COMMONWEALTH OF VIRGINIA
DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT
DIVISION OF MINERAL RESOURCES

GEOLOGIC FACTORS AFFECTING LAND MODIFICATION, WARREN COUNTY, VIRGINIA

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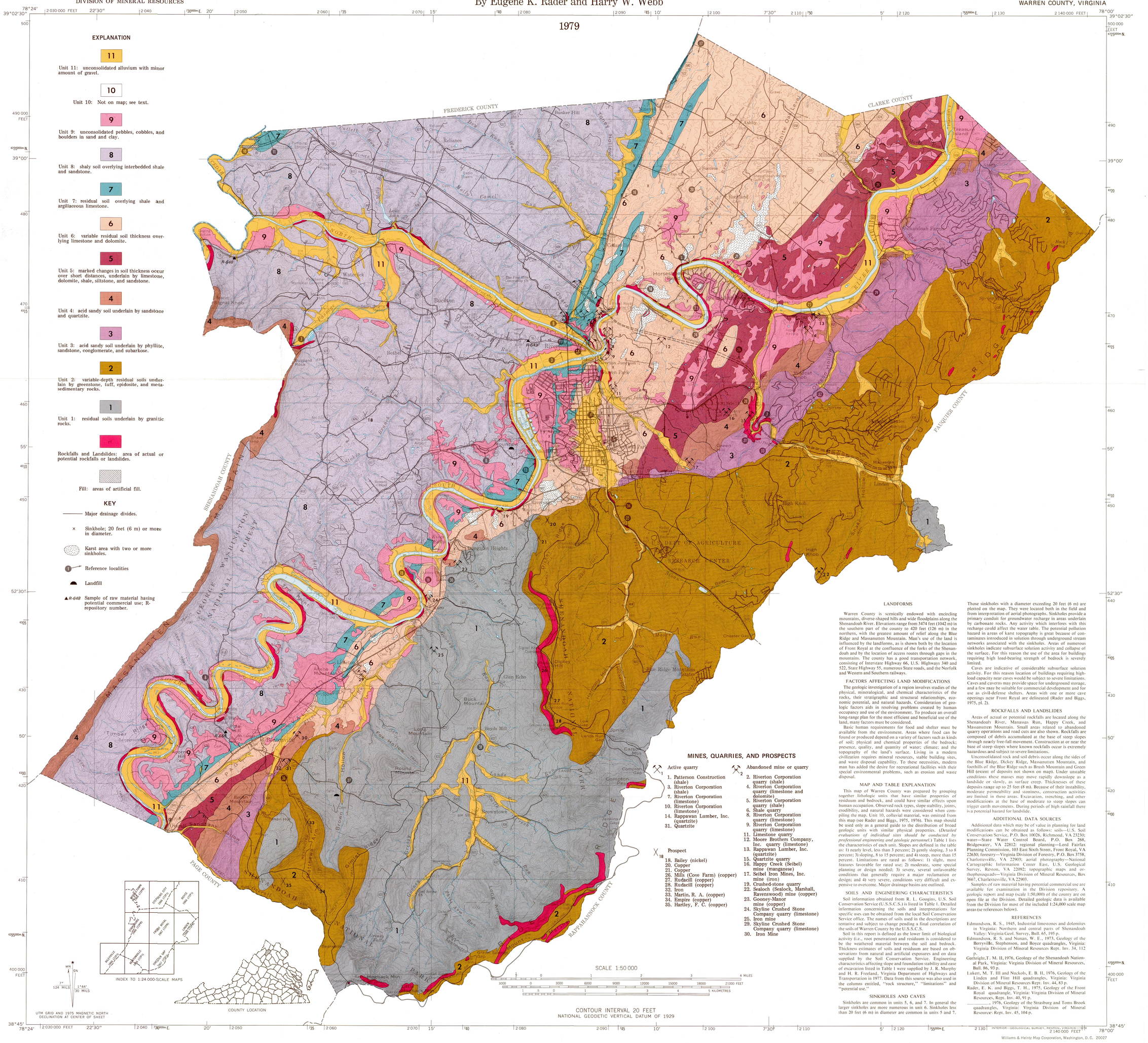
PUBLICATION 15
WARREN COUNTY, VIRGINIA

1979



LANDFORMS

Warren County is scenically endowed with encircling mountains, diverse-shaped hills and wide floodplains along the Shenandoah River. Elevations range from 3474 feet (1042 m) in the southern part of the county to 420 feet (126 m) in the northern, with the greatest amount of relief along the Blue Ridge and Massanutten Mountain. Man's use of the land is influenced by the landforms, as is shown both by the location of Front Royal at the confluence of the forks of the Shenandoah and by the location of access routes through gaps in the mountains. The county has a good transportation network, consisting of Interstate Highway 66, U.S. Highways 340 and 522, State Highway 55, numerous State roads, and the Norfolk and Western and Southern railways.

FACTORS AFFECTING LAND MODIFICATIONS

The geologic investigation of a region involves studies of the physical, mineralogical, and chemical characteristics of the rocks, their stratigraphic and structural relationships, economic potential, and natural hazards. Consideration of geologic factors aids in resolving problems created by human occupancy and use of the environment. To produce an overall long-range plan for the most efficient and beneficial use of the land, many factors must be considered.

Basic human requirements for food and shelter must be available from the environment. Areas where food can be found or produced depend on a variety of factors such as kinds of soil; physical and chemical properties of the bedrock; presence, quality, and quantity of water; climate; and the topography of the land's surface. Living in a modern civilization requires mineral resources, stable building sites, and waste disposal capability. To these necessities, modern man has added the desire for recreational facilities with their special environmental problems, such as erosion and waste disposal.

MAP AND TABLE EXPLANATION

This map of Warren County was prepared by grouping together lithologic units that have similar properties of residuum and bedrock, and could have similar effects upon human occupation. Observed rock types, slope stability, joints, erodibility, and natural hazards were considered when compiling the map. Unit 10, colluvial material, was omitted from this map (see Rader and Biggs, 1975, 1976). This map should be used only as a general guide to the distribution of broad geologic units with similar physical properties. (*Detailed evaluations of individual sites should be conducted by professional engineering and geologic personnel.*) Table 1 lists the characteristics of each unit. Slopes are defined in the table as: 1) nearly level, less than 3 percent; 2) gently sloping, 3 to 8 percent; 3) sloping, 8 to 15 percent; and 4) steep, more than 15 percent. Limitations are rated as follows: 1) slight, most features favorable for rated use; 2) moderate, some special planning or design needed; 3) severe, several unfavorable conditions that generally require a major reclamation or design; and 4) very severe, conditions very difficult and expensive to overcome. Major drainage basins are outlined.

SOILS AND ENGINEERING CHARACTERISTICS

Soil information obtained from R. L. Googins, U.S. Soil Conservation Service (U.S.S.C.S.) is listed in Table 1. Detailed information concerning the soils and interpretations for specific uses can be obtained from the local Soil Conservation Service office. The names of soils used in the descriptions are tentative and subject to change pending a final correlation of the soils of Warren County by the U.S.S.C.S.

Soil in this report is defined as the lower limit of biological activity (i.e., root penetration) and residuum is considered to be the weathered material between the soil and bedrock. Thickness estimates of soils and residuum are based on observations from natural and artificial exposures and on data supplied by the Soil Conservation Service. Engineering characteristics affecting slope and foundation stability and ease of excavation listed in Table 1 were supplied by J. R. Murphy and H. R. Freeland, Virginia Department of Highways and Transportation in 1977. Data from this source was also used in the columns entitled, "rock structure," "limitations" and "potential use."

SINKHOLES AND CAVES

Sinkholes are common in units 5, 6, and 7. In general the larger sinkholes are more numerous in unit 6. Sinkholes less than 20 feet (6 m) in diameter are common in units 5 and 7. Those sinkholes with a diameter exceeding 20 feet (6 m) are plotted on the map. They were located both in the field and from interpretation of aerial photographs. Sinkholes provide a primary conduit for groundwater recharge in areas underlain by carbonate rocks. Any activity which interferes with this recharge could affect the water table. The potential pollution hazard in areas of karst topography is great because of contaminates introduced in solution through underground stream networks associated with the sinkholes. Areas of numerous sinkholes indicate subsurface solution activity and collapse of the surface. For this reason the use of the area for buildings requiring high load-bearing strength of bedrock is severely limited.

Caves are indicative of considerable subsurface solution activity. For this reason location of buildings requiring high-load capacity near caves would be subject to severe limitations. Caves and caverns may provide space for underground storage, and a few may be suitable for commercial development and for use as civil-defense shelters. Areas with one or more cave openings near Front Royal are delineated (Rader and Biggs, 1975, pl. 2).

ROCKFALLS AND LANDSLIDES

Areas of actual or potential rockfalls are located along the Shenandoah River, Manassas Run, Happy Creek, and Massanutten Mountain. Small areas related to abandoned quarry operations and road cuts are also shown. Rockfalls are composed of debris accumulated at the base of steep slopes through nearly free-fall movement. Construction at or near the base of steep slopes where known rockfalls occur is extremely hazardous and subject to severe limitations.

Unconsolidated rock and soil debris occur along the sides of the Blue Ridge, Dickey Ridge, Massanutten Mountain, and foothills of the Blue Ridge such as Brush Mountain and Green Hill (extent of deposits not shown on map). Under unstable conditions these masses may move rapidly downslope as a landslide or slowly, as surface creep. Thicknesses of these deposits range up to 25 feet (8 m). Because of their instability, moderate permeability and stoniness, construction activities are limited in these areas. Excavation, trenching, and other modifications at the base of moderate to steep slopes can trigger earth movements. During periods of high rainfall there is a potential hazard for landslide.

ADDITIONAL DATA SOURCES

Additional data which may be of value in planning for land modifications can be obtained as follows: soils—U.S. Soil Conservation Service, P.O. Box 10026, Richmond, VA 23230; water—State Water Control Board, P.O. Box 268, Bridgewater, VA 22812; regional planning—Lord Fairfax Planning Commission, 103 East Sixth Street, Front Royal, VA 22630; forestry—Virginia Division of Forestry, P.O. Box 3758, Charlottesville, VA 22903; aerial photography—National Cartographic Information Center East, U.S. Geological Survey, Reston, VA 22092; topographic maps and orthophotoquads—Virginia Division of Mineral Resources, Box 3667, Charlottesville, VA 22903.

Samples of raw material having potential commercial use are available for examination in the Division repository. A geologic report and map (scale 1:50,000) of the county are on open file at the Division. Detailed geologic data is available from the Division for most of the included 1:24,000 scale map areas (se references below).

REFERENCES

Edmundson, R. S., 1945, Industrial limestones and dolomites in Virginia: Northern and central parts of Shenandoah Valley: Virginia Geol. Survey, Bull. 65, 195 p.

Edmundson, R. S. and Nunan, W. E., 1973, Geology of the Berryville, Stephenson, and Boyce quadrangles, Virginia: Virginia Division of Mineral Resources Rept. Inv. 34, 112 p.

Gathright, T. M. II, 1976, Geology of the Shenandoah National Park, Virginia: Virginia Division of Mineral Resources, Bull. 86, 93 p.

Lukert, M. T. III and Nuckols, E. B. II, 1976, Geology of the Linden and Flint Hill quadrangles, Virginia: Virginia Division of Mineral Resources Rept. Inv. 44, 83 p.

Rader, E. K. and Biggs, T. H., 1975, Geology of the Front Royal quadrangle, Virginia: Virginia Division of Mineral Resources, Rept. Inv. 40, 91 p.

———, 1976, Geology of the Strasburg and Toms Brook quadrangles, Virginia: Virginia Division of Mineral Resources Rept. Inv. 45, 104 p.

UNITS[1]	TOPOGRAPHY	LITHOLOGY AND THICKNESS[1]	GEOLOGIC AGE AND FORMATION	ROCK STRUCTURE	OUTCROPS/ SINK HOLES	SOIL SERIES	SOIL DEPTH IN (cm)	MISCELLANEOUS SOIL DATA	ERODIBILITY	STABILITY	EASE OF EXCAVATION	GEOLOGIC RESOURCES	LIMITATIONS	POTENTIAL USE	UNITS[1]
11	Flood plains and stream channels—nearly level.	Quartz sand, fine-grained, dark brown; minor silty sand and silty clay; pebble-size quartzite and sandstone fragments (1); roundstone in stream channels (2); thickness-15′-20′ (4.5-6.0 m) along Shenandoah River; 0-15′ (0-4.5 m) along tributary streams.	Quaternary, Alluvium	Unconsolidated		Buckton Chagrin Chavies Unnamed clayey soil Hawksbill Craigsville	48 (120) 60 (150) 76 (190) 60 (150) 60 (150)	Well-drained Well-drained Well-drained Poorly-drained Well-drained; cobbly to very cobbly Well-drained; cobbly to very cobbly	Severe erosion along stream channels and flood-plains during excessive run-off.	Cuts and excavations subject to slides or sluffing; excess water increases probability and severity of movement.	Easily excavated with light equipment.	Potential as local source of sand and gravel; reserves may be limited.	Severe limitations for urban development and solid and liquid waste disposal because of periodic flooding.	Prime agricultural area; source of top soil; recreation.	11
9	Low terraces along rivers and major streams—nearly level; high terraces generally adjacent to drainage divides have low to moderate slopes.	Quartz sand, fine-grained, brown; minor silty sand and silty clay; roundstones of pebble- to boulder-size quartzite and sandstone (3, 4, 5, 6). Thickness-0-25′ (0-8 m).	Quaternary; Terrace deposit	Unconsolidated		Unison Braddock Monongahela Guernsey	72 (183) 85 (216) 60 (150) 60 (150)	Well-drained Well-drained Moderately well-drained; fragipan Moderately well to well-drained	Severe erosion if vegetative cover removed, or during intense rainfall.	Unstable where fine matrix removed on moderate slopes or where base of slope is cut.	Easily excavated with light equipment.	Potential as local source of gravel and sand; reserves may be limited.	Severe limitations for solid and liquid waste disposal because of high permeability; moderate to severe limitations for urban development because of seasonal high water table and low bearing capacity.	Good for pastures and small grains except where limited by slope, gravel, or seasonal high waterstable; good for recreational use not requiring on-site liquid waste disposal.	9
8	Hills low, linear to arcuate; valleys broad; slopes of drainage divides nearly level, valley sides steep to moderate slopes.	Sandstone, impure, fine-grained, greenish-gray; silty shale, olive-green to gray; quartz sandstone, medium grained, brown (7, 8). Thickness-3000′ (914 m).	Ordovician; Martinsburg Formation (middle and upper)	Folded, many small displacement faults; steep southeast dipping cleavage; bedding thin to thick.	Outcrops abundant along valley sides.	Berks Weikert Sequoia Unnamed clayey soil	33 (84) 18 (46) 40 (102)	Well-drained; shale chips Well-drained Well-drained Seasonally wet; poorly-drained	Severe erosion on steep slopes, or where vegetation is removed.	Cut stability good to poor depending on orientation of cut to bedding and cleavage; foundation stability adequate for all classes of structures if excavation extends to unweathered rock.	Locally blasting required; where seismic velocity less than 3000 fps rock may be ripped; drilling rates 1-20 fph.	Shale for fill: active quarry (1), abandoned quarry (6); brick and light-weight aggregate potential sources R-648; brick and tile potential source R-649; brick potential R-666.	Moderate to severe limitations for liquid and solid waste disposal because of shallow depth to rock; perched watertable causes seasonal wetness locally; agricultural uses restricted by slope, thin soils, and seasonal wetness.	Fair to good for pasture and small grains; good potential for urban development not requiring on-site liquid waste disposal.	8
7		Slaty shale, black to dark gray, calcareous (9). Thickness-200′ (61 m). Siltstone, gray, calcareous (10). Thickness-15′ (5 m). Limestone, dense, black; limestone, fine-grained, dark-gray, cobbly-weathering; shale, black, fissile (11, 12, 13). Thickness-150′-435′ (46–133 m).	Ordovician; Martinsburg Formation (lower), Oranda Formation, Edinburg Formation	Bedding laminated to thick; joints locally abundant and well-developed, open or soil filled; steep dips.	Outcrops common on steep slopes, sparse on low slopes; large sinkholes rare, small sinkholes common.	Carbo Chilhowee Edom Dandridge	40 (102) 25 (64) 46 (115) 16 (41)	Well-drained; moderate to high shrink-swell clay Well-drained; moderate to high shrink-swell clay Well-drained; shaly subsoil Excessively drained; shaly subsoil	Severe erosion on thin soils with shaly subsoil on moderate to steep slopes.	Cut stability good to poor depending on orientation of cut to bedding and cleavage; foundation stability good for light to medium weight structures if excavation extends to unweathered rock.	Excavation moderately easy with heavy equipment; blasting required in unweathered rock; drilling rates 1-25 fph.	Shale for cement: active quarry (3), abandoned quarries (2, 5).	Severe limitations on urban development because of high shrink-swell clays and shallow depth to rock; severe limitations on liquid and solid waste disposal because of potential groundwater contamination and thin soils.	Very good to poor agricultural area depending on soil type and slope; urban development potential good if the combination of wells and septic systems are avoided.	7
6	Hills, long to short, linear to nonoriented with broad valleys; adjacent to Shenandoah River and its forks are scattered broad, flat-topped, steep-sided hills.	Limestone, medium-grained, dark- to medium-gray with black, blocky chert; one thin bed of light-gray, coarse-grained, high-calcium limestone (14, 15). Thickness-25′-50′ (8-15 m). Limestone, dense, medium-light gray, in part argillaceous (14, 15); carbonate-pebble conglomerate (16). Thickness-0-20′ (0-6 m). Limestone, fine-grained, medium-gray in part, dolomitic and mottled; thin sandstone and chert lenses (17, 18, 19). Thickness-2400′ (732 m). Limestone, fine-grained, medium-gray to black, crinkly partings of quartz silt and clay in lower 100′ to 150′ (30-46 m) (20). Thickness-600′-650′ (183-198m). Dolomite, light-gray; limestone, medium-gray; carbonate-pebble conglomerate; calcareous sandstone (21, 22). Thickness-2300′ (701 m). Dolomite, medium-gray, yellowish-gray weathering with interbedded algal limestone and dolomitic limestone; (23, 24). Thickness 1600′-1700′ (488-518 m).	Ordovician; Lincolnshire Formation, New Market Limestone, Rockdale Run Formation, Stonehenge Formation Cambrian; Conococheague Formation, Elbrook Formation (upper)	Bedding thick to laminated; folded; southeast dipping cleavage.	Outcrops abundant along streams and locally in upland areas; large sinkholes common to abundant, small sinkholes abundant, karst valley east of Rockland; cave openings common.	Frederick Carbo Unison Braddock Monongahela	95 (241) 40 (102) 72 (183) 85 (216) 60 (150)	Well-drained Well-drained, moderate to high shrink-swell clay Well-drained Well-drained Moderately well-drained; fragipan	Severe erosion on steep slopes and on moderate slopes where vegetation removed.	Cut slope stability good to excellent; foundation stability excellent in unweathered rock; stability decreases where pinnacles, weathered pockets, and solution features are present.	Drilling and blasting required; drilling rate 1.5-6 fph; soil-rock contact highly irregular; soil-residuum may be 40′ thick adjacent to an outcrop.	Limestone for cement and crushed rock: active quarries (7, 10); abandoned quarries (4, 8, 9, 11, 12); chemical analyses available (Edmundson, 1945).	Moderate to severe limitations on urban development because of rock pinnacles, sinkholes, and high shrink-swell clays; severe limitations on liquid and solid waste disposal; agricultural uses subject to limitations of slope, rock outcrops, high shrink-swell clays.	Agricultural potential generally good.	6
5		Dolomite, fine-grained, greenish-gray, in part shaly; limestone, fine-grained, gray; calcareous siltstone (25). Thickness-300′-400′ (91-122 m). Shale, multi-colored; sandstone, moderate-reddish brown; chert; dolomite fine-grained, gray, in part saccharoidal; limestone, mottled (26). Thickness-800′-1200′ (244-366 m). Dolomite, fine- to medium-grained, gray (27). Thickness 50-70′ (15-21 m).	Cambrian; Elbrook Formation (lower), Waynesboro Formation, Shady Formation	Bedding laminated to massive; folded; southeast dipping cleavage; jointing well-developed, locally blocky.	Outcrops common to abundant along streams; small sinkholes common to abundant.	Frederick Frankstown Carbo	95 (241) 60 (150) 40 (102)	Well-drained Well-drained Well-drained; moderate to high shrink-swell clay	Severe erosion where vegetation removed or in times of high rainfall on steep to moderate slopes.	Cut stability good if oriented perpendicular to rock structure; foundation stability good for all classes of structures if excavation extends to unweathered rock.	Drilling and blasting required in limestone, dolomite, and sandstone; drilling rate 0.2-20.0 fph; shale generally rippable with heavy equipment; soil-rock contact highly irregular on limestone and dolomite; soil-residuum may be 40′ thick adjacent to an outcrop.	Potential as source of crushed stone; shale may be used as fill.	Moderate to severe limitations on urban development because of rock pinnacles, sinkholes, and high shrink-swell clays; severe limitations on liquid and solid waste disposal; agricultural uses subject to limitations of slope, rock outcrops, high shrink-swell clays.	Agricultural potential generally good.	5
4	Ridges linear, steep-sided, oriented northeast-southwest; drainages aligned parallel and perpendicular to ridges. Mountain steep-sided in western area.	Sandstone and quartzite, fine- to coarse-grained, white to gray, conglomeratic. Thickness-400′ (122 m). Subarkosic quartzite and quartz-granule and -pebble conglomerate (28). Thickness-400′-600′ (122-183 m). Breccia, quartzite blocks with iron oxide cement (goethite, hematite, and limonite) (29). Ironstone, angular carbonate fragments replaced by silica and iron oxides; associated with terrace deposits near Shenandoah River (30).	Silurian; Massanutten Sandstone Cambrian; Antietam Formation Unknown; Breccia, Ironstone	Bedding thick to massive; folded; joints widely spaced, well-developed; locally closely-spaced joints produce rectangular blocks 1″-6″ (2.5-15 cm) long.	Outcrops abundant on steep slopes, low to moderate slopes often covered with rectangular blocks in a sand matrix.	Hazelton Dekalb	60 (150) 34 (89)	Well-drained; acid; high percentage of coarse fragments	Low erosion except moderate on steep bare slopes.	Cut stability poor in moderate to steep cuts, close-spaced jointing forms rectangular blocks that may produce rockfalls; foundation stability good for all classes of structures if excavation extends to unweathered rock.	Drilling and blasting required, drilling rate 0.15-1.0 fph.	Quartzite for riprap and fill; potential source of sand and sandstone for fill and crushed stone, active quarry (14, 31); abandoned quarries (13, 15); manganese for steel alloys, abandoned quarry (16); iron for steel manufacture, abandoned quarries (17, 25, 30).	Severe limitations for urban development and agricultural uses because of steep slopes and thin and rocky soils.	Potentially good for woodland and recreational activities that require minimal construction and no on-site waste disposal.	4
3		Phyllite, bronze-weathering, sandy; sandstone; quartzite; quartz-pebble conglomerate (31). Thickness-2000′ (610 m). Quartz-pebble conglomerate; phyllite, greenish-gray, silty and sandy; subarkose (32, 33). Thickness-400′-500′ (122-152 m).	Cambrian; Harpers Formation, Weverton Formation	Bedding massive in sandstone; phyllites foliated; folded; southeast dipping cleavage; sandstone and quartzite with well-developed joints.	Outcrops abundant on steep slopes.	Hazelton Hartleton DeKalb Cardiff	60 (150) 46 (115) 34 (89) 34 (89)	Well- to excessively drained; acid; high percentage of coarse fragments.	Low to moderate erosion except moderate to severe on steep bare slopes.	Cut slope stability good at 3:1 to 1:1, close-spaced jointing forms rectangular blocks that may produce rockfalls; rockfalls common on bare steep slopes; foundation stability good for all classes of structures if excavation extends to unweathered rock.	Drilling and blasting required in sandstone and quartzite units; phyllite generally rippable with heavy equipment; drilling rate 0.15-20.0 fph.	Potential as source of phyllite for fill; sandstones, quartzites and conglomerates for riprap.	Severe limitations for urban development and agricultural uses because of steep slopes and thin and rocky soils.	Potentially good for woodland and recreational activities that require minimal construction and no on-site waste disposal.	3
2	Mountain linear with steep-sides and some cliffs, crests relatively flat; valleys narrow, V-shaped, somewhat broader along perennial streams.	Greenstone; green phyllite; red argillite; epidosite; rhyolitic metatuff; meta-arkose; sandstone (34, 35). Thickness-1500′-2000′ (457-762 m). Metagraywacke; sericitized meta-arkose; phyllite (36). Thickness-0-150′ (0-46 m).	Precambrian (?); Catoctin Formation, Swift Run Formation	Closely spaced jointing; southeast dipping cleavage.	Outcrops abundant on steep slopes.	Fauquier Myersville Montalto Catoctin Lew	40 (102) 40 (102) 40 (102) less than 40 (102) 80 (200)	Well-drained Well-drained Well-drained Well-drained Well-drained; high content of cobbles	Low erosion except moderate on steep bare slopes.	Cut slope stability depends on orientation of cut to structure, perpendicular to structure most stable; foundation stability excellent for all classes of structures if excavation extends to unweathered rock; rockfalls common on bare steep slopes.	Drilling and blasting required; drilling rate average 0.2 fph; bit life short.	Potential for non-phyllitic units as sources for crushed stone and riprap; for copper mines and prospects (20, 21, 22, 23, 26, 27, 28, 33, 34, 35).	Severe limitations for urban development and agricultural uses in areas of steep slopes and rocky soils; moderate limitations on low to moderate slopes.	Potential for urban development and agricultural uses good on low to moderate slopes in areas of non-skeletal soils.	2
1	Hills linear, steep-sided; mountains with broad valleys and linear steep-sided hollows. Highest elevation in the county at Hogback Mountain—3474′ (104.2 m).	Quartz monzonite (37); quartzofeldspathic granulite; narrow greenstone dikes (38).	Precambrian; Pedlar Formation	Massive; joints well-developed; exfoliation boulders common.	Outcrops common to abundant on steep slopes.	Hayesville Jefferson Porters Fauquier Myersville	48 (120) 60 (150) 40+ (102+) 36 (91) 58 (145)	Well-drained Well-drained Well-drained Well-drained; dominant only along Gooney Run	Low to moderate erosion except severe where vegetation is removed.	Cut slope stability good except in rock with open or soil filled joints; foundation stability excellent for all classes of structures if excavation extends to unweathered rock; rockfalls common on bare steep slopes.	Drilling and blasting required; drilling rate average 0.2 fph; bit life short.	Potential as sources for rip-rap, building stone, fill material, and non-polishing aggregate; severe crusher jaw wear limits crushed stone potential.	Severe limitations for urban development and agricultural uses in areas of steep slopes and rocky soils; moderate limitations on low to moderate slopes.	Potential for urban development, agricultural uses, and solid waste disposal good on low to moderate slopes.	1

[1]Unit 10: not on map; see text for explanation.
[2]Numbers (1) refer to reference localities.