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Effects of Faulting on Past and Present Hydrogeology in Long Cave, Mammoth Cave National Park

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Introduction

Long Cave is located near the southeastern corner of Mammoth Cave National Park, and the Cave Research Foundation survey stands at 1.32 miles or 2.13 kilometers (Osburn 2003). Though Long Cave is not very long by local standards, almost all of it is large trunk passage corresponding to Palmer's Level B in Mammoth Cave (Palmer 1981). There are many fascinating aspects to Long Cave, such as the activities of prehistoric Indian cavers, large colonies of bats, saltpeter mining during the War of 1812, cave tours in the 19th century, a hermit (Sides and Warnell 2013), and of course geology.

In general, geologic structure in the area is subtle, with strata dipping to the northwest roughly at less than a degree (Palmer 1981) although the Turnhole Bend area of the park displays considerable faulting (Olson and Toomey 2009). Long Cave is unusual in that seven faults are visible in less than a mile and a half of passages.

These faults probably date to the Cretaceous Period about 100 million years ago, and appear to have had effects on cave development in the range of 3-10 million years ago under phreatic conditions. In some cases there are apparent effects today under vadose conditions. The faults described in this paper have not been previously reported, and were discovered during paleontological inventory work conducted in 2001.

Field Measurements

Strike and dip data were taken with Suunto compass and clinometers respectively. Displacements were measured with a fiberglass survey tape graduated in feet and tenths of feet where possible. The faults are described in the following paragraphs, with locations shown in Figure 1, and data summarized in Table 1.

The first significant fault encountered in the cave is at the junction of the entrance passage and Grand Avenue, near survey station A19, there is a normal fault with a strike of 45 degrees, a dip of 47 degrees to the northwest, and a displacement of 46 centimeters (18 in) down to the southeast. There is also a fracture running down the axis of the entrance passage near station Z8 with an orientation of 46 degrees but with no visible displacement or dip. However, there is a breccia zone up to 15cm (6in) wide (Figures 1 and 2).

At the junction of the main passage and the Echo Passage, a fault is visible in the north wall near survey station X1 (Figure 3). This is a reverse fault with a strike of 62 degrees, a dip of 83 degrees to the northwest, and a displacement of 1.37 meters (54 inches) down to the southeast. The fractures exposed in the wall at X1 are very complex so this description may not be complete. What seems likely to be the same fault or closely related is visible in the walls of a shaft complex at survey station DA5. It is too high up the wall to measure the displacement directly, but is estimated to be about 1.2 meters (48 inches) down to the southeast. It has a strike of 54 degrees and appears to be vertical. Being so close to one another, it is difficult to imagine that the faults at X1 and DA5 are not closely related despite the differences in strike and dip. This part of the cave needs closer study.

Further south in the Echo Passage, a fault crosses near survey station D19. This vertical fault has a strike of 49 degrees, and a displacement of approximately 30 cm (12 inches), down to the southeast.

Near the end of the Echo Passage there are two more small faults. One is located near survey station X33, and is vertical with a strike of 48 degrees and a displacement of 15 cm (6 inches), down to the southeast. The other fault is near survey station D2B, is also vertical, and has a displacement of 30 cm (12 inches), but is down to the northwest, opposite of all the others.

Finally, in Grand Avenue about 60 meters (200 feet) west of the Echo Passage/Grand Avenue junction, there is a fault at survey station Y6. This is a vertical fault with a strike at 75 degrees and a displacement of 50 centimeters (20 inches), down to the southeast.

Table 1: This tabulation summarizes location, orientation, displacement, and other characteristics of faults observed in Long Cave.

Nearby Station	Fault Type	Displacement	Strike	Dip
A19	Normal	46cm /1 8in	45º	47º
X1	Reverse	1.37m / 54in	62º	83º
DA5	Normal	~1.2m / 48in	54º	90º
D19	Normal	30cm / 12in	49º	90º
X33	Normal	15cm / 6in	48º	90º
D2B	Normal	30cm / 12in	38º	90º
Y6	Normal	50cm / 20in	75º	90º

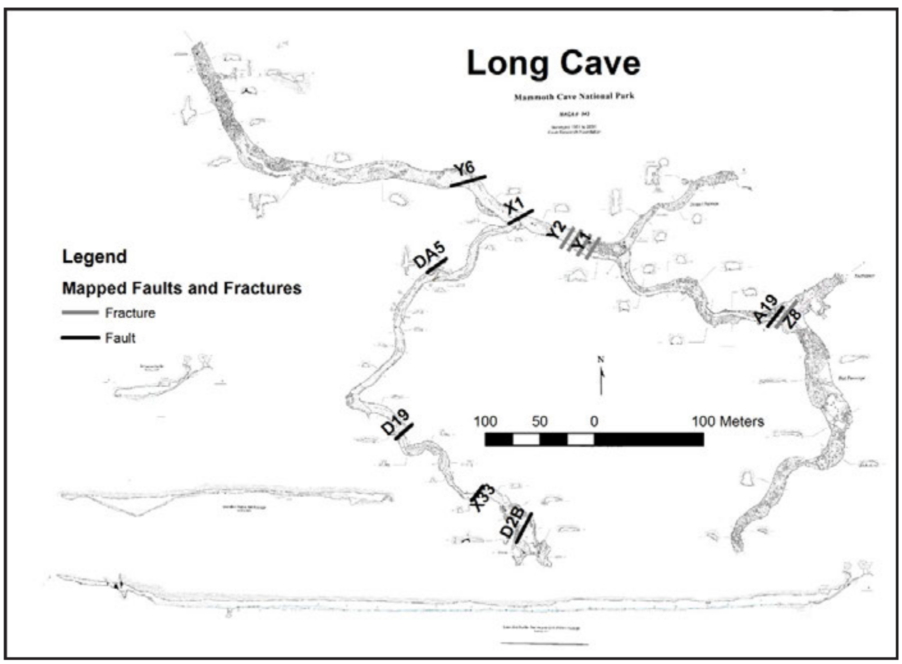

Figure 1: Map of Long Cave showing locations of faults and fractures discussed in the text. Base map courtesy of Bob Osburn and the Cave Research Foundation; map modified by Rick Toomey.

Effects of the Faults and Fractures

Passages in the Mammoth Cave area are not generally fault or fracture controlled, so it would be unusual if the entrance passage development was affected by the fault at A19 or the fracture with breccia running down the entrance passage ceiling at Z8 (see Figure 1). However, we can make a couple of observations that raise interesting questions.

First, if the entrance passage was tributary to the main flow coming from the south, then there would be two large passages contributing to westward flow in Grand Avenue, but this passage is smaller in cross-section. Second, there is a phreatic ceiling channel along the axis of the fracture seen at Z8, which could indicate flow to the northeast. The beginning of this phreatic ceiling channel and the fracture can be seen in Figure 2, and more of it is visible in an unpublished LIDAR scan conducted by Aaron Addison of the Cave Research Foundation. This part of the cave needs closer examination.

At survey station X1, the fault resulted in a high phreatic ceiling fissure across Grand Avenue to the junction with the Echo Passage, which was a tributary to Grand Avenue. The displacement of this fault is more than most in the Mammoth Cave area, and it appears to have caused an unusual orientation between this tributary and Grand Avenue.

Normally a tributary passage joins a main passage at an angle of 90 degrees (perpendicular) or less such that the

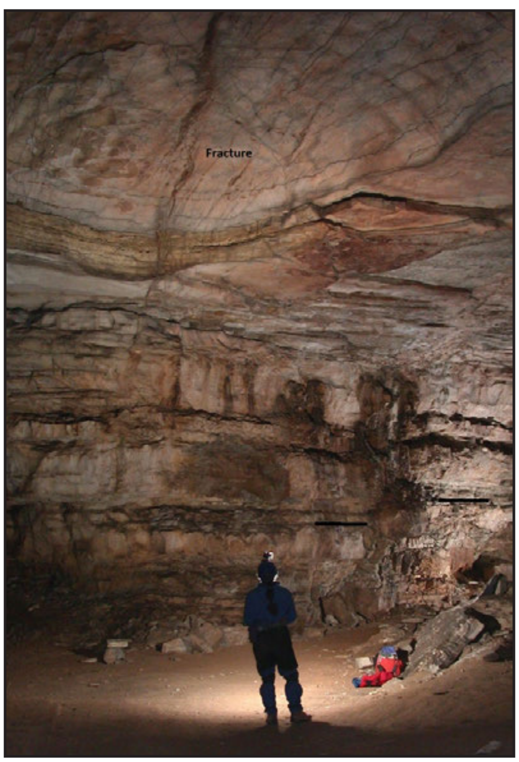

Figure 2: Fault at A19 and fracture at Z8 where the entrance passage joins Grand Avenue. The fault is shown with black bars to the right of Mona Colburn, and the brecciated ceiling fracture is labelled at top center. All photos are by Rick Olson unless otherwise noted.

Figure 3: Fault in Grand Avenue at X1. Displacement is shown with black bars on either side of Mona Colburn.

waters flow together in a normal dendritic pattern. In this case however, water from Echo Passage was flowing eastward in the direction of about 80 degrees and had to turn 140 degrees to join the main flow in Grand Avenue. At this passage junction, it appears that water would have flowed to the southeast, but scallops in Grand Avenue indicate flow to the west and north.

The shaft complex at DA5 is developed within the same fault seen at X1, or in one closely related. Apparently this fault allowed water to penetrate the sandstone/shale cap rock in a part of the cave that is otherwise very dry (Figure 4).

On either side of the fault at D19, passage morphology is quite different. To the southeast (paleo-upstream) it is a walking-height canyon. Northwest of the fault, the passage abruptly becomes a low wide tube of stoop-walking height. As well, the passage changes from moist in the southeast portion to dusty dry in the northwest. This is because an intermittent stream flowing from the southeast sinks under the northwest wall of the passage where the fault is located (Figure 5).

The fault at X33 facilitated development of a high phreatic ceiling fissure approximately 6 meters (20 feet) high with much breccia visible. The nearby fault at D2B also resulted in upward solution along the fracture. At both of these faults a purple patina is prominent on the ceiling, and at D2B there is flowstone tinted green. The cause of this coloration is not known, but investigation by a microbiologist is recommended (Figure 6). These two faults and the one at D19 are all oriented toward Grand Avenue between the entrance passage and the beginning of Echo Passage, but the only expression of tectonic action in this area is a fracture swarm with a strike of 31 degrees located near survey

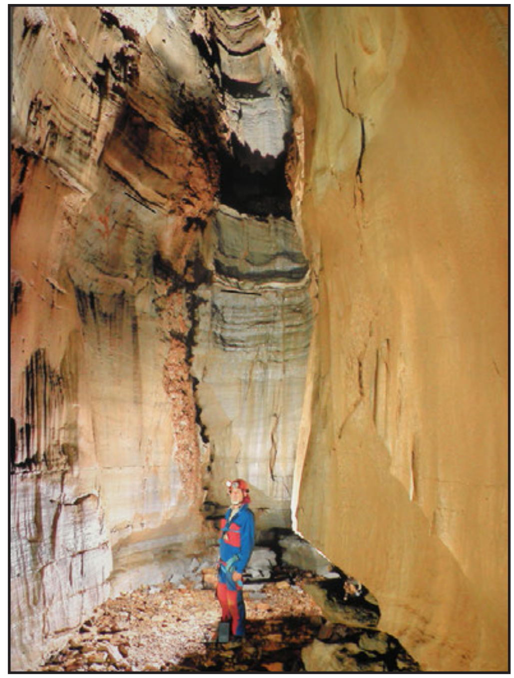

Figure 4: Fault in shaft off the Echo Passage near DA5. Displacement is shown with black lines high above and left of the caver. Rough looking material exposed in the wall to the left of the caver is breccia. Photo by Gary Berdeaux.

Figure 5: Echo Passage at D19 showing the change in passage cross-section from walking canyon to the southeast and stoop way to the northwest (direction of view) on either side of the fault. The hole in sediment to the right of Mona Colburn is where water from an intermittent stream sinks.

stations Y1-2. (Figure 7). Passage orientation and general morphology appear to have been unaffected by this fracture swarm.

At the fault near survey station Y6, Grand Avenue turns from trending 330 degrees to 270 degrees at the fault. However, there is no way to know if the fault caused this bend.

Regional Setting

All of the faults and fractures noted are oriented generally northeast/southwest, and are possibly related to the Pennyrile Fault System, which is part of the southern boundary of the Rough Creek Graben (Figure 8), an arm of the Illinois Basin. The park is within the eastern end of the graben, which extends west as far as Southern Illinois. Locally, structural effects of the graben are comparatively subtle, but to the west in the deepest part of this depression, basement rocks are as much as 7 kilometers or a little more than 4 miles below the surface (Kolkata and Nelson 1997). Generally, faults on the margins of the graben have displacement stepping into the graben, but only one of the observed faults in Long Cave does that. As well, the largest fault in this set (at X1) is a reverse fault that would be formed under compression rather than the tension creating the graben. So the faults in Long Cave may be related to a different geological event.

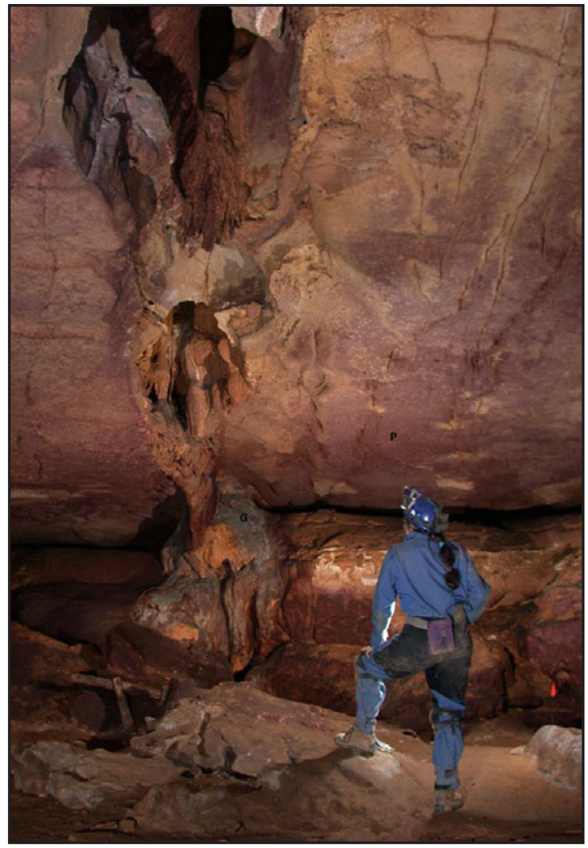

Figure 6: Fault at D2B showing the ceiling channel plus green tinted flowstone (G) and purple wall coatings (P).

Figure 7: Fracture swarm in Grand Avenue at Y1-Y2. This impressive fracture set apparently had no influence on passage development.

Conclusion

Long Cave has an unusual concentration of faults for the region. The fault at A19 and especially the fracture at Z8 may have influenced development of the entrance passage. The fault at DA5 appears to have controlled shaft development adjacent to Echo Passage, and a likely related one at X1 appears to have affected the entry angle of Echo Passage with Grand Avenue. Another fault at D19 in Echo Passage may have caused a change in cross sectional shape, and affects modern hydrology of the passage. Unusual purple coloration on passage walls at X33 and D2B plus green flowstone at the latter station may indicate unusual microbial activity. As usual, more research is needed.

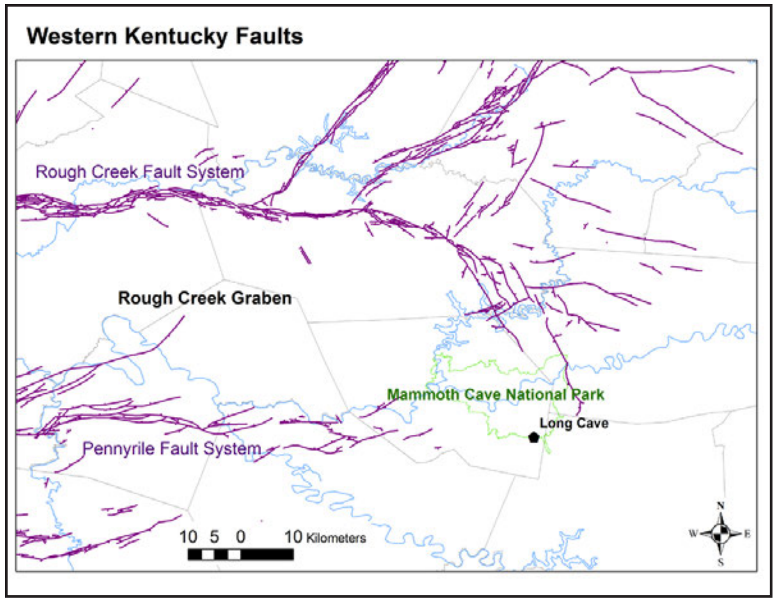

Figure 8: Map showing the location of Long Cave and Mammoth Cave National Park within the Rough Creek Graben. Base map by Kentucky Geological Survey; map modified by Rick Toomey.

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