A STRUCTURAL EXPLANATION FOR THE RELATIVELY LARGE MAPPED LENGTH OF SNAIL SHELL CAVE, CENTRAL TENNESSEE

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ABSTRACT

At >14.5 km in length, Snail Shell Cave is the westernmost of the 8 caves having the largest mapped lengths in Tennessee. The Western and Central parts mostly trend 270–280º and comprise >35% of the cave's mapped length. A structure surface (digital elevation model of a geologic contact) of the late Ordovician Lebanon-Carters contact shows that the Western and Central parts of the cave are within 378 ±9 m of and are parallel to the crest of a gentle doubly-plunging ~4.8 km long anticline trending ~282º, associated with ~18 m of structural relief, and occupying an area of ~6.17 km^2. The surface was constructed using natural neighbor interpolation of the elevations of the Lebanon-Carters and late Ordovician Ridley-Lebanon contacts. Elevations are from a LiDAR-based digital elevation model having a nominal point spacing of 1.5 m and a vertical accuracy better than ±9 cm. In Tennessee, similar relationships between gentle structural highs and groundwater conduits exist within Mississippian limestones at locations ~105–145 km to the east. On geologic maps, those locations are within ~11 km of macroscale faults, but Snail Shell Cave is ~95 km W of the nearest macroscale Appalachian foreland fault mapped at the surface.

INTRODUCTION: WHAT NEEDS EXPLAINING?

In Kentucky, USA, the Interior Low Plateaus geomorphic province contains Mammoth Cave, which currently has the largest mapped length of any in the world. To the S, six of Tennessee's eight longest caves are located farther E within the Cumberland Escarpment (Fig. 1A) at the boundary between the Interior Low Plateaus province and the Cumberland Plateau, a part of the Appalachian Plateaus geomorphic province. Of the other two, one is located along the Highland Rim Escarpment at the edge of the Nashville Basin, a lowland within the Interior Low Plateaus province. In contrast, Snail Shell Cave has a mapped length of >14.5 km (>9.1 mi) and is located in Rutherford County within the Nashville Basin to the W of the other long Tennessee caves.

Some caves in eastern Tennessee formed within gentle anticlines and domes (Crawford, 1984).

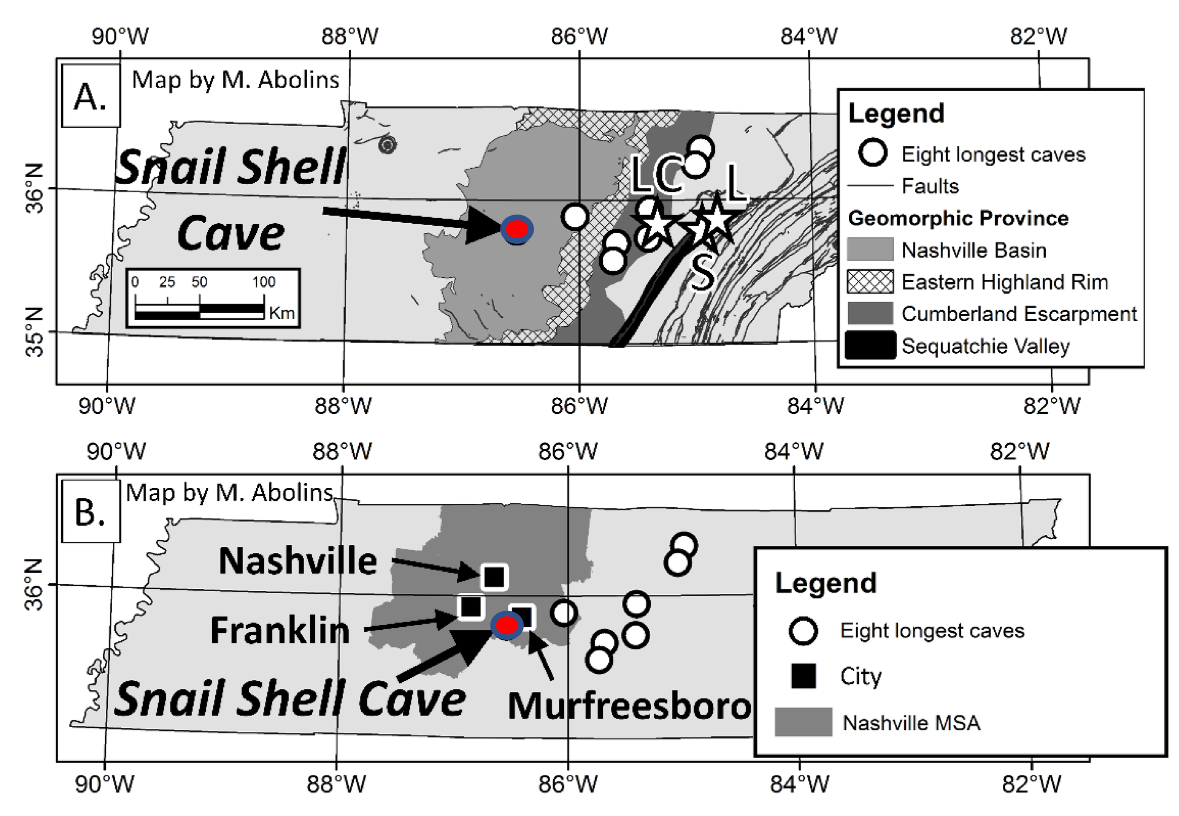

Figure 1. A. Location of Snail Shell Cave, Tennessee in relation to other long caves (Gulden, 2019), geomorphic provinces, and macroscale faults mapped at the surface (Hardeman et al., 1966). The Nashville Basin and Eastern Highland Rim are part of the Interior Low Plateaus geomorphic province, and the Cumberland Escarpment is the boundary between the Interior Low Plateaus and the Cumberland Plateau, a part of the Appalachian Plateaus province. Locations (stars) where Crawford (1984) described groundwater conduits associated with gentle anticlines and domes: S-Swagerty Cove, L-Little Cove, LC-Lost Creek Cove. The geomorphic provinces are as depicted in Niemiller and Zigler (2013). B. Location of Snail Shell Cave with respect to the Nashville Metropolitan Statistical Area (MSA), Tennessee and principal cities within the MSA.

DATA AND METHODS

Data: Cave Map (Matthews and Biddix, 2012). Snail Shell Cave has distinct Western, Central, and Eastern parts (Fig. 2). The Western ~3.15 km (~1.96 mi) of the cave consists almost entirely of a single passage trending WNW. The Central part of the cave has a straight-line length of ~1.29 km (~0.80 mi) and also trends WNW, but is more complex. The Central part of the cave is itself divided into west-central and east-central parts. The west-central part consists of two main passages separated by up to 210 m (690 ft), and the east-central part is anastomosing. The two parts meet near the principal entrance to the cave, a steep-sided sinkhole having a depth exceeding 25 m according to the LiDAR-based DEM. Much of the Eastern part of the cave differs markedly in orientation from the Western and Central parts, having many passages trending NE.

Data: Geologic Map (Wilson, 1965) and LiDAR DEM. The structure surface (digital elevation model of a geologic contact) is comprised of cells containing values for the actual and interpolated elevation of the Lebanon-Carters contact. Wilson (1965) mapped the contact in areas above the cave and near the cave in the northern part of Fig. 2, and we extracted the nearest elevation from the LiDAR-based Earth surface elevation DEM (1.5 m point spacing and accuracy better than ±9 cm) to each point on the contact in those areas. To the S, exposures of the contact are greater than 1,250 m (~4,100 ft) and mostly greater than 2,000 m (~6,560 ft) from the cave, providing limited information about structure near the cave. However, the Ridley-Lebanon contact outcrops closer to the cave to the S and SW of the cave. At those locations, we estimated the elevation of the Lebanon-Carters contact by adding the ~24 m (79 ft) estimated thickness of the Lebanon Limestone to the elevation of the Ridley-Lebanon contact.

Method: Interpolation. We used ArcGIS software to interpolate a natural neighbor surface (Sibson, 1981). By its nature, a natural neighbor surface passes through control points, nearby control points contribute the most to the elevation of each location on the surface, and the number of nearby points varies from place to place.

We checked for errors either (a) introduced by interpolation or (b) reflecting mistakes on the geologic map (Wilson, 1965). To do so, we intersected the Lebanon-Carters structure surface with the LiDAR-based DEM of the Earth's surface to identify areas where the Lebanon-Carters contact should be exposed at the surface if the structure surface is accurate.

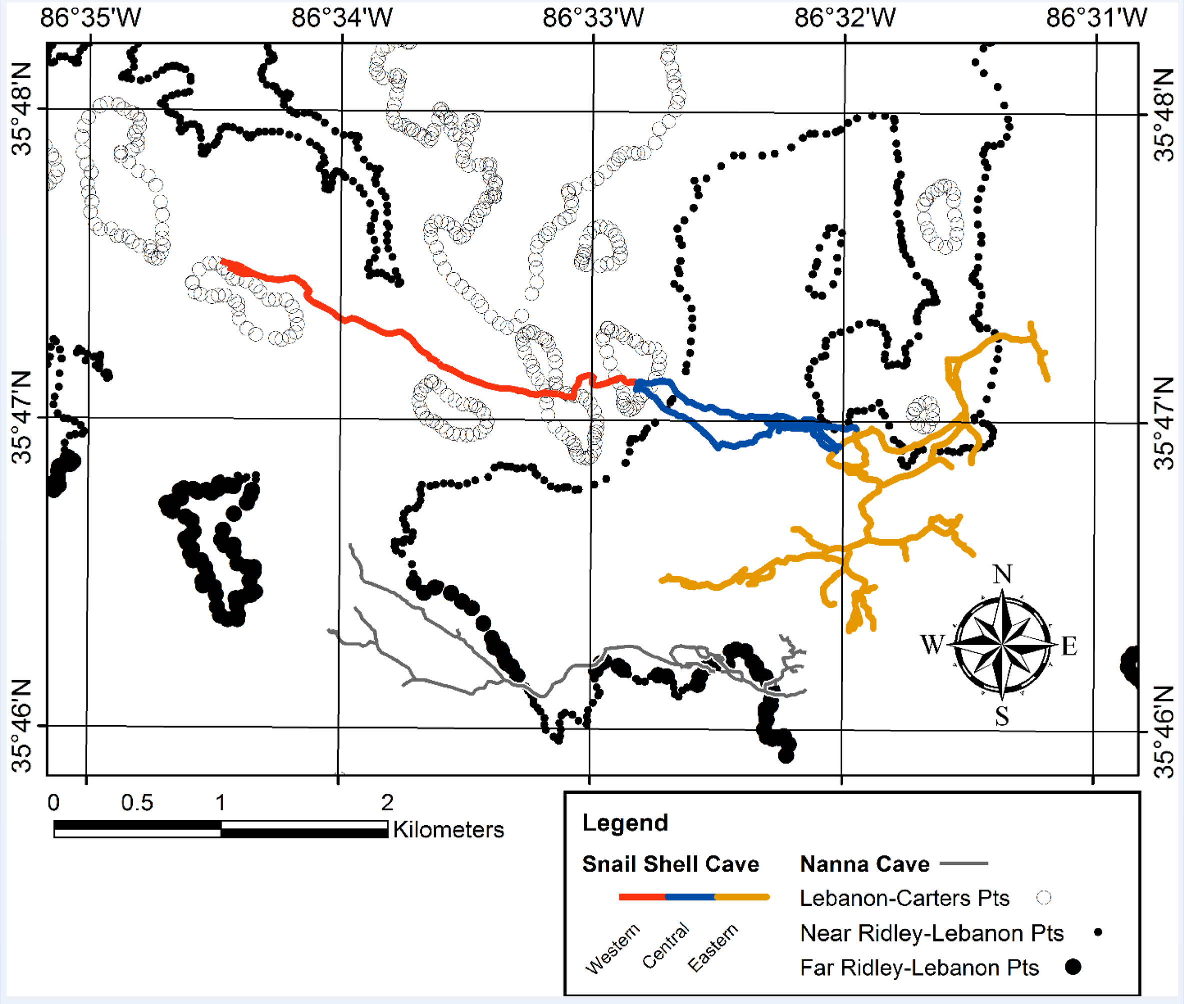

Figure 2. Control points on the late Ordovician Lebanon-Carters and late Ordovician Ridley-Lebanon contacts in the vicinity of Snail Shell Cave. "Near" Ridley-Lebanon points are those within ~914 m (3,000 ft) of the Lebanon-Carters contact, and "Far" points are those at a greater distance. Geology from Wilson (1965). Cave maps from Matthews and Biddix (2012).

RESULTS

Application of natural neighbor interpolation to control points shows that the Western and Central parts of the cave are within a doubly-plunging anticline (Fig. 3) herein named the "Snail Shell Anticline." The anticline is defined as the area in which the structure surface exceeds ~272 m (891 ft) above mean sea level because elevations exceeding this value define a closed ~6.17 km^2 (~2.38 mi^2) area which is separate from other high-elevation areas on our interpolated surface. Within the anticline, relief on the contact is ~17.7 m (~58 ft). The error analysis described under "Method: Interpolation" revealed a few errors, but none are within the anticline.

Western Snail Shell Cave is consistently 100–378 m ±8.9* m NNE of the crest as mapped by using the LiDAR elevations of the control points, and the Western cave is within the limb of the anticline, parallels the crest, and is not co-located with the crest. Central Snail Shell Cave is also within the anticline and parallels the crest. However, the location of the crest is not as well-constrained near that part of the cave, so Central Snail Shell Cave is either near the crest or in places co-located with the crest. The Western and Central cave comprise >35% of the total length of the cave, and the cave would not be among the eight longest in Tennessee without those parts. In contrast, the Eastern cave lies outside the anticline and much of it trends NE.

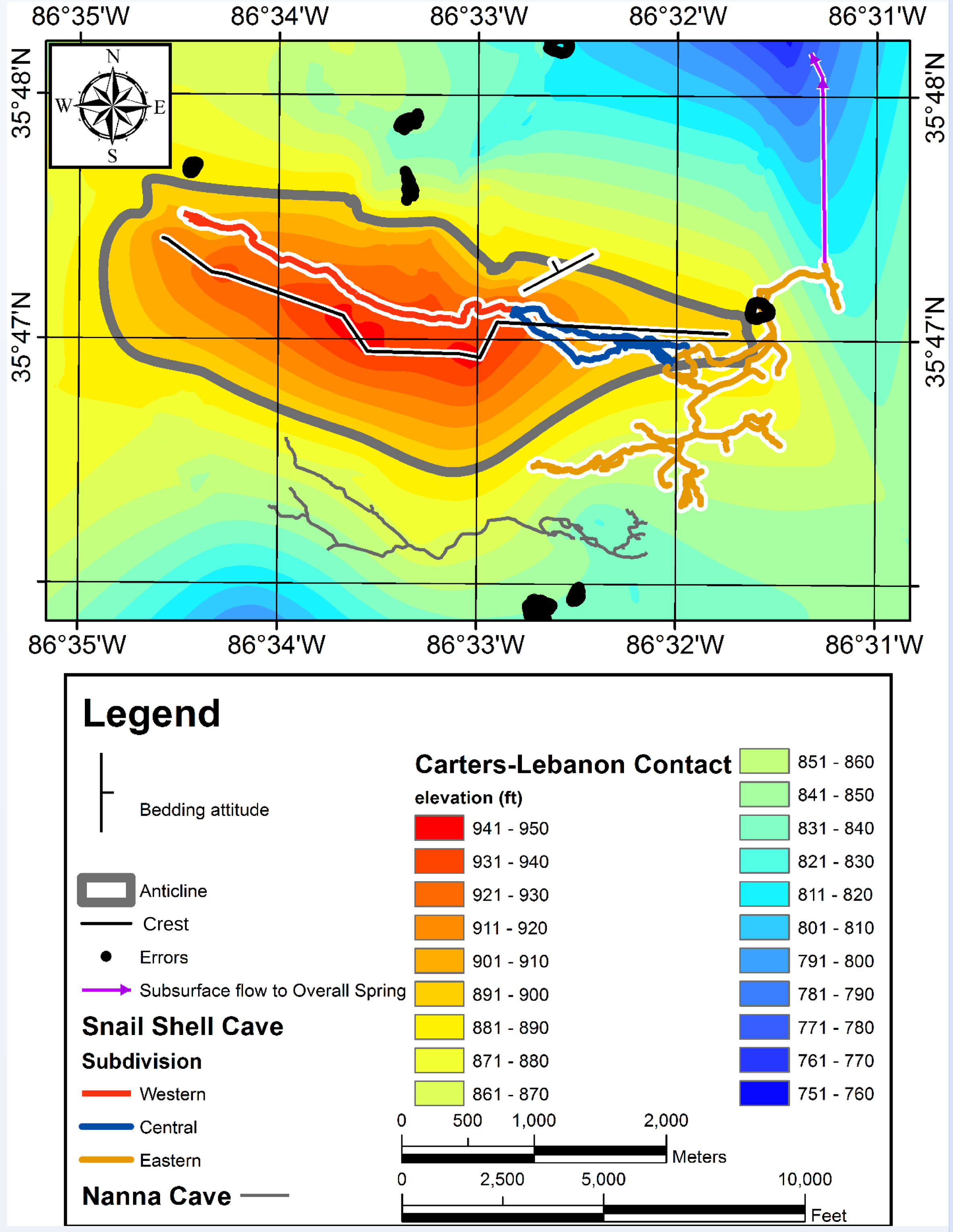

Figure 3. Surface showing interpolated elevation of the Lebanon-Carters contact, the crest of the anticline, Snail Shell Cave, the orientation of bedding at a single location (Wilson, 1965), a dye trace connecting the cave stream with Overall Spring, and errors. See Fig. 2 for control points. Cave map and dye trace from Matthews and Biddix (2012).

* The positional accuracy of the structure surface is ±8.9 m which is the square root of the sum of the squared positional accuracies of the digital captures of the geologic map (~4.6 m), the generalized cave map (~7.6 m), and the DEM (1 m). The positional accuracy of the original cave survey map depicted in Matthews and Biddix (2012) is unknown.

CONCLUSIONS

- More than 35% of the mapped length of Snail Shell Cave is attributable to the development of cave passages in gently-dipping late Ordovician strata within the limb of an anticline near the fold's crest.
- The anticline is the site-specific structure explaining why Snail Shell Cave is the westernmost of Tennessee's 8 longest caves.
- Structural controls on the orientation of Western Snail Shell Cave are similar to those on groundwater conduits ~145 km to the E beneath Swagerty Cove, Tennessee (Crawford, 1984) and at other locations in eastern Tennessee. Similarities demonstrate the broader applicability of a model originally developed for the location and orientation of cave passages within gently-folded Mississippian strata as close as ~4.35 km to a foreland thrust. The model is applicable to a cave developed in Ordovician strata ~95 km W of the westernmost exposed macroscale foreland fault.

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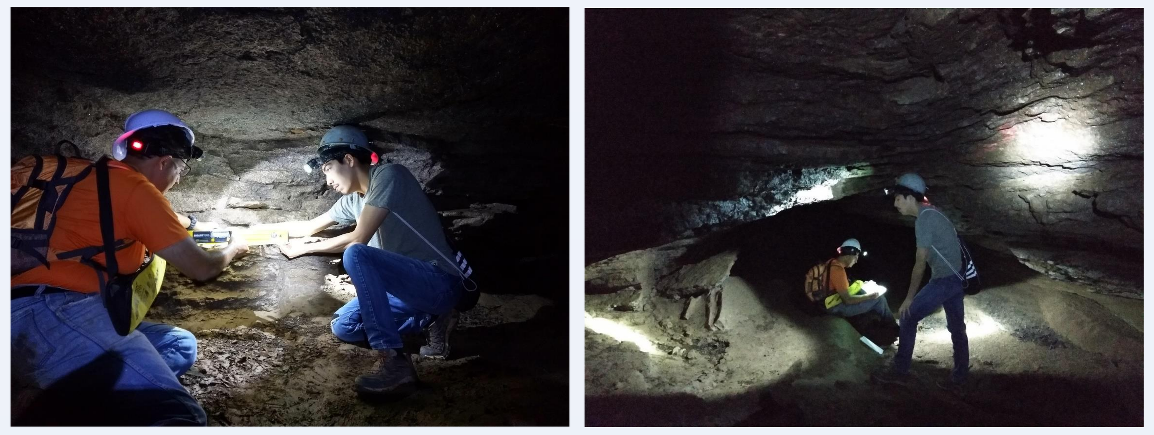

Two views of Dr. Mark Abolins (left) and MTSU Undergraduate Mark Olivera (right) in Snail Shell Cave, July, 2018. Photos by Josh Upham, City of Murfreesboro, TN.

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Although the Snail Shell Cave map appears in Matthews and Biddix (2012), numerous cave explorers contributed to the map. See Matthews and Biddix (2012) for the history of Snail Shell Cave exploration.

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