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Stratigraphy-Karst Relationships in the Frederick Valley of Maryland

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Abstract

Karst features are present in strata of Triassic, Ordovician, and Cambrian age in the Frederick Valley of Maryland. While the Triassic Leesburg Member of the Bull Run Formation and Rocky Spring Station Member of the Cambrian Frederick Formation have large numbers of surface depressions developed within their outcrop belts, it is the Lime Kiln Member of the Frederick Formation and the overlying Ordovician Grove Formation that present the greatest danger for active sinkhole development. Springs are most likely to develop in the Adamstown Member of the Frederick Formation. The relative susceptibility of the different units of the Frederick Valley appears to be related to the relative purity of the individual units. Those units with abundant clay and silt are less likely to have active sinkhole develop than those units with greater carbonate purity.

INTRODUCTION

The Frederick Valley of Maryland's western Piedmont represents the state's second largest karst terrane. Although the largest is located in eastern Washington County and is known as the Hagerstown Valley or Great Valley, the Frederick Valley has had more incidences of catastrophic collapse and active subsidence than its larger neighbor. The Frederick Valley is a lowland region that stretches from the Potomac River northward to Woodsboro in northern Frederick County, an area of approximately 400 km^2. The Maryland Geological Survey, in conjunction with the Maryland State Highway Administration, has been conducting detailed geologic mapping along with karst feature identification. This report is the preliminary results of that study which is currently in progress.

REGIONAL SETTING

The Frederick Valley is a broad synclinorium that is overturned along its eastern flank. It lies near the western edge of the Piedmont Physiographic Province of Maryland. The western Piedmont encompasses a number of geologic subdivisions including the Frederick Valley, the Triassic Basins, and the western edge of the metamorphosed phyllites and schists that characterize the Piedmont proper. The Frederick Valley is composed of Cambrian and Ordovician limestones that, beyond their intense folding, exhibit very little metamorphism. The eastern boundary of the Frederick Valley is commonly placed at the contact between the limestones of the Frederick Valley and sandstones and siltstones of the subjacent Araby Formation.

The Frederick Valley is bounded on the south by the Potomac River and is overlapped to the west and north by Triassic rocks. In Maryland, parts of two separate Triassic basins are present. From the Potomac River north to U.S. Route 40, Triassic rocks were deposited in the Culpeper Basin. From just north of the northern terminus of the Culpeper Basin at U.S. 40 northward to the Pennsylvania State Line and beyond, the Triassic sediments were deposited in the Gettysburg Basin. Because there is very little topographic relief between the Frederick Valley proper and the Triassic sediments, discerning between the two separate subdivisions of the western Piedmont can be difficult. Moreover, because extensive areas underlain by Triassic strata are carbonate, and are prone to similar types of dissolution and erosion as the limestones of the Frederick Valley, the Triassic sediments are included as part of the Frederick Valley within the current study. The western limit of the Triassic rocks is along a linear fault that is presumably of Triassic age and places the Triassic against the edge of the Blue Ridge Province.

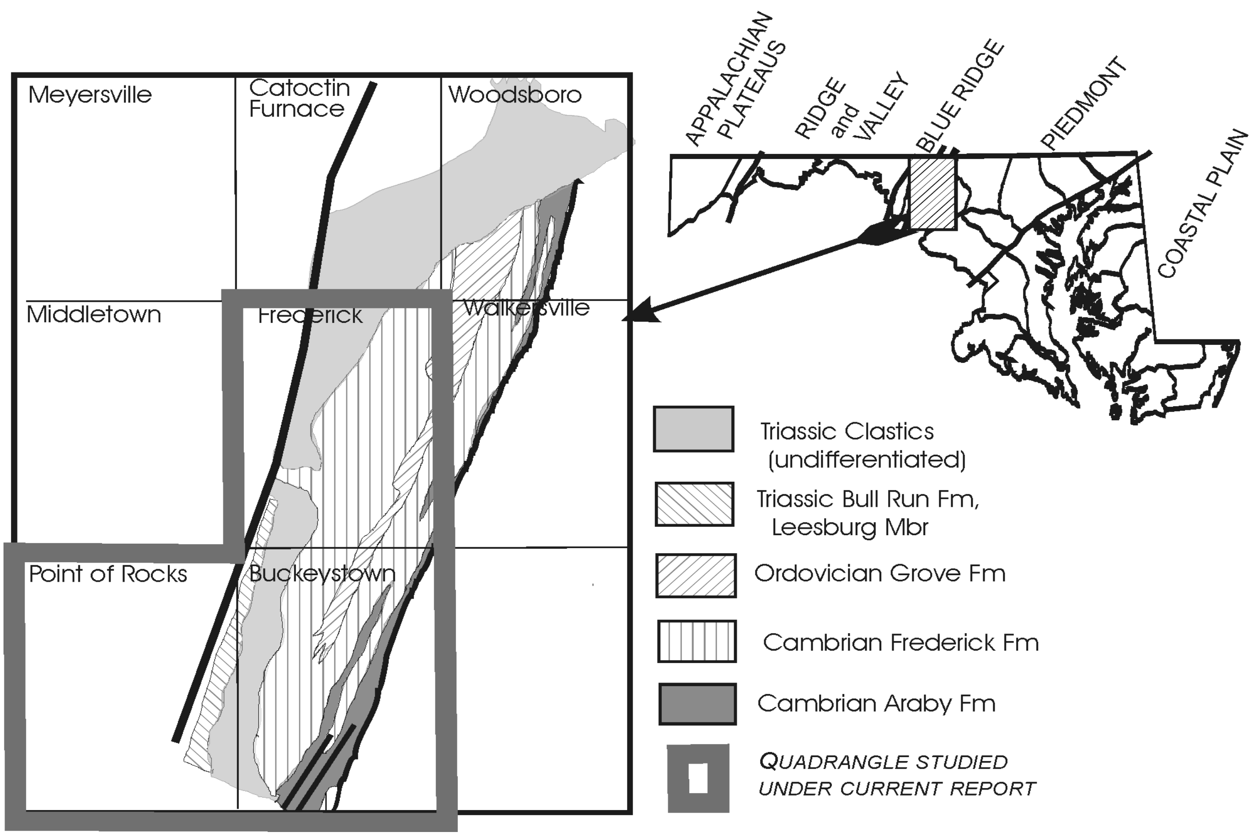

Figure 1. Location map of the Frederick Valley and the location of the Buckeystown, Point of Rocks, and Frederick quadrangles.

STRATIGRAPHY

Triassic Units

Bull Run Formation: Leesburg Member

The Leesburg Member is characterized by a light reddish gray, cobble to boulder, limestone and dolomite conglomerate. Locally, thin layers of reddish brown, sandy siltstone partings are interbedded with the conglomerate. Most of the clasts are rounded to subangular and poorly sorted. The average size of the clasts that make up the conglomerate varies widely, from pebbles less than 1 cm in diameter to cobbles more than 30 cm across. The clasts are cemented by light reddish brown to reddish gray, silty carbonate cement. Although no detailed size analysis was conducted, there appears to be a relative decrease in cobble size from the western edge of the outcrop belt toward the east.

Bull Run Formation: Balls Bluff Siltstone Member

Lee (1979) interpreted the Balls Bluff Siltstone to be a fine-grained lateral equivalent to the conglomerates that constitute the Leesburg Member. The Balls Bluff Siltstone consists of reddish-brown to brownish-red, thin- to medium-bedded, argillaceous, sandy siltstone to silty mudstone. Locally, thin beds of argillaceous, silty, micaceous sandstone are present. Many of the mudstone intervals are characterized by strata that are pervaded by carbonate nodules and blebs. The extensive rooting and abundance of carbonate nodules are interpreted as caliche horizons.

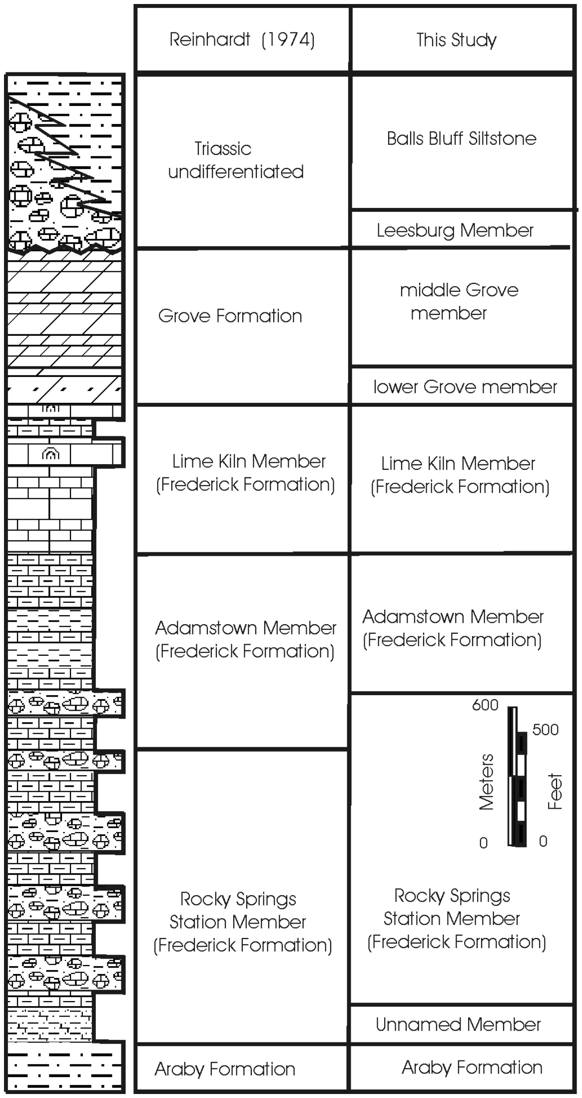

Figure 2. Generalized bedrock stratigraphy of the Frederick Valley, Frederick County, Maryland.

Manassas Formation

The Manassas Formation consists of four members in Virginia, but only two, the Poolesville and the Tuscarora Creek members are present in Maryland (Lee, 1979; Lee and Froelich, 1989). The Poolesville Member consists of thick intervals of reddish-brown, coarse-grained, sandstone interbedded with red, and reddish-brown, silty mudstone, and laminated, micaceous siltstone.

The Tuscarora Creek Member, a thin carbonate conglomerate, crops out along the eastern margin of the Triassic belt at the base of the Manassas Formation. The Tuscarora Creek Member consists of thickly bedded, light gray weathering carbonate conglomerate to breccia. The clasts range in size from 1 to 8 cm in diameter and are typically well rounded.

Cambrian Units

Araby Formation

Creating the eastern border of the Frederick Valley is a ridge of Lower Cambrian clastics assigned to the Araby Formation. This unit consists of thickly bedded, medium gray to dark greenish gray, fine-grained sandstone and sandy siltstone with numerous interbeds of greenish gray to dark gray, slaty shale. In fresh outcrop the sandstone intervals commonly exhibit an anastomosing network of burrows; in some intervals this so pervades the strata that all indications of bedding have been obliterated. Furthermore, because of the Araby's fine-grained character, secondary cleavage further penetrates the rocks, making recognition of stratification extremely difficult.

Frederick Formation: *Unnamed* member

Along the eastern margin of the Frederick Valley is an interval of limestone interbedded with black shale. This interval will herein be termed the *Unnamed* member. The *Unnamed* member of the Frederick Formation consists of a knotty lime mudstone with angular carbonate clasts surrounded by dark gray, dolomitic shale. The carbonate clasts within this knotty-appearing lithology have a tendency to weather more rapidly than does the surrounding siliciclastic matrix. Interbedded with this knotty lithology are intervals of very dark gray to black, platy, calcareous shale ranging from 1 to 8 m thick.

Frederick Formation: Rocky Spring Station Member

Reinhardt (1974) named the Rocky Spring Station Member for approximately 300 m of interbedded very thinly bedded dark gray shaly limestone, medium bedded, sandy gray limestone, and thick bedded, medium gray, polymictic (multiple lithology) limestone breccias the occur near the base of the Frederick Formation. The Rocky Spring Station Member is characterized by dark gray, very thinly bedded lime mudstone interbedded and interlaminated with black calcareous shale, sandy limestone, flaggy limestones and very thick, to massively bedded limestone breccia. These polymictic breccia beds are diagnostic of this member and are key characteristics to the origin and recognition of this member

Frederick Formation: Adamstown Member

Overlying the Rocky Spring Station Member is an interval characterized mainly by dark gray, very thinly bedded, lime mudstone with shaly partings. Reinhardt (1974) named this interval the Adamstown Member.

Reinhardt (1974, p. 24) estimated the thickness of the Adamstown at nearly 325 m. This thickness was verified by measured sections along the Monocacy River, along the eastern side of the Frederick Valley synclinorium.

Frederick Formation: Lime Kiln Member

The youngest and stratigraphically highest member of the Frederick Formation is named the Lime Kiln Member (Reinhardt, 1974). The Lime Kiln Member consists of thinly interbedded dark gray, thinly bedded lime mudstone and black calcareous shale with a few thicker layers up to 30 cm in thickness in the lower part of the member. The scattered thicker layers become more prominent and abundant up-section at the expense of the thinly interbedded limestone and shale intervals. Also appearing and becoming common near the middle and top of the member are lenticular, medium gray, sandy, lime grainstone and packstone that exhibit a sharp, presumably erosional base, and gradational upper contacts. These sandy intervals are up to 10 m thick. The upper 65 m of the member is marked by thick intervals of medium to dark gray, crudely bedded, algal thrombolite lime mudstone and stromatolitic lime mudstone interbedded with thinly bedded lime mudstone. The Lime Kiln Member is approximately 250 m thick at the type section.

Ordovician Units

Grove Formation: *lower* member

Jonas and Stose (1938) recognized and mapped a quartzose dolomitic unit at the base of the Grove Formation. This unit, which comprises the basal 30 to 70 m of the Grove Formation, is herein informally termed the *lower* member. This member consists of light gray, fractured, sandy, dolomite that is interbedded with intervals of very light gray, fractured, fine-grained dolomite. At least one of these non-sandy interbeds is interpreted to be a dolomitized algal thrombolite. The sand which characterizes the dolomitic intervals of this member vary from fine-grained to very coarse-grained and make up between 5 to 45 percent of the rock. Most of the larger sand grains are well rounded. Some sandy layers exhibit abundant cross-bedding, some of which is herringbone.

Grove Formation: *middle* member

Overlying the distinctive lower member, and making up the bulk of the formation's thickness is an interval composed of thickly bedded, thrombolitic lime mudstone, tan, laminated, dolomitic lime mudstone to dolostone, and light gray, sandy, intraclastic lime packstone to grainstone. This member, while attaining a thickness of more than 700 m in the vicinity of Woodsboro, Maryland, is probably represented in the southern part of Frederick Valley by no more than 60 to 120m of stratigraphic thickness.

KARST FEATURES

This study recognized and recorded three types of karst features: closed depressions, active sinkholes, and karst springs. By far the most common feature recognized were closed depressions, otherwise known as dolines. These features are recognizable topographic lows towards which the surrounding area is inclined and can be from a few meters to 100 m across. The second category of karst features recorded is active sinkholes. These features are differen-tiated from depressions by the recognition of

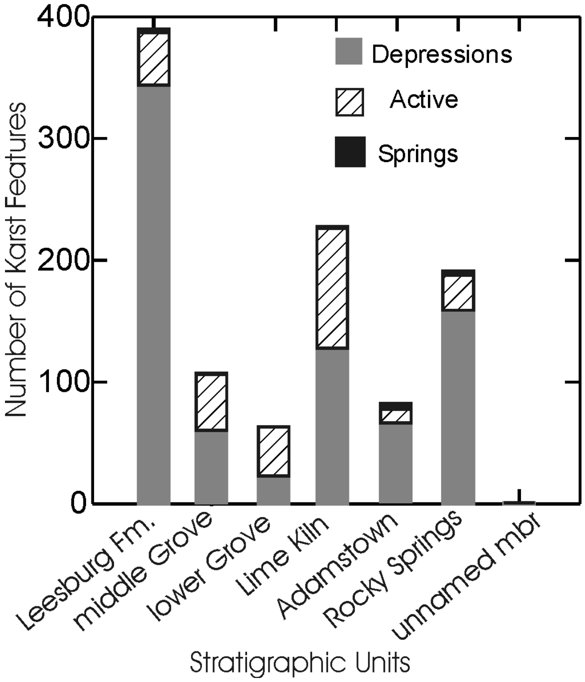

Figure 3. Stacked bar chart of karst features recorded from the Buckeystown, Point of Rocks, and Frederick quadrangles.

recent activity, or an open throat. The third category of karst features recognized is springs.

Data for the current study were attained through detailed geologic mapping of both geology and karst features for the southern part of the Frederick Valley. Such field analysis allowed for both the exact locations of geologic outcrops as well as karst features. While geology was plotted on a 7.5-minute topographic quadrangle map, all karst features were recorded utilizing Trimble GeoExplorer II and GeoExplorer III Global Positioning System (GPS) receivers. All GPS files were post-processed, an office procedure whereby the locations taken in the field are differentially corrected to increase the locations' precision. These corrected locations typically gave a precision of less than 1 m.

SUMMARY OF KARST FEATURES

One thousand and seventy-nine karst features have been identified in the southern part of the Frederick Valley (Buckeystown, Point of Rocks and Frederick 7.5 minute quadrangles).

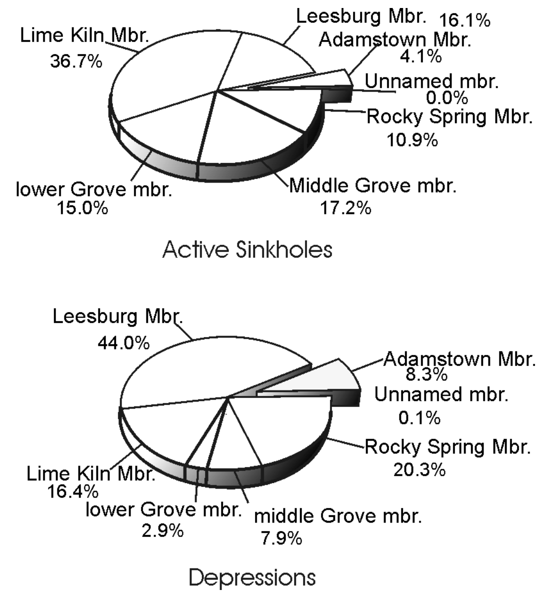

Figure 4. Pie diagrams illustrating break-down of active sinkholes (A) and depressions (B) for the Buckeystown, Point of Rocks, and Frederick quadrangles.

Figure 3 gives a breakdown of the types of features in a stacked bar chart. Depressions are by far the most common feature recorded, making up nearly 74 percent of all the readings. While active sinkholes comprised nearly 25 percent of the features, springs were a distant third making up only 1.3 percent of all karst features.

As one might suspect karst features were not distributed evenly throughout the Frederick Valley carbonate units. Some geologic units appear to have greater numbers of features than do others. Clearly, the Triassic Leesburg Formation has the greatest number of depressions (344), the Lime Kiln Member of the Frederick Formation has the largest number of active sinkholes (98), and the Adamstown Member the largest number of springs (5). These data are summarized more thoroughly in Table 1. One can see that most active sinkholes (69%) are contained within the Lime Kiln Member of the Frederick Formation (36.7%), lower Grove (15%), middle Grove (17.2%), and Leesburg (16.1%) (Figure 4). Although the Lime Kiln, lower Grove, middle Grove, and Leesburg contain the largest number of active sinkholes, most of the depressions (>80%) are

Table 1. Summary of karst feature distribution within susceptible stratigraphic units and their relative areal distributions

Unit	Depressions	Active	Springs	Area (sq.mi.)	Features/mile	Active/mile
Unnamed mbr.	1	0	0	2.72	0.37	0.0
Rocky Springs Station Mbr.	159	29	3	29.39	6.50	0.99
Adamstown Mbr.	65	11	5	9.4	8.6	1.17
Lime Kiln Mbr.	128	98	2	5.94	38.38	16.5
lower Grove mbr.	23	40	0	2.44	25.82	16.39
middle Grove mbr.	62	46	1	2.65	41.13	17.37
Leesburg Mbr.	344	43	3	8.72	44.72	0.96
Totals	782	267	14	61.26		

contained in the Leesburg Formation (44%), Rocky Springs Station Member of the Frederick Formation (20.3%), and Lime Kiln Member of the Frederick Formation (16.4%) (Figure 4). Only the Lime Kiln Member has large numbers of both active sinkholes and depressions. This summary illustrates that not all karst-prone units in the Frederick Valley are equally susceptible. However, it does little to tell why this is so.

KARST FEATURE DISTRIBUTION

One of the main purposes of this study is to both map the distribution of karst features and to examine their distribution with respect to the stratigraphic unit. As discussed above a general pattern of karst features and can be gleaned from the data now at hand. The comparatively high incidence of karst features within the Lime Kiln is again illustrated in Table 1.

It would appear, utilizing raw numbers of Table 1, that the most karstic unit studied is the Leesburg Formation with almost 400 features recorded within its outcrop belt. Likewise, dividing the area (in square miles) underlain by that unit by the number of karst features recorded for that unit gives an average of 44.72 karst features per square mile. This is the most of any unit discerned. Conversely, the Rocky Spring Station Member, which has nearly 200 karst features recognized within its outcrop belt has an average of only 6.5 features per square mile, because the area underlain by this unit is so large.

When one normalizes the number of sinkholes in a similar fashion as above, by dividing the number by the area underlain by each unit, a slightly different image develops. The Leesburg Formation, with an average of 44.72 features per square mile, has only 0.96 active sinkholes per square mile. The Rocky Springs Station likewise has a low 0.99 active sinkholes per square mile. However, the Lime Kiln Member of the Frederick Formation, which has a relative high 38.38 karst features per square mile, has a relatively high 16.5 active sinkholes per square mile. The two Grove members produce some of the highest numbers of any of the units with 16.39 and 17.37 active sinkholes per square mile, respectively. Consequently, from unit to unit there are notable differences between the likelihood of encountering depressions and active sinkholes (see Table 1).

KARST SUSCEPTIBILITY

Figure 5 gives the general relationships of the susceptibility of the stratigraphic units of the Frederick Valley of Maryland that were utilized in this study. While this curve on the right is general and empirical, it is meant to give a relative susceptibility of the individual stratigraphic units. From this graph one can see that the relative susceptibility for the lower units of the Frederick Formation is low, with the exception of some of the purer breccia beds of the Rocky Springs Station Member. The upper Frederick (Lime Kiln Member) and the lower Grove member are rated as highly susceptible based upon the large number of active sinkholes recorded in these units. The Triassic Leesburg is relatively low in its susceptibility even though there are large numbers of depressions recorded within its outcrop belt. It is rated low because very few active sinkholes have been identified within it.

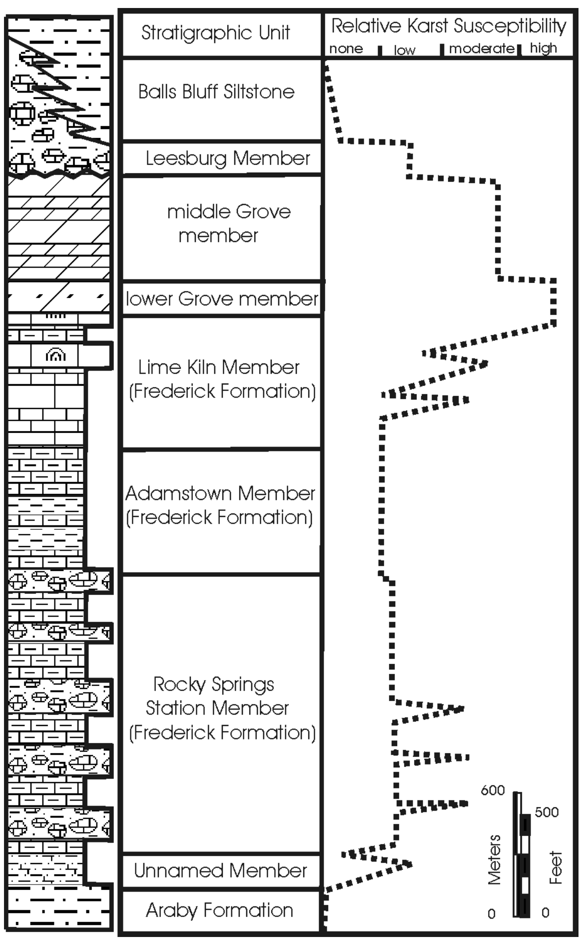

Figure 5. Relative karst susceptibility of the stratigraphic units of the Frederick Valley.

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