

Stratigraphic Distribution of Cave Volume in the Edwards Limestone, Southern Travis County, Texas

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Introduction

The Edwards Aquifer of Texas, especially the Barton Springs Segment of the aquifer just south of Austin, is developed in limestone units with several distinctive hydrologic members (Hanson, 1995; Hanson and Small, 1995; Small and others, 1996). These members provide a unique opportunity to examine the effects of variations in stratigraphy on the development of caves and solution conduits.

Many current accounts of speleogenesis discuss in detail the development of large cave systems, but one important aspect is generally neglected: the stratigraphic control of solution. Most discussions assume the existence of a thick, relatively homogeneous sequence of soluble rock. They discuss in detail the influence of joints, bedding planes, regional groundwater levels, and upwelling aggressive groundwater and the production of sulfuric acid and mention the occasional "resistant horizon" like the Hartstelle Sandstone in the southeastern United States. But there are few discussions of cases like the Edwards Aquifer of Texas, where groundwater flows along the strike of the limestone for long distances, units of varying physical and chemical composition are exposed to solution, and groundwater is free to establish flow paths through favorable units. In the Edwards Aquifer, there is a complex interplay between chemical composition, mechanical strength, grain size, chemical composition, and diagenetic history. The study of the stratigraphic control of solution in the Edwards Aquifer provide important information on the role of stratigraphy in karst development and have important implications for reservoir formation and water resource development.

Methods

The location (TSS, 2007) and stratigraphic position of the solution volume of 122 caves in the outcrop area of the Barton Springs Segment of Edwards Aquifer was determined: all caves in the Travis County portion of the aquifer were surveyed, except for 14 small caves on the cliffs overlooking Town Lake and 15 small caves for which the stratigraphic position could not be determined due to uncertainty in location. In addition, one cave on the Travis-Hays county line and one cave a few hundred feet into Hays County are included. Many of the caves intersected an obvious marker bed, which was used to determine the stratigraphic location of the solution

volume. In caves without marker beds, the position of the cave was plotted on a geologic map of the Barton Springs Segment of the Edwards Aquifer (BSEACD, 1997, and more recent editions), and the stratigraphic location was determined. Then, using cave maps from the Texas Speleological Survey, the volume of the cave was divided into 10-foot stratigraphic intervals. There was no attempt to adjust the solution volume to include the volume of sediment in a cave; only the actual observable space was counted. Overall, cave fills, mostly Pleistocene red clay and recent black clay from surface erosion, have reduced the cave volume by only a small percentage. In addition, shelter caves were not included in the study since much of their volume is due to enlargement by surface-related processes.

A standard stratigraphic column for the Edwards Aquifer was developed as a model against which to plot the stratigraphic position of each cave volume. The members were assumed to have the following thicknesses (based on information from Brune, 1983; Hanson, 1995; and Hauwert, 1995): Leached-Collapsed: 70 feet, Regional Dense: 20 feet, Grainstone: 50 feet, Kirschberg: 70 feet, Dolomitic: 130 feet, and Walnut: 60 feet, for a total Edwards Aquifer thickness of 400 feet. This is only an approximation as the members do not have a constant thickness across the area surveyed. If the average thickness of a member is somewhat exaggerated, then the relative cave volume shown for this member will be diminished, but this effect is not believed to be large except for the Leached-Collapsed Member. To preserve the relationship between the Regional Dense Member and stratigraphic position, all stratigraphic thicknesses are measured from the base of the Leached-Collapsed Member just above the Regional Dense Member, and since the Leached-Collapsed Member thins across the study area, the upper portion of the member is likely somewhat more favorable for cave development than indicated.

Results

The total volume of accessible cave in each ten-foot stratigraphic interval was plotted to form the graph displayed in Figure 1. As might be expected in a sequence of rock with different depositional environments and chemical composition, the amount of solution volume in each interval varies considerably, ranging from a complete absence of known caves to zones with numerous significant caves.

The total cave volume measured was 724,980 cubic feet in an outcrop area of about 44 square miles, or 1,226,649,600 square feet. This is approximately 0.0006 cubic feet of cave volume per square foot over the entire Edwards outcrop. If the Edwards Limestone in the outcrop area averages 300 feet thick (400 feet stratigraphic thickness less 100 feet of erosion) and the average percentage of interconnected voids is 5 percent, then there is 300 times 0.05 or 15 cubic feet of volume under each square foot. So far, we have access to 0.0006 cubic feet of cave per square foot of outcrop, or 0.004 percent (0.0006/15) of the potential volume. Even though much of this volume is in openings too small for humans to enter, there is likely much more cave to be found.

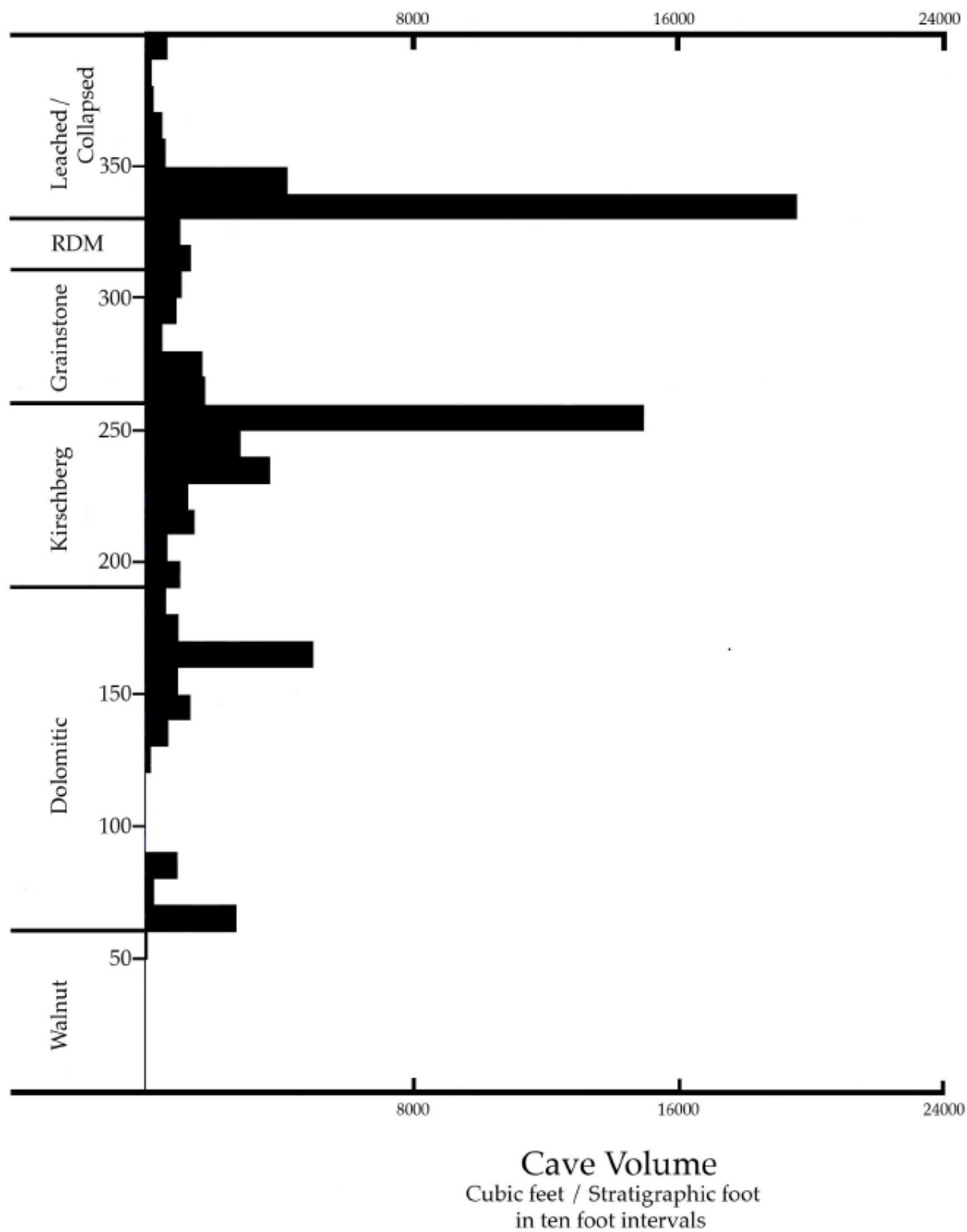


Figure 1. Distribution of Cave Volume in the Edwards Limestone in Southern Travis County, Texas. The vertical axis is the stratigraphic thickness measured in feet.

Discussion

There are two conspicuous zones in the Edwards Aquifer especially favorable for cave formation. The uppermost is the Upper Solution Collapse Zone, first identified by Rodda (Rodda and others, 1970) that includes Airman's Cave and numerous smaller caves. This zone is developed at the base of the Leached-Collapsed Member, just above the Regional Dense Member. The Regional Dense Member is resistant to solution and acts as a local barrier to water flow, forcing groundwater to flow laterally through solutionally favorable beds in the lowermost Leached-Collapsed Member, greatly increasing the amount of solution at this level and causing the collapse that gave this member its name.

The other zone especially favorable for cave formation is the uppermost Kirschberg Member, where many caves are formed along the contact between the Kirschberg Member and the overlying Grainstone Member. The Kirschberg Member is a very soluble unit but is mechanically weak. Caves developed at the top of this member are protected from collapse by competent beds of the overlying Grainstone Member, while conduits developed within the member are blocked by frequent collapse, limiting their ability to form large cave systems. Caves developed at the top of the Kirschberg Member include Whirlpool Cave, County Line Bat Cave, Barker Bat Cave, Tres Amigos Cave, Get Down Cave and many others. Less prominent concentrations of cave development also occur near the top of the Dolomitic Member and near the base of the Dolomitic Member.

There is a 30-foot zone in the lower Dolomitic Member with no known cave development. Streams in the lower levels of Blowing Sink Cave are perched on this insoluble zone, passages in Flint Ridge Cave end at this stratigraphic level, and Backdoor Spring that flows into Barton Creek is developed above this zone. This zone is not completely effective in blocking water flow—fracturing along faults likely allows some flow through this unit—but it does tend to concentrate solution above this zone. There is very little cave development in the Walnut Member, on which a few springs are perched but, in most areas, there is enough solution in the Walnut Member so that springs issue from within the member.

As in most karst areas, Travis County caves have a logarithmic size distribution with a few large caves and a large number of small caves. The largest cave, Airman's Cave, has a volume of 138,000 cubic feet or 19 percent of the total explored volume. This cave represents 71 percent of the volume of the upper solution/collapse zone; if the entrance to this cave had not been dug out by cavers, the upper solution/collapse zone would appear to be less prominent. Though the distribution of cave volume is strongly influenced by the few large caves, cavers looking for caves were not aware of the geologically favorable parts of the Edwards Aquifer outcrop, so all areas were searched with equal diligence. Thus, the distribution of explored cave volume likely approximates the distribution of all large voids in the Edwards Aquifer. Outcrop characteristics and water well data also support the conclusions derived from the cave data. The observed distribution of large voids does not appear to be just an artifact of exploration.

The distribution of sinkhole volume is significantly different from the distribution of cave volume. Large surface sinks are concentrated on the outcrop of the Kirschberg Member, where over 90 percent of the sinkhole volume is also located, while only 33 percent of the cave volume is in the Kirschberg Member. This is due to the nature of the Kirschberg Member, with numerous thin, easily dissolved beds that are entirely removed by solution, causing collapse that forms

laterally extensive debris piles. The openings in this solution rubble transmit large amounts of water but are much too small to be explored, and so do not count as cave volume. The major cave-forming conduits develop at the top of the Kirschberg Member, where the overlying Grainstone Member forms a supporting roof that allows large openings to form. When the solution rubble is exposed to surface weathering, it tends to form broad shallow sinkholes, as weathered surface material is carried down into the numerous voids.

At least 20 percent of the solution volume listed for the Regional Dense Member is not solution, but rather volume created by collapse. The Regional Dense Member normally acts as a barrier to groundwater flow, and so caves form where groundwater can flow through fractures in the Regional Dense Member. These fractured areas concentrate flow into the underlying more soluble units and form large solution voids. Thereafter, large blocks of the fractured Regional Dense Member collapse into the voids. In most cases, an accurate estimate of the volume of the collapsed blocks was not possible, so no attempt was made to adjust the volume to exclude the collapse volume.

Acknowledgments

This report would not have been possible without the help of the many cavers who have contributed information to the Texas Speleological Survey. Their many hours spent mapping and exploring the caves of the area have provided the information used in this note. The cooperation and comments by the staff of the Barton Springs/Edward Aquifer Conservation District, the City of Austin Watershed Protection Department, and the City of Austin Wildlands Conservation Department are most appreciated. Nico Hauwert of the City of Austin Watershed Protection Department has been invaluable in all aspects of this note, and his review is much appreciated. In the immediate future, we plan a more detailed report on solution development that will cover the entire Barton Springs Segment of the Edwards Aquifer.

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Biography

William H. Russell is a long-time Austin cave explorer and student of the karst. He graduated from The University of Texas at Austin in 1969 with a degree in geography, concentrating in physical geography. He studied under J. Hoover Mackin and other prominent geologists at the university and has been updating their insights with current data ever since. He has published geologic studies on karst areas in Texas and Mexico. Local publications include a study of the Buttercup Creek Karst in northern Travis and southern Williamson County and an analysis of the Circle C pipeline spill in southern Travis County.