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

SELECTED KARST FEATURES OF THE NORTHERN VALLEY AND RIDGE PROVINCE, VIRGINIA

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SELECTED KARST FEATURES OF THE NORTHERN
VALLEY AND RIDGE PROVINCE, VIRGINIA

EXPLANATION

6

Non-Carbonates
Includes the following formations:

Pocono Formation, Hampshire Formation, Foreknobs Formation, Chemung Formation, Brallier Shale, Millboro Shale, Mahantango Formation, Marcellus Shale, Needmore Shale, Ridgeley Sandstone, Wills Creek Formation, Bloomsburg Formation, McKenzie Formation, Williamsport Formation, Mifflintown Formation, Keefer Sandstone, Massanutten Sandstone, Rose Hill Formation, Tuscarora Sandstone, Juniata Formation, Oswego Sandstone, Martinsburg Formation, Oranda Formation, Reedsville Shale, Dolly Ridge Formation, Antietam Formation, Harpers Formation, Weverton Formation, Catoctin Formation, Swift Run Formation, and Pedlar Formation.

5

Helderberg Group
limestone with thin beds of sandstone, chert and shale

Tonoloway Limestone
limestone

4

Nealmont Limestone
limestone with minor shale

Moccasin Formation
mudstone and limestone

Witten Limestone
limestone

Wardell Formation
limestone and shale

Benbolt Limestone
limestone

Peery Limestone
limestone

Ward Cove Limestone
limestone

Lincolnshire Limestone
limestone with minor chert

Five Oaks Limestone
limestone

Elway Limestone
limestone with minor chert

Blackford Formation
limestone with some dolomite

3

Edinburg Formation
limestone with some shale

Lincolnshire Limestone
limestone with minor chert

New Market Limestone
limestone

2

Beekmantown Group
dolomite with minor chert

1

Beekmantown Group
limestone with some dolomite grades to dolomite with some limestone to south

Conococheague Formation
limestone with some dolomite and minor sandstone

Elbrook Formation
limestone with some dolomite grades to dolomite with some limestone to south

Waynesboro Formation
argillite, sandstone, and dolomite

Shady Dolomite
dolomite with some limestone

KEY

- Sinkholes
- Cave entrance
- Multiple cave entrances
- Contact line
- Fault; tick mark and "T" indicate direction and dip of major overthrust sheets
- Major drainage divides; see inset map for drainage basin names

Base map from U. S. Geological Survey

INTRODUCTION

This publication is intended as a regional guide to the planner to minimize unnecessary development of potentially hazardous karst areas. The term "karst" refers to a terrain characterized by solution of bedrock, underground drainage and distinctive landforms such as sinkholes and caves. Significant karst development is exhibited in the Paleozoic limestones and dolomites of the Valley and Ridge physiographic province in Virginia. The northern segment of this province is examined in this report. The study area is bounded on the south by the 38th parallel of latitude and on the east by clastics, volcanics and plutonics of the Blue Ridge province. To the north and west, the area is bounded by the West Virginia state line. Five drainage basins are represented in the study area (inset map).

The regional geologic map of the carbonate rocks in the study area was compiled from published and manuscript maps on file at the Division of Mineral Resources (see References). Six map divisions are illustrated in this report: 6 - noncarbonates (Lower Mississippian to Precambrian) dominantly clastics except along the eastern edge of the study area where volcanics and plutonics are also present; 5 - limestones (Devonian and Silurian); 4 - limestones of the western belt (Upper and Middle Ordovician); 3 - limestones of the central and eastern belts (Ordovician); 2 - limestones and dolomites of the fault-truncated western and central belts (Lower Ordovician); and 1 - limestones and dolomites of the eastern belt (Lower Ordovician and Cambrian).

Areas of karst development represent land undergoing differential settlement. "Soil cover" in these areas ranges from zero to in excess of one hundred meters often within the distance of a few meters. Subsidence may be barely detectable over years or spontaneous, involving "soil cover" and/or bedrock. Alluvial deposits, such as flood plains or river terraces overlying carbonates, may also be subject to rapid subsidence or collapse during periods of drought and/or induced drawdowns of the water table.

Sinkholes are input points from the surface to the subsurface drainage system in karst terrains. Dumping of waste materials into sinkholes often results in contamination of the subsurface water supply. In karst terrains, leaks, spills and discharges of commercial or industrial operations can rapidly enter the ground water supply and compromise nearby municipal water supplies, residential water wells and recreational waters.

In general, areas of the map with high densities of sinks and caves may be expected to exhibit some of the hazards discussed in this report. In areas of lower densities of sinks and caves, as on floodplains or debris fans, potential subsidence or pollution problems may still occur. Adequate planning is necessary to reduce these hazards. This report is not detailed enough or intended for use in specific site planning. Individual site studies must address the specific set of parameters relevant to the formation of karst features and hazards at each location. The report is intended to indicate, on a regional basis, areas where special site planning and engineering considerations are necessary to avoid potential subsidence or collapse, groundwater pollution, and/or sinkhole flooding hazards.

KARST DEVELOPMENT

The term karst refers to a terrain characterized by bedrock solution and distinctive landforms indicative of underground drainage, such as sinkholes and caves. Sinkholes are defined as closed depressions resulting from subsidence due to solution or collapse of void space resulting in a basin-like or funnel-shaped landform. Caves are defined as naturally occurring voids, large enough for a person to enter.

The sinkholes indicated in this report range in size from 30 to 11,400 feet in diameter. This range in size was observed from stereo examination of low altitude (20,000 feet) aerial photography. Numerous other sinkholes in the study area are within this range, but are not indicated due to the difficulty in recognizing some low relief features on aerial photography in both fields and woodlands. Both sinkholes and caves are termed intermediate scale landforms (33 to 3300 feet), as the majority of these features in this study area are within this range. Sinkholes smaller than about 30 feet in diameter are not illustrated in this report. A particular area of the map may indicate a sparse distribution of sinks when in fact, the area contains a very high density of small sinkholes.

Patterns of these landforms often betray the influence of the various factors affecting karst development. Geologic factors which influence karst development include lithology, structure, hydrology and "soil cover."

Lithology

Lithologic influences on karst development are only grossly demonstrated on a regional basis in this report. Careful examination of the karst map indicates numerous linear trends (NE - SW) of sinks and caves. Some of these trends represent the occurrence of features within specific beds. This is readily apparent along the contact of the Ordovician limestones (3) and the Cambro-Ordovician carbonates (2) in the central region of the map (Harrisonburg vicinity). Limestone beds in the top of the Cambro-Ordovician carbonates (Beekmantown Group) are lithologically very similar to the middle Ordovician limestones (New Market Limestone).

Lithologic control is further indicated by the abundance of large sinkholes observed in the Devonian-Silurian limestones (5 and 4) and the Cambro-Ordovician limestones and dolomites (2 and 1). These large sinks seem to be largely limited to the eastern and western belts and are possibly partly due to aggressive (low pH) runoff from forested high-relief noncarbonate terrain. Debris aprons (colluvium) may inhibit the surficial expression of karst development (patterns of sinkholes).

Structure

Structural influences on karst development are closely linked to lithological influences. A fold may exhibit karst development along its axis showing both lithologic and structural influences. Linear trends of sinks and caves have been demonstrated to coincide with fold structures (Hubbard, 1981). Joint patterns in folded rocks may influence karst development.

Hack (1965) asserts that sinkhole development favors synclinal structures. However, in this report anticlinal structures seem to show definite enhanced karst development in the western belt. The remaining areas of the study show no apparent preferential development for either type structure at this scale.

With the exception of the western belts, structure has a distinctive influence on the limestones of the Devonian-Silurian system. These beds are inclined at steep attitudes and have been largely removed through solution. Outcrop of these carbonates in the Eastern and Central belts is virtually nonexistent. Solution has resulted in the slumping of adjacent sandstones and replacement of carbonate units by clastic debris; occasionally these features exceed 100 meters in depth. These occurrences are not illustrated on the karst map but are noted here as locally significant karst features.

Hydrology

The two major hydrologic influences of karst development are hydraulic gradient and fluctuation of the water table. Hack (1965) notes that sinkhole development is favored by close proximity to streams. The steepened hydraulic gradient proximal to an entrenched stream, in combination with the increased rate of groundwater flow at such locations, tends to enhance karst development. Clustering of karst features is observed along both forks of the Shenandoah River and just below their confluence. Steep hydraulic gradients and considerable ground water movement at these locations appear to contribute to the development of these sinkhole concentrations.

Extreme fluctuations of the water table, either rapid or over extended time periods, have long been established as a cause of sinkhole formation and ground subsidence. The more rapid the reduction in water level, the more violent and often extensive the subsidence or collapse of the overlying and surrounding surface. The initial cause for collapse or subsidence is the loss of buoyancy resulting from desaturation of the materials. Yield pumping tests in large wells can result in local sinkhole collapse or subsidence. Longer-term water-level reductions may occur during droughts.

Later collapse or subsidence may occur after soil materials have dried out from a lowering of the water table and these materials are rewetted (e.g. rainfall). This subsequent rewetting results in a reduction of the shear strength of these materials and their potential failure into void spaces. These voids may be due to loose packing, winnowing of fine material by groundwater flow or from dissolution of carbonate materials.

Water-table-fluctuation mechanisms of karst development are closely related to the depth of "soil cover". Hack (1965) states that approximately 15 percent of the Shenandoah Valley is covered by terrace gravels and flood plains. Lowering of the water levels in these deposits may result in collapse or subsidence sinkholes as materials collapse into voids or differentially subside during compaction resulting from desaturation.

POTENTIAL KARST HAZARDS

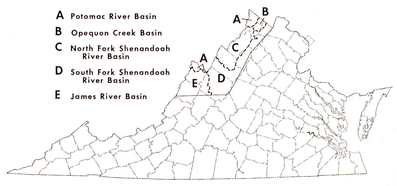
The potential hazards of karst terrains can be categorized into three major concerns: 1) differential subsidence or collapse, 2) pollution of groundwaters, and 3) sinkhole flooding.

Sinkholes exist because of differential settling of surface materials. This settlement can be slow or instantaneous (collapse). Settlement or subsidence results from various processes, such as compaction due to loading, compaction due to dewatering, settling as materials are removed, stoping into void space and subsequent compaction and spontaneous collapse into void space. These processes are continuously active in karst areas. Man's attempts to temporarily deter or modify these dynamic processes can and often do result in their acceleration.

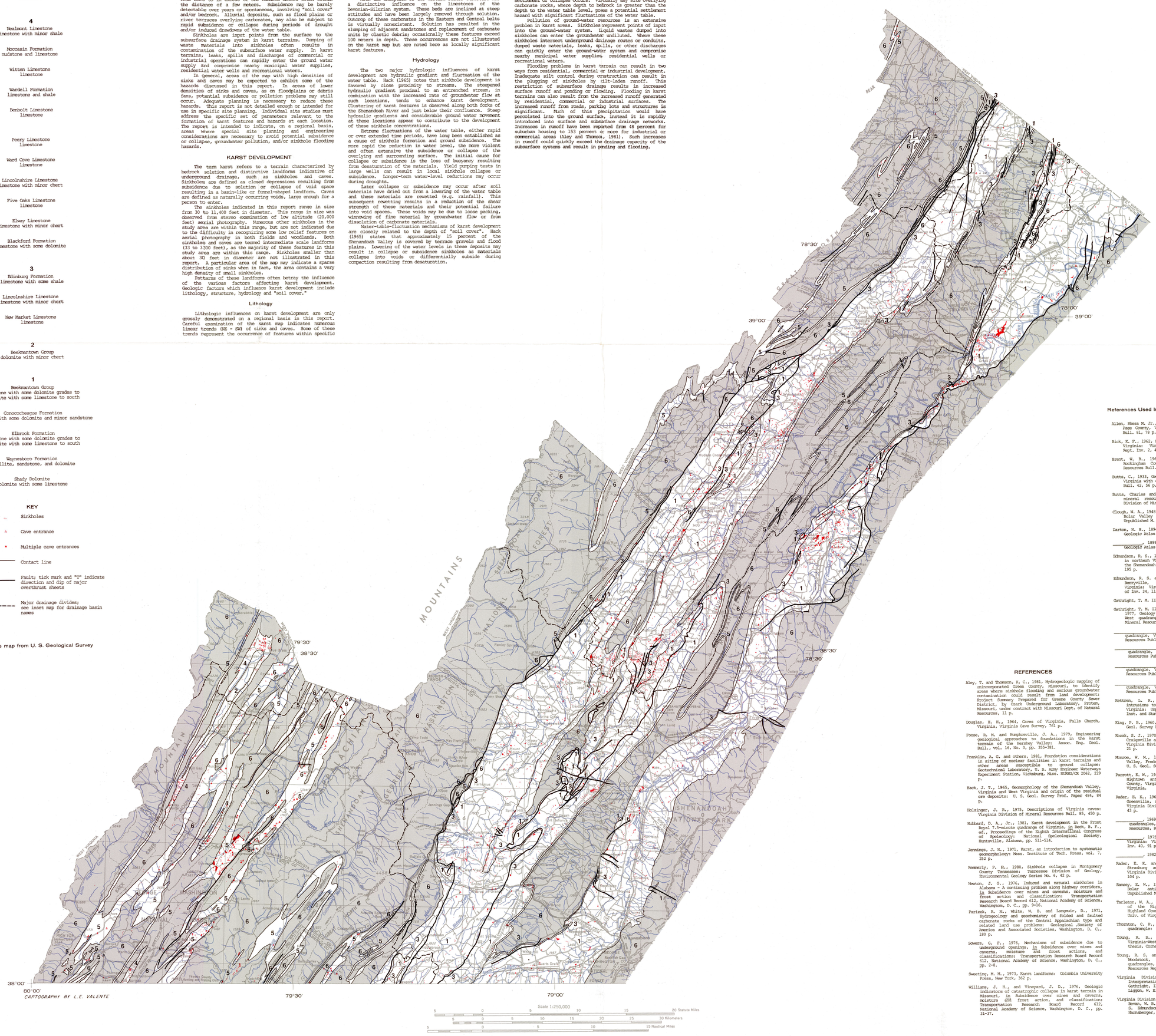
A field of sinkholes is readily recognized as a site requiring special developmental considerations at best. However, not all areas of potential karst hazards are obvious. Terrace gravels and floodplains overlying carbonates may not show any sinkhole development. They often have high water tables and high yields. Both features may be potentially hazardous with regard to differential or spontaneous subsidence or ground-water pollution. Most planners avoid floodplains up to the 100-year-flood limit for residential, commercial, or industrial development. Although terraces may appear to be highly desirable sites for residential or industrial development, extreme fluctuation in the water table level can be disastrous in such sites. Such sites may be developed for some time before additional demands on the water supply (wells) and/or drought conditions reduce the water table to the point where settlement or collapse occurs. Virtually any site overlying carbonate rocks, where depth to bedrock is greater than the depth to the water table level, poses a potential settlement hazard with significant fluctuations of the water table.

Pollution of ground-water resources is an extensive problem in karst areas. Sinkholes represent points of input into the ground-water system. Liquid wastes dumped into sinkholes can enter the groundwater undiluted. Where these sinkholes intersect underground drainage routes or conduits, dumped waste materials, leaks, spills, or other discharges can quickly enter the ground-water system and compromise nearby municipal water supplies residential wells or recreational waters.

Flooding problems in karst terrain can result in two ways from residential, commercial or industrial development. Inadequate silt control during construction can result in the plugging of sinkholes by silt-laden runoff. This restriction of subsurface drainage results in increased surface runoff and ponding or flooding. Flooding in karst terrains can also result from the increased runoff generated by residential, commercial or industrial surfaces. The increased runoff from roads, parking lots and structures is significant. Much of this precipitation would have percolated into the ground surface, instead it is rapidly introduced into surface and subsurface drainage networks. Increases in runoff have been reported from 48 percent for suburban housing to 153 percent or more for industrial or commercial areas (Aley and Thomas, 1981). Such increases in runoff could quickly exceed the drainage capacity of the subsurface systems and result in ponding and flooding.



LOCATION AND DRAINAGE BASIN MAP



CARTOGRAPHY BY L.E. VALENTE

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