Plain, P - Piedmont, BR - Blue Ridge, VR - Valley and Ridge, AP - Appalachian Plateau
[2]Locally moderate to severe along shoreline bluffs as shown by dotted pattern (Calvert Cliffs, Popes Creek-Potomac River, and Patuxent River)
[3]Locally moderate to severe along shoreline bluffs
[4]Variability in the lithology of many map units precludes a single ranking as shown for the left side of column

Base from U.S. Geological Survey
Maryland and Delaware, 1973

Scale 1:500,000
1 inch equals approximately 8 miles
10 0 10 20 30 40 Miles
10 0 10 20 30 40 50 Kilometers
Lambert conformal conic projection
Standard parallels 33° and 45°
Contour interval 200 feet
National geodetic vertical datum of 1929

Manuscript approved for publication, March 2, 1988.

Table 1.—*Maryland Coastal Plain stratigraphic units*

[Modified from Cleaves and others (1968) and Glaser (1971)]

SYSTEM	SERIES	GROUP	STRATIGRAPHIC UNIT	THICKNESS IN FEET (METERS)	LITHOLOGIC CHARACTER
Quaternary	Pleistocene to Holocene		Quaternary Deposits undivided	---	Undifferentiated gray to buff sand and gravel, gray to brown lignitic silt and clay, occasional boulders, and rare shell beds.
			Lowland Deposits	0-150 (45)	Interbedded quartz gravel, medium- to coarse-grained sand, and silt-clays grayish-white to dark greenish-gray peat, and sparse molluscan fauna.
			Upland Deposits (Eastern Shore)	0-90 (27)	Gravel, sand, silt, and clay. Mostly cross-bedded, poorly sorted, medium- to coarse-grained white to red sand and gravel; boulders near base; minor pink and yellow silts and clays.
Tertiary	Pliocene(?)		Upland Deposits (Western Shore)	0-70 (21)	Quartz gravel and medium- to coarse-grained sand overlain by massive silt; orange to reddish-brown where oxidized, otherwise pale-gray; rare plant fossils.
	Miocene	Chesapeake	St. Marys Formation	0-80 (24)	Interbedded bluish-gray silt-clay and fine-grained argillaceous sand, glauconitic in part; fossiliferous.
			Choptank Formation	0-55 (17)	Interbedded bluish-gray to gray-green silt-clay and abundantly fossiliferous fine- to medium-grained sand.
			Calvert Formation	0-150 (45)	Olive-gray to olive-brown, fine-grained argillaceous sand, silt and clay (diatomaceous silt near base); some beds abundantly fossiliferous.
	Eocene	Pamunkey	Nanjemoy Formation	0-120 (36)	Dark greenish-gray, argillaceous, glauconitic sand and silty minor dark-gray silty clay; fossiliferous.
			Marlboro Clay	0-33 (10)	Pale-red to silvery-gray plastic clay with thin lenses of pale-gray silty sparingly lignitic.
	Paleocene		Aquia Formation	0-100 (30)	Dark greenish-gray, fine- to medium-grained glauconitic sand and silty sporadic calcite-cemented sandstone; fossiliferous.
			Brightseat Formation	0-20 (6)	Dark green to gray-green, argillaceous, highly glauconitic, well-sorted, fine- to medium-grained sand.
Cretaceous	Upper Cretaceous	Potomac	Monmouth Formation	0-40 (12)	Dark greenish-gray to black, sometime glauconitic, fine-grained micaceous clayey sand and silty quartzose gravel at base; fossiliferous.
			Matawan Formation	0-70 (21)	Dark-gray, micaceous, glauconitic, argillaceous, fine-grained sand and silt.
			Magothy Formation	0-60 (18)	Loose, white, cross-bedded, "bagshy" lignite sands and dark gray, laminated silty clays.
	Lower Cretaceous		Patapsco Formation	0-800 (240)	Red and gray mottled silty clay and fine- to medium-grained, gray to yellow sand; rare plant fossils.
			Arundel Clay	0-100 (30)	Dark gray and maroon lignitic clays.
			Patuxent Formation	0-250 (76)	White or light gray to orange-brown, moderately sorted, cross-bedded, argillaceous, angular sands and subrounded quartz gravels; silts and clays subordinate, predominantly pale gray.

Table 2.—*Geologic units and derivative soils that are highly susceptible to sliding in the Coastal Plain of Maryland*

GEOLOGIC UNIT[1]	COUNTY	LITHOLOGY	DEPOSITIONAL ENVIRONMENT	SOIL SERIES[2]	COUNTY	AMERICAN ASSOCIATION OF HIGHWAY OFFICIALS CLASSIFICATION[2]	SHRINK-SWELL POTENTIAL[2]
Potomac Group (Cretaceous) Undifferentiated Patapsco Formation, clay facies Arundel Formation Silt-clay facies (Arundel-Patapsco Formations) Patuxent Formation, clay facies Arundel Patuxent Formation Red to variegated and white clay	Cecil, Harford, Charles Baltimore Baltimore Anne Arundel Baltimore Howard Prince Georges	Buff, red, red-yellow, brown, gray, black mottled kaolinitic and illitic clays with interbeds and pods of sand and silt. Variable in thickness laterally both vertically and horizontally because of non-marine deposition. Thickness exceeds 300 m.	Mixed fluvial (mostly Patuxent Formation), floodplain (mostly Patapsco Formation), and marsh or swamp (Arundel Formation)	Loamy and clayey land Leonir Christiana Keyport Muirkirk Sandy and clayey land Silty and clayey land Gravelly land	Anne Arundel, Baltimore, Harford Baltimore Anne Arundel, Baltimore, Cecil, Prince Georges Anne Arundel, Cecil, Harford, Howard, Prince Georges Anne Arundel, Prince Georges Howard, Prince Georges Prince Georges Charles County	A-7 A-6, 7 A-7 A-6, 7 A-7 A-7 A-7	Moderate to high Moderate to high Moderate Moderate Moderate High Moderate
Marlboro Clay (Eocene)	Prince Georges, Anne Arundel, Charles	Pale red to silvery-gray clay, massive to finely laminated, platie to brittle, with minor silt partings and lenses. Poorly sorted, fine sand in places. Clayey. Excellent marker horizon which lies between glauconitic sands. Thickness 1 to 11 m.	Very shallow marine and brackish water; possibly a tidal flat environment (Glaser, 1971).	Not distinguishable on soils maps	----------	----------	----------

[1]From Maryland Geological Survey and U.S. Geological Survey reports: Howard County (Cloos and Broedel), 1948); Baltimore County (Crowley and others, 1976)); Anne Arundel County (Glaser, 1971); Charles County (Glaser, 1974); Prince Georges County (Nash, 1975); Cecil County (Bartlett, 1975); Harford County (Southwick and Owens, 1968).
[2]From U.S. Soil Conservation Service reports: Cecil County (Anderson and Matthews, 1973); Charles County (Hall and Matthews, 1974); Prince Georges County (Kirby and others, 1967); Anne Arundel County (Kirby and Matthews, 1972); Howard County (Matthews and Hershenberger, 1968); Baltimore County (Reybold and Matthews, 1975); Harford County (Smith and Matthews, 1975).

Table 3.—*Clay mineralogy of selected landslide material in Maryland*

[X-ray diffraction by Virginia Gonzalez, USGS]

LITHOLOGY	FORMATION OR GROUP[1]	LOCATION	PHYSIOGRAPHIC PROVINCE[2]	CLAY MINERALOGY[3]
Blue-gray clay	Upper Pottsville (P) or lower Allegheny (P)	Bear Creek Rd., Friendsville, Garrett Co.	AP	I (50), K (43), I/S (7)
Red to green silty clay	Mauch Chunk (M)	Sang Run area, Garrett Co.	AP	I (69), K (22), I/S (9)
Red silty clay	Lower Mauch Chunk (M) or upper Greenbrier (M)	Meadow Mountain Rd., Grantsville, Garrett Co.	AP	I (70), K (17), I/S (13)
Blue-gray plastic clay	Hampshire (D)	Accident area, Garrett Co.	AP	I (85), K (8), I/S (7)
Red clay	Potomac Group (K)	Elk Neck, Cecil Co.	CP	K (81), I (13), I/S (tr)
Red clay	Potomac Group (K)	Palmer Rd., Prince Georges Co.	CP	K (97), I/S (3), I (0)
Brownish clay	Potomac Group (K)	Relay, sw of Baltimore, Baltimore Co.	CP	I (56), K (38), I/S (6)
Light-gray clay	Potomac Group (K)	Indian Head, Charles Co.	CP	I/S (47), I (33), K (20)
Red clay	Marlboro Clay (E)	Southwestern Prince Georges Co.	CP	K (81), I (13), I/S (9)
Red clay	Marlboro Clay (E)	Eastern Prince Georges Co.	CP	K (47), I (33), I/S (18)
Dark-gray silty clay	Chesapeake Group (Mi)	Calvert Cliffs, Calvert Co.	CP	I (63), K (23), I/S (14)

[1]P-Pennsylvanian, M-Mississippian, D-Devonian, K-Cretaceous, E-Eocene, Mi-Miocene
[2]AP-Appalachian Plateau, CP-Coastal Plain
[3]I-Illite, K-Kaolinite, I/S-Illite/Smectite (expandable clay). Listed in order of decreasing abundance by percent

Table 4.—*Generalized stratigraphic section of bedded rocks and relative susceptibility of weathered material to landsliding in the Appalachian Plateau and Valley and Ridge physiographic provinces of Maryland*

[Bedded rocks taken from Cleaves and others (1968). See also Amsden (1955), Berryhill and others (1956), and Edwards (1978)]

SYSTEM	GROUP	FORMATION	APPROXIMATE THICKNESS IN FEET (METERS)	LITHOLOGY Limestone (L), Limestone (Ls), Claystone (Cl.), Mudstone (Md), Coal (Cl), Sandstone (SS), Conglomerate (CG), Shale (Sh), Dolomite (D), Siltstone (St)	RELATIVE SUSCEPTIBILITY OF DERIVATIVE SOILS AND WEATHERED ROCK TO LANDSLIDING
Permian	Dunkard	———	300+ (90)	SH, SI, SS, L, C	Moderate
Pennsylvanian		Monongahela	240-375 (73-113)	Cl., L, SH, SS, C	Moderate
		Conemaugh	825-925 (250-282)	Cl., SH, SS, SS, C	Moderate to high
		Allegheny	275-325 (83-98)	SS, SI, Cl., SH, C	Moderate
		Pottsville	60-440 (18-134)	SS, SI, Cl., SH, C	Low to moderate
Mississippian	Pocono	Mauch Chunk	500-800 (152-243)	SH, SI, SS	Low to moderate
		Greenbrier	200-300 (60-91)	SH, SS, L	Low to moderate
		Purslane Sandstone	318-1,700 (76-518)	SS, CG, SH, SI, M, SI, C	Low to moderate
		Rockwell	(total for Group)		
Devonian	Hamilton	Hampshire	1,400-3,800 (420-1,150)	SH, M, SI, SS	Low to moderate
		Chemung	2,000-3,000 (600-910)	SS, SI, SH	Low to moderate
		Parkhead Sandstone	400 (121)	SH, SS	Very low to low
		Stroller	1,700-2,000 (510-600)	SH, SI	Low
		Millheim Shale	1,000 (300)	SH, SI	Low
		Mahantango	800-1,200 (180-360)	SH, SI, SS	Low
		Marcellus Shale	250-500 (76-152)	SH	Low
		Tioga Metabentonite Bed	1 (0.3)	SH	Low
		Needmore Shale	70-145 (21-43)	SH, L	Low
	Oriskany	Ridgeley Sandstone	10-165 (3-43)	SS, L	Very low to low
		Shriver Chert	15-170 (4.5-51)	SS, CH	Low
		Helderberg	160-320 (48-98)	L, CH, SH, SS	Low
Silurian-Devonian		Keyser Limestone	200-300 (60-91)	L, SH	Very low to low
Silurian	Clinton	Tonoloway Limestone	450-600 (121-182)	L, SH, SS	Very low to low
		Wills Creek Shale	450-600 (137-182)	M, SH, L, SS	Moderate
		Bloomsburg	30-350 (9-98)	SS, SH, L	Low to moderate
		McKenzie	160-380 (48-115)	SH, L, SS	Low to moderate
		Rochester Shale	25-40 (7.5-12.1)	SH, L	Low to moderate
		Keefer Sandstone	10-35 (3-10.6)	SS	Low
		Rose Hill	300-570 (91-173)	SH, SS	Moderate
		Tuscarora Sandstone	60-300 (18-121)	SS, SH	Low
Ordovician	Juniata		180-500 (54-152)	SI, SH, SS, CO	Low
	Martinsburg		1,050-2,300 (305-760)	SH, SI, SS	Low
	Chambersburg Limestone		225-250 (67-76)	L	Very low to low
	New Market Limestone		150-200 (45-60)	L	Very low to low
	Row Park Limestone		150-480 (46-207)	L	Very low to low
	Pinesburg Station Dolomite		375-500 (113-152)	D	Very low to low
	Rockdale Run		1,700-2,200 (510-760)	D, L	Very low to low
	Stonehenge Limestone		500-800 (152-243)	L, D	Very low to low
Cambrian	Conococheague Limestone		1,600-1,900 (480-570)	L, CO, SH, D	Very low to low
	Elbrook Limestone		1,400-2,000 (420-910)	L, SH, D	Very low to low
	Waynesboro		600 (182)	SI, SH, SS, D	Low

Figure 1A.—Block diagrams showing idealized earth flows. *A*, Surface features; *B*, Subsurface features. From Keefer and Johnson (1983).

Figure 3A.—Diagram showing percent and angle of slope.

Figure 3B.—Diagrams showing 1:1, 2:1, and 4:1 slopes.

Figure 5.—Relict and recent landslides in the Crabtree Creek area, Garrett County, Md. Geology from Amsden (1950).

EXPLANATION

- Recent landslide, definitely to probably caused by tropical storm Juan, Nov. 1985
- Old landslide, hatchures show head scarp
- Pap Pottsville and Allegheny Formations
- Mgb-Mme Greenbrier and Mauch Chunk Formations
- Mp Pocono Sandstone
- Dh Hampshire Formation
- Dj Jennings Formation
- Contacts, approximate to inferred
- Strike and dip of inclined bedding

Figure 8A.—Schematic diagram of May 28, 1968 landslide along U.S. Route 48 west of Cumberland (from Balter, 1970). Strike and dip directions are shown on the slope.

Figure 8B.—Cross section of U.S. Route 48 landslide west of Cumberland showing corrective action. Modified from Balter, 1970. Values are in feet.

Figure 9.—Buttressed slope holding back colluvium. Note steeply dipping sandstone (Oriskany Group) in background. Located on Md. Route 51 southeast of Cumberland.

Figure 1B.—Diagrammatic representation of a complex slope movement. Ss, sandstone; Sh, shale; Slts, siltstone. Tilted trees show influence of movement.

Figure 2A.—Map of Maryland showing average annual precipitation. Modified from University of Maryland (1963).

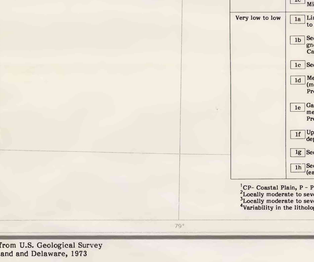


Figure 2B.—Graph showing precipitation data for four selected localities in Maryland, 1960-1985 (National Oceanic and Atmospheric Administration, 1961-1986).

Figure 4A.—Head scarp (A) of Potomac Group slump along Elk River near the head of Chesapeake Bay. Slope failure predates 1938 aerial photography.

Figure 4B.—Large trash-filled slump involving underlying Potomac Group clays. The head scarp (A) is 130 m long. The scarp (B) is one of several fissures. The slightly tilted surface (C) implies rotational movement.

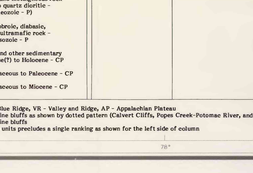


Figure 4C.—Abandoned house atop head scarp of slump in Quaternary fluvial deposit overlying the Miocene-age St. Mary's Formation.

Figure 6A.—Displaced abandoned railroad bench 2 km north of Frostburg caused by earthflow from regraded strip mine surface above and to the right of tracks (Monongahela Formation).

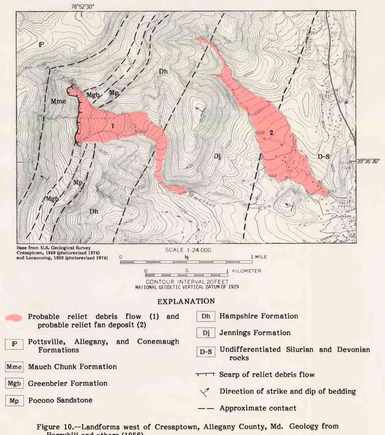
Figure 6B.—Impending rockfall along joint planes (valley stress release) in Allegheny Formation sandstone, Savage River road west of Bloomington.

EXPLANATION

- Srh Rose Hill Formation
- St Tuscarora Sandstone
- Oj Juniata Formation
- Contacts, approximate to inferred
- Head scarp of rockslide. Stratigraphic relationships within rockslide scar are incomplete
- Axis of Wills Mountain anticline
- Strike and dip of inclined bedding
- Horizontal bedding

Base from U.S. Geological Survey
Cumberland, 1969 (photorevised 1974)

Figure 7.—Relict rockslide (red area) on Wills Mountain, Allegany County, Md. Geology from Berryhill and others (1956) and unpub. data from C.S. Southworth and A.P. Schultz, USGS.



EXPLANATION

- Probable relict debris flow (1) and probable relict fan deposit (2)
- P Pottsville, Allegany, and Conemaugh Formations
- Mme Mauch Chunk Formation
- Mgb Greenbrier Formation
- Mp Pocono Sandstone
- Dh Hampshire Formation
- Dj Jennings Formation
- D-S Undifferentiated Silurian and Devonian rocks
- Scarp of relict debris flow
- Direction of strike and dip of bedding
- Approximate contact

Figure 10.—Landforms west of Cresaptown, Allegany County, Md. Geology from Berryhill and others (1956).

MAP SHOWING LANDSLIDE SUSCEPTIBILITY IN MARYLAND

By
John S. Pomeroy

1988

INTERIOR—GEOLOGICAL SURVEY, RESTON, VA—1988

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