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Mystery Cave Geology Resources Evaluation

Management Report

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INTRODUCTION

This is the management portion of the final report for the LCMR project **Mystery Cave Geology Resources Evaluation** (part of the Mystery Cave Resource Evaluation). Funding for this project was approved by the Minnesota Legislature M. L. 91, Chapter 254, Article 1, Section 14, Subd. 3(l), as recommended by the Legislative Commission on Minnesota Resources, from the Future Resources Fund. This project concerns the geology, mineralogy, and origin of Mystery Cave. A summary of these topics in non-technical terms is given in a separate Interpretive Report, and the technical aspects are covered in a separate Technical Report. This Management Report contains recommendations on how best to protect the geologic features in Mystery Cave, as well as recommendations for future research.

PROTECTION OF CAVE FEATURES

The most important aspect of cave management is protection of the cave and its features. Of these features, speleothems are generally considered most worthy of preservation. This viewpoint is generally valid, but in the case of Mystery Cave it is of paramount importance. Although the minerals and speleothems in Mystery Cave are not unusually attractive in comparison to those in certain other well-known caves, they are among the most significant in the entire country. In our experience, Mystery Cave holds more clues to the origin of various exotic crystal forms and speleothems than any U.S. cave east of the Black Hills.

The following features should be protected to the fullest possible extent:

1. Folia on the walls just before Turquoise Lake. These are wavy, horizontal bands of fungoid-looking shelfstone that have previously been identified in only a few western caves. They have already been damaged somewhat.

2. Organic filaments and pool fingers in the Yellow Flow at the western end of Fourth Avenue. These are known only in only a few other caves, mainly in the Guadalupe Mountains of New Mexico. The angular cross sections of those in Mystery Cave are, to our knowledge, unique. This area should be off limits to casual parties, and anyone visiting the area should be warned not to touch anything in the Yellow Flow. Knobby, unattractive pool fingers also occur at the far end of Turquoise Lake, but these are fairly safe from damage.

3. Raft cones throughout the cave. These are rare in any cave, and especially rare as actively growing speleothems. There are enough of them in Mystery Cave that they are not particularly endangered, but many are in the direct line of traffic and have already been severely damaged

-- for example, those directly in the path on the route to the Bomb Shelter and a few hundred feet beyond the Bomb Shelter. The delicate ones around Sugar Lake in Fifth Avenue are especially susceptible to damage, and someone has already stepped on them. Others are located in Turquoise Lake and Dragon's Jaw Lake. Blue Lake contains the largest examples, although their internal structure is not as clear as those elsewhere.

4. Iron-oxide-cored speleothems. These are extremely rare, having been described only in Lechuguilla Cave, N.M. Their origin is a matter of debate. In Mystery Cave they include the Bird Bath and the disrupted stalactites in the Formation Room, plus the large flowstone drapery near the Pipeline on the Door-to-Door Route. A few related features occur elsewhere in the cave, including the passage leading to the Helictite Route and Lily Pad Route.

5. Calcite shrubs. These are crystalline pool deposits that look like little bushes. They are rare, and the ones in Mystery Cave hold many clues to the origin of crystal shapes. A great many of these were removed during early (pre-DNR) trail building in the route to the Bomb Shelter. These were unceremoniously dumped in the large depression below Frozen Falls. During the recent restoration of Mystery I most of them were removed from the cave, dumped next to the driveway, and covered with soil. At that time their significance was not realized. Others were removed to the old outhouse, and a few of the larger pieces were placed in the Cathedral Room and in the Bomb Shelter. The location of the dump should be recorded, in case future researchers want to re-excavate them. Those in the old outhouse should be returned to the cave for safe storage. (Ordinarily an out-of-place speleothem is of little scientific value. However, the original location and growth habit of these is clear.) The ones on display in the Bomb Shelter should be moved to a safer spot or cordoned off. Those few remaining in the walls and floors of the route to the Bomb Shelter and elsewhere should be protected. A fine display of calcite shrubs is located in an exposed position in the crawlway of Fourth Avenue, along with a rare example of boxwork. This is one more reason why casual visits to Fourth Avenue should not be allowed.

6. Chenille spar. This is unusual, although not exceptionally rare. It is found mainly in Dragon's Jaw Lake and Turquoise Lake in areas that are not particularly endangered.

7. Delicate burrows in the Stewartville Formation. Although these burrows are common throughout this and other rock layers, it is very rare for them to be exposed by weathering to the degree that they are in Mystery Cave. These delicate features should be protected from damage, even though they might seem to the casual observer merely to be part of the rock, and therefore "not worth protecting."

Many other areas are delicate and attractive, although not particularly rare. Lily Pad Lake, for example, is very susceptible to damage and should be circumvented by exploring parties. Sediment exposures are also very significant, as they may someday help unravel the glacial history of the area. Explorers should be advised not to disturb natural sediment banks in the cave (for example, those in Enigma Pit).

We recommend not modifying Mystery II to "improve" the trails, except where it is appropriate for safety and for protection of cave features. Even with the exceptional care taken in the improvement of trails in Mystery I, many features were inevitably destroyed or covered. We feel that it is not necessary, or even desirable, to have two artificially modified tour routes, and the experience of visiting a relatively pristine cave with hand-held lights is considered a highlight of many visitors' experience. However, there are a few places, such as the route to the Garden of the Gods, which, if re-opened to the public, would benefit from protective railings and installed lighting. It is also appropriate to maintain the security of visitors with bridges, railings, etc., in exposed areas. If the bridge at Blue Lake is replaced, creosote should not be used as a preservative, as this substance has a deleterious effect on the lake water.

Bats are important visitors to the cave, but their guano can be deleterious to speleothems. Bat droppings tend to corrode and stain speleothems, and if not removed can easily become incorporated within the speleothem fabric. Guano should be cleaned from all speleothem surfaces (i.e., any surface that has grown by mineral accretion within the cave), and also from bedrock surfaces that are considered part of the scenic attraction of the cave. Methods should be investigated, in cooperation with biologists, to prevent access to bats in delicate parts of the cave, or at least to protect particularly sensitive speleothems from the accumulation of guano (e.g., the white flowstone in Garden of the Gods).

Likewise, dust kicked up from trails by tours should be minimized, as it tends to coat cave features. Speleothem surfaces are dulled by this material. Loose gravel tends to produce much dust and should be removed from the trails (in the few places where it is present) and replaced with a more stable material.

We also recommend a moratorium on collecting speleothems for U/Th dating, unless there is a new approach or a chance for unusually promising results. The few dates we obtained for this study did not particularly further our knowledge of the cave. The dating by Richard Lively of the Minnesota Geological Survey has been especially useful and thorough, and other researchers should not be encouraged to do the same. Enough dates have now been obtained that they are becoming redundant. It seems appropriate to save the available speleothem fragments until better dating techniques are developed in the future.

MINERAL STABILITY

Certain speleothems are stable only within a limited range of environments and become unstable if the environment changes. In Mystery Cave the only one particularly susceptible to environmental change is the very soluble gypsum, which could dissolve or detach itself from the walls if the rate of water seepage increased into the gypsum areas of the cave.

Changes in land use could affect the rate of infiltration or its chemical composition. Aside from the obvious avoidance of contamination of cave water, there is no clear ideal for which to strive. If the infiltrating water diminishes in rate, speleothems such as dripstone, flowstone, and pool deposits will be less stable, but others such as helictites, popcorn, gypsum, and possibly aragonite will become <u>more</u> stable. The trend would be the other way if the rate of infiltration were to increase. The following events would tend to decrease the amount of water infiltrating into the cave: increased agriculture, clearing of forests, and thinning of the soil. Although there is little that can be done about them, changes in climate could also have an effect: diminishing precipitation, increase in temperature, and a shift to dryer winters and wetter summers (causing most of the water to be lost as evapotranspiration). The opposite trends would have the opposite effect on infiltration rates.

The high-CO_2 content of the infiltrating water is important to many of the significant speleothem types in Mystery Cave. Fortunately there is little that could affect it, except for stripping of the soil. Rapid degassing of CO_2 in the cave atmosphere is another important phenomenon, especially to the growth of calcite rafts, raft cones, and pool linings. Keeping the cave well aerated is therefore important (at least in principle). The present doors provide for ample ventilation, although even if they did not, it is likely that air circulation from small natural openings would be sufficient to maintain the low P_{CO2} of the cave atmosphere. Evaporation is essential for the development of aragonite, cave popcorn, and gypsum. Maintaining rapid air movements will help to keep them stable. On the other hand, restricting the air circulation would favor the growth of delicate crystals and helictites. Some of the most beautiful caves, such as Caverns of Sonora in Texas, have developed spectacular speleothems in nearly closed environments, where the speleothem growth is very slow. It is unlikely that changes in air circulation could have a significant effect on speleothems, however, and bottling the cave up will not turn it into another Sonora.

The present cave doors contain openings for the access of bats. It is important that the doors be kept closed during the winter, because there are historical records of speleothems freezing and cracking when cold air enters caves during exceptionally cold weather. Bat access routes should perhaps be closed during the daytime during cold weather, although it is unlikely that cold air from such small openings could damage the speleothems in the cave.

It is important that pool levels be maintained in the cave. Lowering or draining of pools causes the speleothems to desiccate, since they are probably not in a position to be wetted by dripping or flowing water. Note the difference between the dull, muddy raft cones on the route to the Bomb shelter compared to the delicate white active ones in Turquoise Lake.

Passage Stability

Most passages in Mystery Cave are fairly stable. Most of the breakdown that is going to take place already has. The exception is around entrances, where freeze-thaw can bring down rocks. The danger of this on the surface is greater than in the cave.

However, there are some areas that need monitoring. Some of the broad, flat ceilings contain sagging beds, and these are good candidates for rockfall. The many thin beds in the Dubuque Formation that are separated by shale have very little attachment to the beds above. In particular, in Fifth Avenue between the route to the Smoking Chamber and the eastern junction with the Angel Loop, there are two roof slabs that show evidence of instability. It would be wise to stabilize them, or at least to monitor them carefully. It is not advisable to run tours under the one that sags the most (between Fourth Avenue and Angel Loop). There is no hint that they will come down in the near future, but it is not appropriate to take chances in a cave open to the public.

The cliff face at the Mystery I entrance has been well stabilized by recent construction. However, the Grotto and the cliff nearby are relatively unstable features, especially during the spring thaw, and visitors should be kept away from them. It seems unnecessary to try to stabilize these features, because they are part of the natural setting and illustrate important processes.

Vibration and Stability

Normal surface traffic seems to have negligible effect on the cave. Vibrations are no greater than the natural background values. Intense low-frequency vibrations, such as those produced by heavy machinery, should be avoided. Blasting in areas a mile or more away, such as in the stone quarries, poses only a minor threat, in view of evidence from other areas.

RECOMMENDATIONS FOR FURTHER STUDY

Several geologic topics were beyond the scope of this project. Although they are related to the project's goals, they will require years of effort by many people before they are resolved. The most significant topics are:

1. Determining the detailed glacial history of the area and relating it to Mystery Cave. Glacial deposits should be mapped with the aid of cores, radiometric dating, and seismic surveys, and they should be correlated with other deposits throughout the region. This is a very difficult project that has concerned glacial geologists for decades and is unlikely to yield definitive conclusions soon. The relationship (if any) of the cave to nearby buried valleys covered by glacial sediment should be examined. The evolution of the Root River is intimately connected with the glacial history, and until it is made clear, the exact evolution of the cave will be uncertain.

2. Relationship between water-table levels in the cave compared with those in non-cavernous parts of the limestone. Continuous monitoring of wells in the limestone aquifer, especially during floods and sudden infiltration events, will help to determine the nature of the limestone porosity (i.e., how much is cavernous and how much is non-solutional; how rapidly infiltration takes place; role of caves in determining the position of the water table and directions of low flow and high flow within the aquifer; etc.).

3. Structural analysis of the fracture patterns in the region. A widespread regional stress analysis is required.

4. Measurement of rates of cave enlargement. *In situ* measurements can be made in active cave streams with a micro-erosion meter. A dial micrometer (indicator dial) is mounted on a triangular metal plate and screwed against the floor with the aid of bolts set into the bedrock. The micrometer and plate are removed, and the procedure is repeated annually to determine the amount of bedrock retreat. Standardized limestone samples can be placed in streams, some sheltered from abrasion by sediment load and others not. Periodic weighing of the samples will show the absolute and relative effects of solution and abrasion.

5. A valid vibration and stability study would help to determine whether bolting of roof beams or stabilization of entrances is necessary. Our vibration study simply showed the small impact that traffic has on vibration amplitude in the cave.