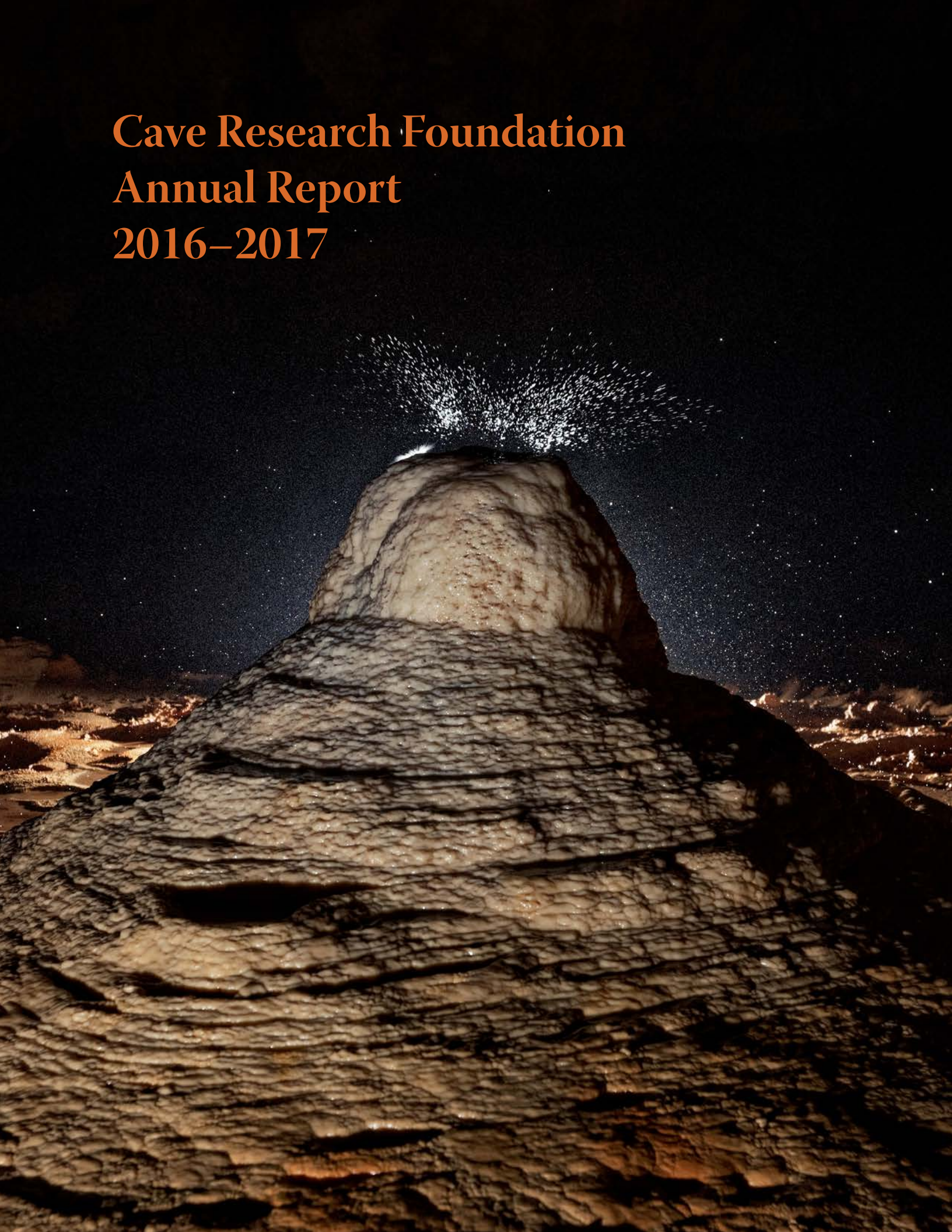
Cave Research Foundation Annual Report 2016–2017



Cave Research Foundation Annual Report 2016–2017

The Cave Research Foundation was formed in 1957 under the laws of the Commonwealth of Kentucky. It is a private, non-profit organization dedicated to facilitating research, management, and interpretation of caves and karst resources, forming partnerships to study, protect, and preserve cave resources and karst areas, and promoting the long-term conservation of caves and karst ecosystems.

Cave Research Foundation 2016–2017 Annual Report

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Front cover photo: Formation in Mossy Spring Cave, Missouri. Photo by Matt Bumgardner.
Back cover photos: *top*, biologists using CRF map in Lime Kiln Quarry, Hannibal, Missouri. Photo by Mark Jones. *Bottom*, Jenn Ellis checks a lead in the Music Room boneyard, Carlsbad Cavern, New Mexico. Photo by Mark Jones.

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CRF 60th Anniversary Remarks

Roger W. Brucker

at Hamilton Valley, October 7, 2017

Abstract: This is an abbreviated version of the banquet talk by Roger W. Brucker on October 7, 2017, at Hamilton Valley. The Cave Research Foundation was celebrating the 60th Anniversary of its founding in 1957. Brucker listed ten Big Ideas accomplished in the years since organization.

Roger Brucker at the 60th Anniversary Banquet.

Good evening, distinguished guests—all of you assembled here. I show you this picture of an acorn—a tree nut. It represents the start of good ideas that have resulted in this large oak tree. But to imagine this oak tree as just a CRF institution would be to miss the point. An oak tree may produce 1000 pounds of acorns annually. These acorns represent the project cavers and scientists that have participated in activities of CRF over the 60-year period. And not just here at Mammoth Cave. CRF has operated in many national parks, such as Carlsbad Caverns, Cumberland Gap, Sequoia–Kings Canyon, Buffalo National River, and Lava Beds. Farther afield CRF has operated in Costa Rica, Puerto Rico, and China.

I have selected 10 Big Ideas accomplished during CRF's life so far to give you an idea what we are about. Those ideas are:

1. Understanding a multi-generation cave,
2. Establishing Speleology as a science,
3. Interpreting a large cave,
4. Conserving a large cave,
5. Managing caving projects,
6. Follow the passage—air and water,
7. House the investigators,
8. Sustain and grow the effort through time,
9. Give it away, and
10. Enjoy the friends and adventures of a lifetime.

I'll amplify each of these ideas and accomplishments in turn.

CRF started as the brain child of four members of the NSS C-3 expedition in 1954 (*The Caves Beyond*, 1955)—Phil Smith, Roger McClure, Jim Dyer, and Roger Brucker. On that expedition, they learned how **not** to run a cave project. Until that time, cave projects in the U.S.A. had a common history. A charismatic caver would find a big cave, enlist a few friends, and commence mapping it. As years passed, younger cavers would be attracted, but the leader groused they were not as good as the old timers. The leader aged and became crotchety. He stopped caving, and in disgust, burned the maps.

In 1957 the founders of CRF met on Phil Smith's front porch in Springfield, Ohio. They ratified by-laws and incorporated Cave Research Foundation as a Kentucky nonprofit and also an institutional member of the National Speleological Society. Their purpose was to study significant caves of the world, interpret them to the public, and conserve them. Establishing speleology as a legitimate science was an unrecorded purpose, but Phil Smith said, "Cave studies have been the dustbin of science. We must change that."

In a meeting soon after in Ann Arbor, Michigan, the CRF directors and several young scientists drew a "wall" of speleology on a blackboard. We had to conduct the

foundational studies as stones on which to build cave science, and several members undertook that task. We set up a grant and fellowship program to award prize money to graduate students. That competition produced hundreds of science papers, but more importantly, launched many teaching scientists who inspired their own students to undertake cave studies. Tom Poulson Ph.D. was the advisor for Kathy Lavoi, who undertook her Ph.D. study and who for the past several years has brought several of her students to CRF's facility for studies. Will White inspired and advised a large number of students, including Rachel Bosch, now studying for her Ph.D.

1. Understanding a multi-generation cave. We had investigated Floyd Collins' Crystal Cave long enough to know it would take scores of years and generations of cavers to do a thorough job. Other big caves fit this pattern. But a five-year project could not succeed. So we organized around principles that would continue to attract new cavers without the drawbacks of quirky personalities. Our systematic survey and mapping produced the folio map that plotted the Flint Ridge Cave System on the topography. The ongoing improvement in survey and cartography took us to setting standards in thorough cave mapping. We learned that we could find natural connections to nearby caves by understanding how verical shafts and their drains integrated the cave levels. Hundreds of books, papers, lectures, and classes have advanced the understanding of big caves.

2. Establishing Speleology as legitimate science. The bringing together of investigators of different disciplines fostered a climate of rapid advancement in cave studies. Patty Jo Watson established the diet record of Eastern paleo people and brought along many archeologists, such as George Crothers, now the Kentucky State Geologist. The multiplier effect of CRF's fellowship program and combined influence on many new scientists is adding knowledge exponentially.

3. Interpreting a large cave. Mammoth Cave, longest cave in the world at 412 miles (announced today by Bob Osburn, CRF Chief Cartographer) was only one of many examples. Carlsbad Caverns, Jewel Cave, Wind Cave, and others worldwide are under continuous study and interpretation. For me, the display of CRF Mammoth Cave maps covering a gym floor was a most vivid example of interpretive efforts. Popular articles and books continue this CRF goal.

4. Conserving a large cave. Phil Smith was the first NSS Conservation Committee Chair and his demands that CRF champion universal cave conservation has paid off. CRF cavers discovered raw sewage in Mammoth Cave. Their efforts led to the relocation of the Job Corps camp, an improved sewage handling system for Mammoth Cave, and helped set today's cave conservation awareness among cavers. CRF also inspired KEEP, Karst Environmental Education and Protection, Inc., a separate nonprofit that has opposed environmental threats to the national park and elsewhere, such as quarries and industrial development. Removal of Lock and Dam No. 6 from Green River restored natural flow through the park—a CRF initiative during the 1960s. If the caves are not protected, they won't exist forever as natural environmental benchmarks.

5. Managing caving projects. CRF developed important principles of cave project management through its experience with national, state, and private landowners. Every project is different, and that dynamic led to CRF to sponsor the Cave Management Symposium, a biennial event attracting cave managers worldwide. Wise use of volunteer efforts, insistence on high quality results and comprehensive useful information, and peer networking are among the principles underlying smart cave management. Cave managers have sometimes relied on CRF expertise to oppose or mitigate threats to their resources.

6. Follow the passages—air and water. Jim Borden and Tom Brucker asked me not to say, "Follow the water." To them it was cliché! And it was no help at all in understanding Carlsbad Caverns. Tom Brucker's preferred mantra is "Does it end?" If you cannot answer yes, then you must explore farther along the passage, map farther, and return if it goes. CRF's experience investigating large caves adopted the principles of survey standards, compass course calibration, quadrangle segmentation, computer survey network

adjustment, cartographic standards, and teaching these and newer disciplines to others. Our success at finding cave connections at Mammoth Cave ensure that its length will grow. I predict 1000 miles after I am long gone. Maybe Sidewinder Bill, a 3-year old here today, will help extend the cave beyond 999 miles.

7. House the investigators. CRF found the hard way that projects can fall apart unless the cavers are housed and fed adequately. Tents and individual freeze-dried meals don't cut it! We evolved through a succession of old building adaption, new building construction, and now CRF's modern field station at Hamilton Valley (the envy of all projects) to our deep understanding of the phrase, "An army travels on its belly." Our construction of facilities at Sequoia-Kings Canyon National Park and our new facility at Lava Beds increases our chances of serving cave areas into the future.

8. Sustain and grow the effort through time. I want to pay tribute to Roger McClure, a founder of CRF. Through the efforts of Red Watson, Roger developed Cave Books into an important publisher and seller of books. The volunteer effort has enriched the literature of caves, but Roger funneled most of the revenue back into CRF. The buildings you enjoy today, including the new archive building, are made possible by the gift of hundreds of thousands of dollars by Cave Books to CRF. Many CRF participants have contributed generously to CRF programs, both in money and time. The Superintendent of Mammoth Cave National Park, Barclay Trimble, said CRF had contributed roughly $5 million in volunteer effort to the NPS over a 60-year span. (CRF President Ed Klausner estimates this is a conservative estimate that does not take into account CRF contributions elsewhere.) CRF's record of welcoming kids has helped sustain us through time. Children and grandchildren of cavers are here every expedition. It's a good environment for children. They meet peers, adults, gain new experiences, and the kids value their times with CRF. They want to return.

9. Give it away. That sounds strange. But if you think about it, the only way to keep something valuable is to give it away. No, CRF never gave away stalactites and stalagmites. But we gave away our findings, sharing them with whoever seemed interested. Some joined our efforts. They in turn brought friends to join the excitement and camaraderie. Prior to CRF the cave owners kept their secrets safe—and wondered why they had few friends. We had a barbecue hosting Fisher Ridge cavers a few years back. We are building bridges to cave investigators.

10. Enjoy the adventures and friends of a lifetime. Consider your own involvement with CRF. You can tell from the expressions on the faces in photos of CRF activities that they are having a fine time. Kids and adults reflect the joy of a rewarding association. When cavers who have been away for many years return, they are welcomed as dear friends, without recrimination (where have you been!) Clearly an important value is the ongoing friendship among those who have thoroughly engaged together in challenging work, and enjoy recounting those days that promise many more to come. As Pete Lindsley, a past president of CRF said, "We broke into a government cave and enjoy each other's families for years and years."

Finally, I remind you, CRF is not just an institution; it is a generator of scientists, project cavers, significant information, friendships, and great memories.

In conclusion: Ergor Rubreck wanted to speak to you for an hour or two, but I said "No." He has invented a new tool—the SpeleoLidarCopter. It is a compact drone carrying a compact lidar chip and memory. It flies down cave passages recording distances, bearings, wall details including names and graffiti. Its low frequency radio transmits this data in real time back to headquarters. The map so generated is indistinguishable from the map hanging on the back wall of this room. Ergor will donate the profits to CRF. (N.B. Bob Osburn says this is not far-fetched. Just a few days ago he was handed a black cube two inches square. It is a miniaturized portable lidar that as you walk along saves data of your surroundings on a SIM card.)

Cave Research Foundation Awards

The Cave Research Foundation awards Fellowship in the CRF to those CRF members who have made significant long-term contributions to the foundation. Individuals who have made significant contributions in a particular area are awarded Certificates of Merit. Both Fellowship and Merit awards are in appreciation of a member's efforts. The following people have received such recognition in 2016 and 2017:

2016 Fellows

Tim Green (Eastern)
Ken Grush (Ozarks)

2016 Certificates of Merit

Aaron Bird (Eastern)
Rachel Bosch (Eastern)
Dillon Freiburger (Ozarks)
Bryant Galloway (Ozarks)
Joseph Jordan (Ozarks)
Pat Kambesis (Eastern)
Marcia Rasmussen (SEKI)
John Rasmussen (SEKI)
Greg Roemer (SEKI)
Rick Toomey (Eastern)
Brandon Van Dalsem (Ozarks)

2017 Fellows

Bill Baus (Eastern)
Chris Beck (South West)
Aaron Bird (Eastern)
Rachel Bosch (Eastern)
Chad McCain (Ozarks)
Joe Sikorski (Ozarks)

2017 Certificates of Merit

Ethan Brown (Ozarks)
Brenda Goodnight (Ozarks)
Bob Lodge (Eastern)
Dennis Novicky (Ozarks)
Tammy Otten (Eastern)
Bob Parrish (Eastern)
Elizabeth Winkler (Eastern)

Operations Areas and Projects

Scott House admires a cave formation in Powder Mill Creek Cave. *Matt Bumgardner*

Eastern Operations Area Summary Report

Charles Fox

Eastern Operations Area Manager

2015–16

	In Park Trips (Hours)	Number of Individuals	Travel Hours	Miles Traveled	Total Hours	Total Individuals
October	201.2	24	161.90	30920.0	363.10	24
Thanksgiving	322.84	33	415.20	22608.4	738.04	33
New Years	297.74	40	517.00	28994.0	814.74	40
February	222.64	37	517.30	35802.0	739.94	37
March	102.82	20	280.90	11258.0	383.72	20
April	157.47	24	432.50	48962.0	589.97	24
Memorial Day	212.50	28	364.80	18612.0	577.30	28
July 4th	1087.50	61	659.90	43158.0	1747.40	61
August	100.98	16	123.50	7806.0	224.48	16
September	365.03	30	382.50	20450.0	747.53	30
Totals	**3070.72**	**313**	**3855.5**	**268570.4**	**6926.22**	**313**

CRF Eastern Operations held ten expeditions at Mammoth Cave National Park in 2015–16. A summary of the work accomplished appears in the table above. In addition another 650 hours were reported for cartography and other work.

Additional survey work was accomplished outside of expeditions, mainly by Art and Peg Palmer. Cartography/survey continues to be our primary focus. We have adopted a policy of concentrating our efforts on areas that have active cartographers who are producing maps.

In addition to cartography, we were involved with several other projects during 2015–16:

1. CRF worked with Dr. George Crothers by providing labor for the project of moving and preserving the War of 1812 era saltpeter mining pipes and other artifacts.
2. We have begun the project of reshooting and updating our current safety and resource protection videos to being them up to current video standards and safety protocols and procedures.
3. CRF has supported and will continue to support many park research and maintenance projects on request. These have included assisting in placing and retrieving dye bugs as well as accompanying researchers to provide caving expertise/support.

A major project for Eastern Operations for 2015–16 was the production of a WNS training video under contract with the USDA Forest Service, primarily for use at Monongahela National Forest. A full report on that project will be provided for the Annual Report at a later time, but the hours spent were as follows:

Editing	111
Video Shoot	125
Writing/Editing Script	17
Administrative	32

The finished video is posted on a CRF YouTube channel and the Bat Conservation International YouTube channel. Views as of October 22 were:

Bat Conservation International	324
Cave Research Foundation	244
Total	**568**

In addition, the Cumberland Gap National Historical Park project continued with a high level of activity.

Date	Target	Team	Time	Report	*
2015-10-24	Gap Cave — no CRS (mapping & geology)	6	24	2015-10-25	A
2015-11-27	Gap Cave — photographic technique development	2	6	2015-12-01	A
2015-11-28	Surface — Civil War features & data processing	2	8	2015-12-01	A
2015-12-19	Surface — Station Creek	3	24	2015-12-21	A
2016-01-30	Surface — Woodson Gap	3		2016-02-01	A
2016-02-27	Surface — Lewis Hollow (with geology)	6		2016-02-28	A
2016-03-25	Powell Mountain Cave — mapping survey with CRS	7	49	2016-03-31	A
2016-04-23	Gap Cave — documenting old survey (Roman numeral)	3	18	2016-04-25	A
2016-05-28	Gap Cave — signatures & Roman numeral survey	2	12	2016-05-31	A
2016-06-25	Administrative day (geology proposal)	4	8		A
2016-07-30	Gap Cave — no CRS (hydrology expedition)			2016-08-04	A
2016-08-27	Expedition canceled				
2016-09-24	Gap Cave — photogrammetry trials	2	8	2016-09-25	A

Team ***refers to team size, in participants;*** **Time** ***refers to total person-hours in cave or on task (excluding house/prep work).***

** Report status is denoted by* **A** *for* **Activity Report** *or* **R** *for* **Research Report**.

The Cultural Resources Survey (CRS) team held nine expeditions. The table summarizes the expedition dates.

Particular focus was placed on documenting evidence of Civil War and early-settler visitation and relating that to the known historical narrative of the cave and historical and pre-historical context of the local surroundings. Most of the cultural features documented were of the following types: signatures and related graffiti made by inscribing or marking rock surfaces with soot, charcoal, pencil, or other dark or colored media; fragments or whole items made of clothing, wood, glass, metal, or other discarded anthropomorphic materials; clay or mud figures; and signs of disturbed soil related to foot traffic or excavations. As much as possible, each documented feature was located approximately (or in some cases precisely) relative to previously marked survey stations. In limited cases, no clear stations were found and cultural features were located in terms of other prominent landmarks (e.g., stairs or tourist trails). Photographs were made of each documented feature whenever possible. Figure 1 shows a historical survey marker in Gap Cave under investigation this FY by the CRS team.

Figure 1. Historical cave survey marker in Gap Cave among a series investigated this FY.

Although not documented above, considerable time (more than in-cave time) was spent outside the cave researching historical records related to the documented items. These included extensive searches of military records, census records, newspaper files, library archives, and interviews with present and past local residents.

The team continues evaluation of previously documented features and investigation of potential connections to historical records outside the cave. All significant findings are reported to the National Park Service (NPS).

In this FY, the CRS team continued to assist the NPS in locating surface features and improving the Park's GIS database of karst features. During four of the winter months, when access to the major caves was restricted during bat hibernation, the team ridge-walked to find new and previously known entrances. Entrance locations were measured with a GPS unit, and the coordinates were communicated to the NPS. Additionally, one cave with entrance on the

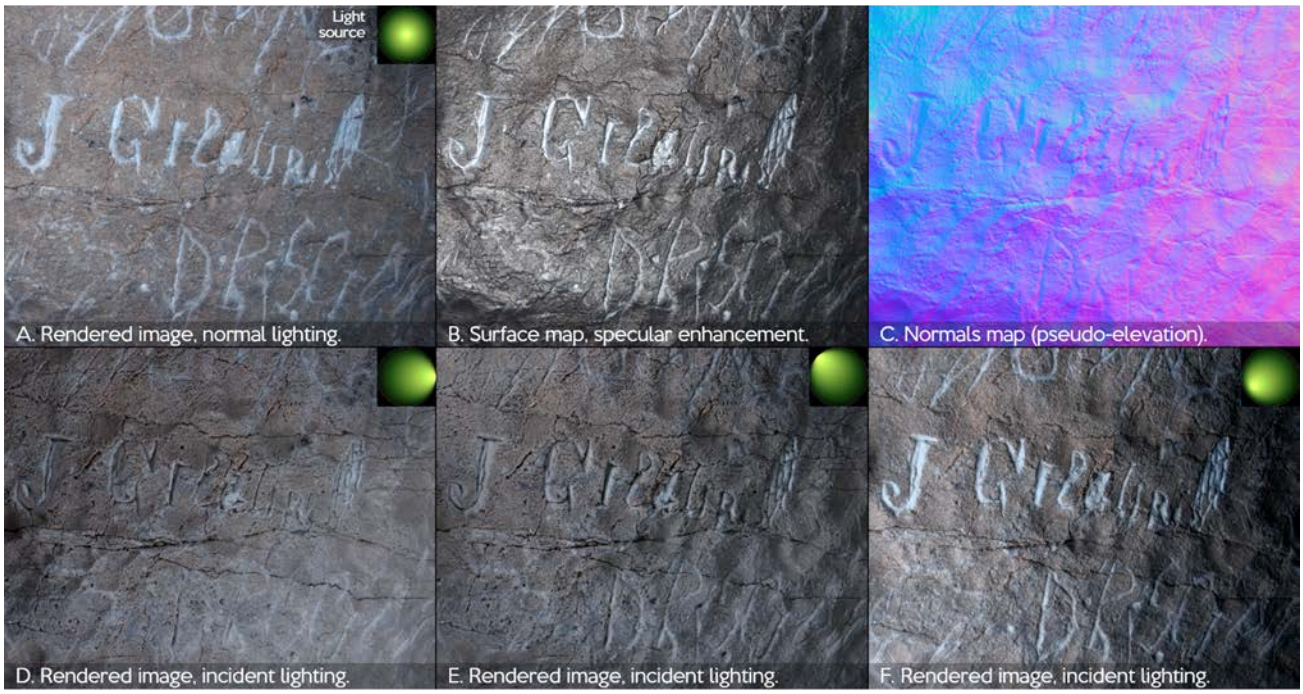


Figure 2. Renderings of a signature in Gap Cave, produced using Reflectance Transformation Imaging (RTI). Panels A, D, E, and F are renderings from the RTI software with difference light-source positions (the software allows arbitrary light-source positions); Panel B is a surface map using specular enhancement to bring out surface details; Panel C is a normals map producing approximate elevation of the surface. Many surface ripples are apparent in other renderings (Panels B-F) not seen in Panel A, with normal lighting.

periphery of the Park boundary and underlying Park lands was surveyed, with initial scoping of cultural resources, to assist the NPS in documentation of nearby resources.

The CRS team focused on photographic techniques to document in-cave features such as signatures while obtaining a three-dimensional representation to preserve the shape of the underlying cave surface. The first of these techniques, **Reflectance Transformation Imaging** (RTI) using the highlight method, was applied with great success in Gap Cave. In this method, a fixed camera records a series of images with incident lighting at different angles, and computer software calculates a surface map which allows viewing with arbitrary lighting angles and enhanced rendering of surface features. Figure 2 shows a montage of a signature in Gap Cave as rendered by the RTI software. The CRS team has been pursuing 3D printing of the RTI maps to produce replicas for display during cave tours, in the visitor center, and for other educational purposes. Also, the team has begun implementing a second photographic technique, **photogrammetry**, to produce a direct 3D representation of object features. In photogrammetry, a fixed object is recorded in a series of images using a camera moved to different perspectives around the object, with reference targets to assist in registration. Computer software then produces a 3D solid model surface of the object. The team is experimenting with determining the minimal number of images required to produce a surface map of sufficient resolution and fidelity to produce a 3D printed replica. These efforts will continue into FY2017.

The CRS team has also been working on public presentation of findings. On February 16, 2016, Charles Finney gave a talk titled, "Cave of Remembered Dreams: Recording Cultural Resources in the Cumberland Gap Cave System" to the East Tennessee Society of the Archaeological Institute of America in Knoxville, Tennessee. In August, the team submitted a proposal abstract for a poster presentation at the 2017 Annual Meeting of the Archaeological Institute of America, titled, "Documenting Cultural Resources in the Caves of the Cumberland Gap National Historical Park." Charles Finney will present the poster on January 6, 2017, in Toronto, Ontario.

2016–17

Mammoth Cave National Park announced that the new official length of the system is 412 miles on October 7, 2017. The new length was determined on cooperation with the CRF cave data managers and represents a 7-mile increase over the last "official" length.

	In Park Trips	Participants	Travel Hours	Miles Traveled	Total Hours
October	203.4	33	423.8	40376.00	627.2
November	248.3	33	380.4	20762.00	628.7
December	169.7	29	383.7	26072.00	553.4
February	207.2	37	444.4	37762.00	651.6
March	40.2	21	288.5	20488.00	328.7
April	351.8	14	267.0	22765.00	618.8
May	289.5	36	502.8	28588.00	792.3
July	1075.5	53	510.4	29194.00	1585.9
August	53.2	17	166.9	10070.00	220.1
September	283.5	35	424.7	22352.00	708.2
Totals	**2922.3**	**308**	**3792.6**	**258429.00**	**6714.9**

CRF Eastern Operations held ten expeditions at Mammoth Cave National Park in 2016–17. A summary of the work accomplished appears in the table above.

Attendance was down slightly over last year for several expeditions but remains strong overall. We are seeing an increasing number of new cavers as well as continued attendance by many long term CRF JVs.

Additional work was performed off expedition for small caves administration, cartography, video, photography, and other work. Also survey work was accomplished off expedition, mainly by Art and Peg Palmer.

Cartography/survey continues to be our primary focus. We continue our policy of concentrating our efforts on areas that have active cartographers who are producing maps.

A positive development in the last year has been the addition of several new cartographers, who are beginning to revive work in areas that have been inactive for several years or longer. Some of these map sheets are remote and have potential for discoveries that will significantly lengthen the cave.

In addition to cartography, we were involved with several other projects during 2016–17:

1. With the removal of a Green River dam, CRF has started making a point to note any changes in base level water levels. We are also developing a list of places that will need to be checked once water levels stabilize within the system.
2. We are continuing the project of reshooting and updating our current safety and resource protection videos to being them up to current video standards and safety protocols and procedures. The plan is to add the video to the CRF YouTube channel once it is complete.
3. CRF has supported and will continue to support many park research and maintenance projects on request. These have included assisting in placing and retrieving dye bugs as well as accompanying researchers to provide caving expertise/support.
4. A modest 60th anniversary of CRF celebration was held at the October expedition and was well attended.
5. A major revision is underway on the EO Expedition Leaders' Manual.

Finally, Aaron Bird is being appointed as the Eastern Operations Assistant Manager. The goal is to acquaint him with the administrative functions of the EOM both so there will be backup and a potential trained replacement for the current manager at some point.

Cumberland Gap National Historical Park

The Cumberland Gap National Historical Park project continued with 11 expeditions being held between October 2017 and September 2017. The number of participants is smaller than in previous years due in part to the length and difficulty of the trips now required to reach areas of the cave under survey. Nonetheless, the project remains productive with a core of good people. Work is being done in the areas of both survey and resource inventory.

Cave Hollow-Arbogast Survey Project

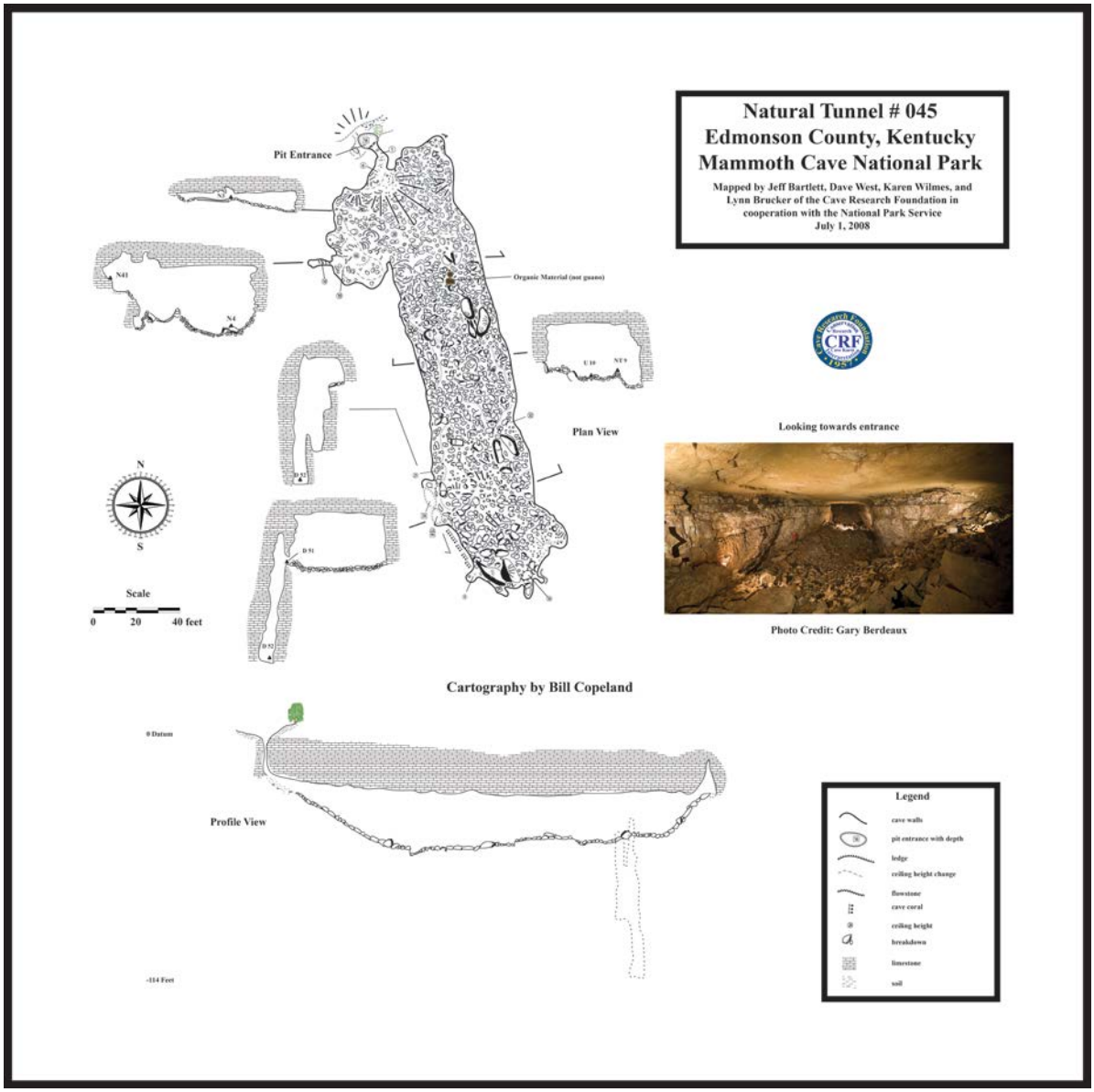
Eastern Operations is pleased to report that the project is now a reality. The first survey trip in the cave was held on September 16, 2017, with more scheduled in the future. Two parties surveyed a bit over 1100 feet. This is the culmination of several years of hard work by Dave West and many other people. A full report will be given by Dave to the Board of Directors.

Lesser Caves of Mammoth Cave National Park Report

Bill Copeland

2016

During the last 12 months, we have taken some great strides in organizing the lesser cave data. During late 2015 to early 2016, James Borden provided space inside the server solely for lesser caves. I began setting up empty file folders for each of the known and suspected lesser caves, and then systematically began placing all the data we had in the empty folders (much like I did in 2014 at Hamilton Valley with the physical files). Next I began placing the survey books (FSBs) that I had on my computer in the server folders that I had come across during the last couple of years I had found on the Washington University (WUSTL) survey book depository, but that was probably less than 30% of the total. I then started searching the FileMaker Pro trip reports for the FSBs I was missing, and I then found all but about 45 on either the WUSTL site or the CRF archive on the server. I sent the list of 45 to Joyce Hoffmaster, and

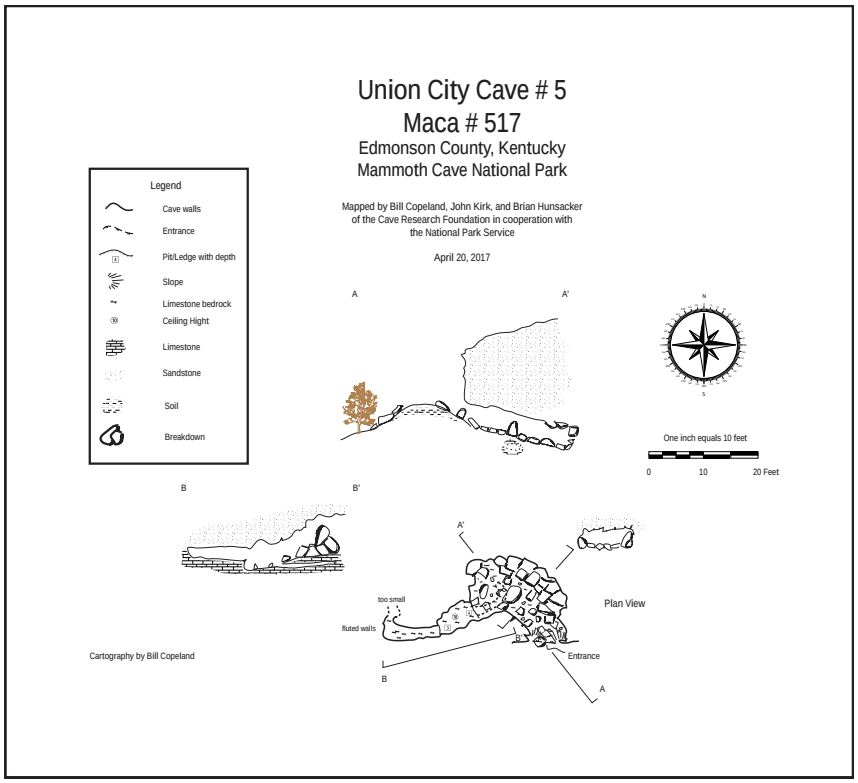


she has been diligently scanning the books in question and sending them to me; then I put them in their respective folder. Lastly, I looked at every survey book listed on the WUSTL site to make sure I had not missed anything. I found two lesser caves on the north side that had been found, surveyed, but never turned in. Each individual folder should contain the following to be considered "finished:"

- FileMaker Pro (FMP) data sheet
- Topo location map
- Finished cave map
- Survey books
- Pictures
- Bio inventories

And a few contain these files:

- Illustrator files
- Walls data



I also began updating the FMP lesser cave data sheets. Many of the caves have been disproven as caves, not found, or surveyed, but unless these sheets are updated, they are basically worthless. Many of the survey books contain bio inventories, so I updated the fauna area also. To date, I have updated almost half of the data sheets.

The following is the best statistical data to date:

- Lesser Cave trips during the last 12 months: 25
- Number of new caves found: 8
- Number of caves surveyed: 11
- Number of caves resurveyed: 3
- Number of larger lesser caves with ongoing surveys: 5
- Number of caves that either don't exist, not within park boundaries, or not caves: 20
- Number of caves completed: 154
- Number of caves that need surveyed: 215
- Number of caves that need finished map: 49
- Number of caves that are in progress of being surveyed: 6
- Number of caves that need to be field checked (I suspect most of these will be taken off): 75
- Total: 499

During the upcoming year I would like to focus on:

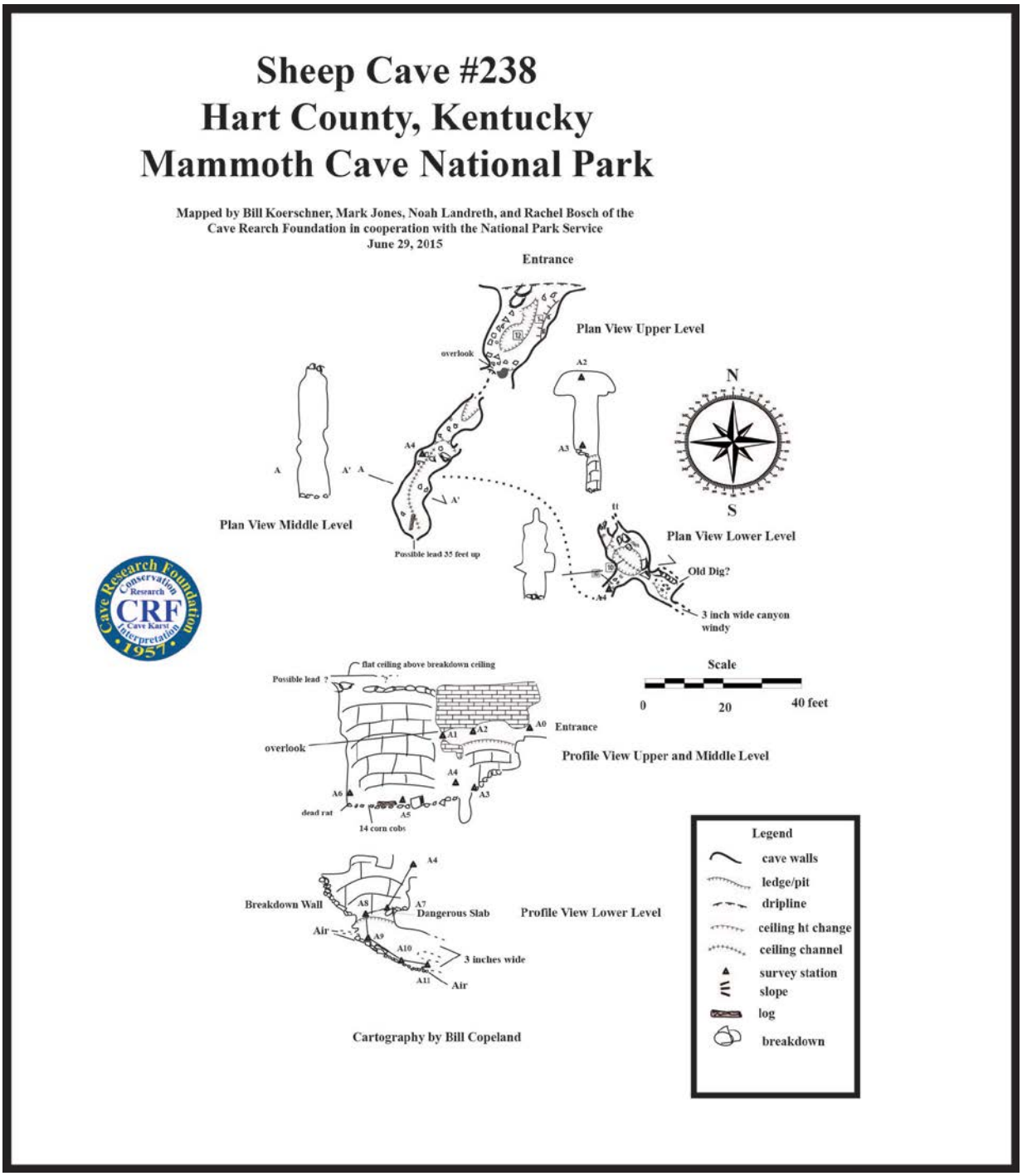
- Field checking the 75 caves still on my iffy list. I think we can accomplish most of this by early spring of 2017.
- Ridgewalk this winter especially in the southwest and northeast areas of the park.
- Continue to diminish our backlog of undrawn lesser cave maps.
- Get entrance pictures of the 40 or so lesser caves we don't have, which really helps the field crews that go out looking for these caves to know if they are at the correct one.
- Get a cleaner version of our FileMaker data sheet (more like the one Scott House uses in Missouri).
- Update the hard lesser cave files at Hamilton Valley.

I would like to thank all the people that have taken the not so glamorous trips to map the lesser caves during the past year. I know these caves are usually small, unexciting, and dull, but the data (especially the bio data) is very helpful to the scientists who study these critters.

2017

Once again, Small Caves inside Mammoth Cave National Park had another busy year. We had a total of 33 trips that concentrated on Small Caves including the following:

- Hydrology: 2 trips
- Survey (cave): 21 trips
- Survey (surface): 2 trips
- Recon: 1 trip
- Photography: 1 trip
- Ridge walking: 6 trips



During the above trips, we found 18 new small caves, eliminated 24 bad locations, and at home, 33 finished maps were completed, leaving about 5 caves without finished maps. Of course, larger small caves like Wilson, Great Onyx, and Smith Valley are ongoing. As of January 1, 2018, by my count, we had a total of 437 verified cave locations (with 218 of them never surveyed) and 41 locations that still need field verification.

Also, near the end of 2017, Stan Sides, Norman Warnell, John Feil, and I began working on the Sides/Church off park property. We have 4 caves so far that we will survey, and lots of property that needs to be ridge walked.

I want to thank Dave West, Mark Jones, Karen Willmes, and Elizabeth Winkler especially for their help in much of the survey work.

Status of Crystal Cave Mapping and Cartography

February 2016

Art and Peggy Palmer

The survey of the known part of Crystal Cave is not quite complete. Several thousand feet of resurvey needs to be done to improve the sketch and obtain better vertical control. A hand-level survey from the early 1970s has provided very good vertical control, but only about 20% of the compass-and-tape stations are tied into the hand-level survey. The entire hand-level loop from the Crystal entrance through to the Austin entrance and back on the surface had a discrepancy of only a few tenths of a foot, but luck was obviously involved. All loop closures within the cave were within a foot.

Most of the early CRF compass-and-tape surveys have been resurveyed with tighter control and better sketches. Multiple resurveys of the major passages have been made to assure best loop closure. A radio location was made at Overlook Pit by Alan Hill in the 1960s, and the present Walls plot for the cave shows about 5 feet of discrepancy with the location of the surface stake above. It is unlikely that further resurveys will improve this closure.

In recent years, several new surveys have been made in new discoveries and in previously explored and unsurveyed passages. For the most part, these simply add more strands to the spaghetti, although a recent re-discovery of an old Bill Austin lead produced a conspicuous extension to the north from B Trail.

Areas that still need work include Left of the Trap (thousands of feet of resurvey), Camp II area (hundreds of feet of multi-level canyons), and squirrely passages in Lost Paradise, some of which threaten bodily and emotional harm. Much but not all of this has been previously explored. A few promising virgin leads contain air movement, but they are very tight.

Assembling the Walls files has gone slowly but smoothly. All of our pre-Walls survey data have been converted, and there are no unaccounted-for loose ends. We are in the stage of reconstructing the map into a separate Walls file—an "incremental build" in which we test various loop closures and add one survey at a time, to provide what appears to be the best possible fit without the stigma of invoking round-tripping via Walls.

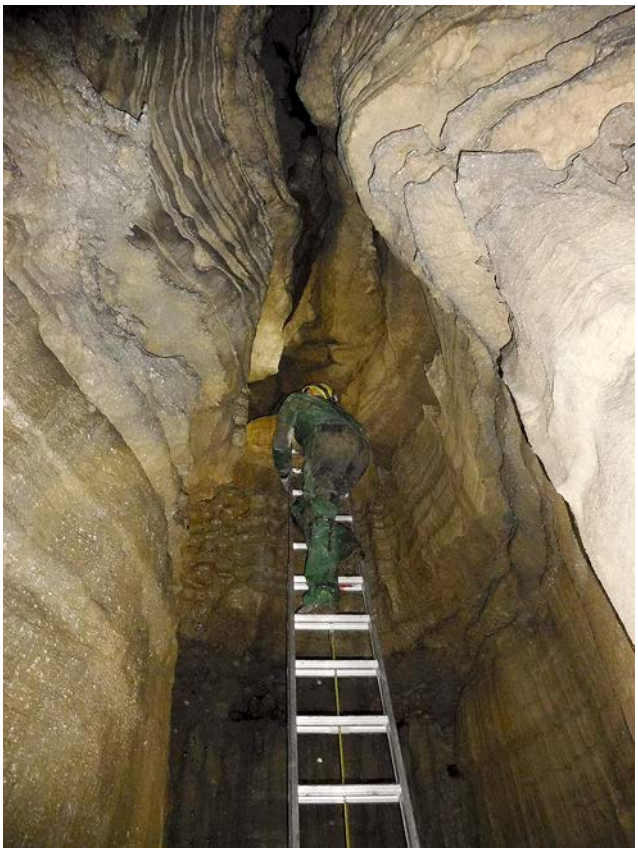
Cartography got off to a fast start in the 1990s before the present CRF standards were established—fortunately using Adobe Illustrator. It has stalled in the past 10 years or so while we wrestle with loop closures, etc. The final map will include geological data on passage cross sections (e.g., contacts between rock units) but not in an intrusive way. The biggest challenge will be to portray the complex multiple levels in an easily comprehended way. We expect the map of the presently surveyed parts of the cave to be complete within about 5 years.

412 Miles in 60 Years

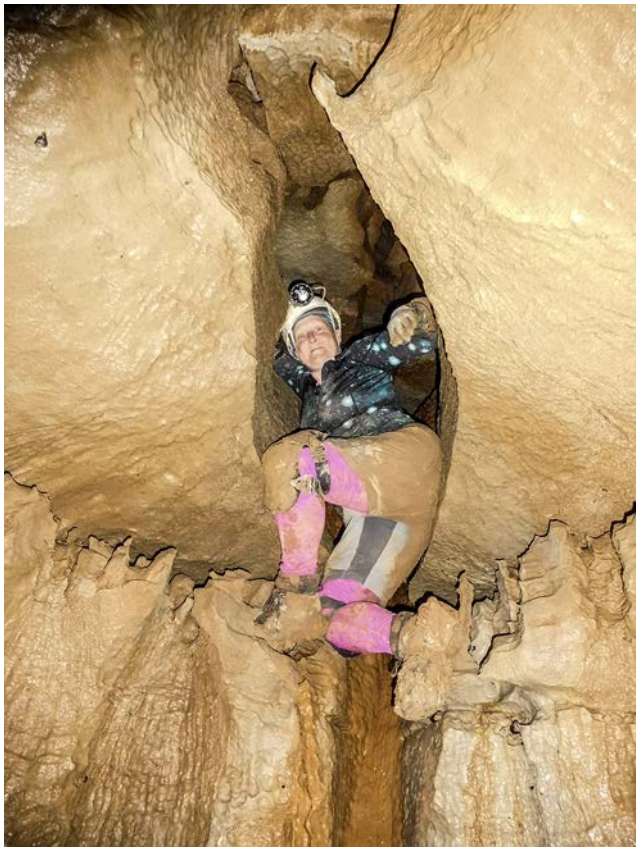
Ed Klausner

The CRF had its 60th anniversary in 2017. A celebration was held at our Hamilton Valley facility bordering Mammoth Cave National Park. This is a fitting location for the celebration as the CRF was founded at Mammoth Cave. Bob Osburn, the CRF Chief Cartographer for Mammoth Cave, announced the latest length of the cave at 412 miles. Later in the day, Rick Toomey (CRF member and Cave Resource Management Specialist and Research Coordinator for Mammoth Cave National Park) announced this at the park's Visitor Center to the public.

The difficulty of a large cave survey over many years is apparent when determining the length of the cave. Survey from 60 years of effort spanning many upgrades in survey standards yields duplicate survey that current cartographers and data managers must untangle. This is difficult in itself but made much more complicated by the fact that there aren't cartographers working on many of the



Rick Olson (NPS) checking a lead in Mammoth Cave.
Ed Klausner



Elizabeth Winkler checking a lead in Mammoth Cave.
Ed Klausner

63 quadrangle map sheets. Each of these map sheets is complicated and generally multilevel. Many contain more than ten miles of passage. Figuring out duplicate survey can be a challenge, especially since some old survey must be left in the survey net due to side passages that are tied to old survey and not new survey. The parallel survey (old plus new) has to have the old survey noted and removed from length calculations. Generally, this is accomplished in the Walls software, created by David McKenzie, that we are currently using.

Originally each cartographer managed the data for his or her map sheet. This proved problematic as many loops cross map sheet boundaries and loop closure can only occur when the entire loop is in the same data set. A solution has been to join all the data into one data set for each of four major areas in the system. This is a convenient solution because each of the areas is joined to the other areas

by one or two connections making a logical division. Mammoth Ridge is managed by Ed Klausner, the River System by Bob Osburn, Flint Ridge by Dave West, and Roppel by Jim Borden. When a survey is done, the cartographer for that map sheet enters the data into Walls and then sends the resulting survey file to one of the three data managers (Jim Borden enters all Roppel data himself). If old survey is removed, a replacement survey file for that old book is also sent with instructions to the ridge data manager about replacement survey files and removal of old survey files.

Changing standards also means that older survey generally needs to be replaced. Older survey did not use backsights, meaning that blunders may exist in the data. This is especially true in the old survey as they did not sketch to scale and sketches were sometimes nothing more than a bunch of dots connected in no particular orientation with two walls drawn with no relationship to the actual distances from the stations to the walls. In addition, no vertical control was used in much of the early surveys and little or no floor detail was sketched. Modern standards dictate plan, profile, and cross sections along with fore and backsights for compass and clino plus sketching to scale.

Instrumentation has also evolved from Brunton compasses to Suunto and now to DistoX2s. CRF has maintained a compass course so that magnetic declination shifts and differences in instruments can be taken into account so the maps are orientated to rotational north.

Rick Toomey (NPS) and Michael Lofthouse checking a lead in Mammoth Cave.
Ed Klausner

Several years ago, the park had an engineering survey done in parts of the cave. They tied to many of the 71 Walker Benchmarks placed in 1935–6 by H. D. Walker of the United States Geological Survey. The engineering survey confirmed the location of these brass monuments and their UTM coordinates have been fixed in the data set. This means that the benchmarks don't move when loops are closed. This is great for Mammoth Ridge, but the Walker Benchmarks were not placed in Roppel, Flint Ridge, or the River System. To get fixed points in these areas, precision GPS locations of the entrances were taken, and survey stations at the entrances have been fixed in the data set. These fixed stations help the cartographer draft the quadrangle map before the survey is complete as newly closed loops do not shift the survey lines much.

With a cave this big and complex, there is still much to do. Exploration and survey are far from complete. Cartographers are needed for areas that have had survey. Detailed lead lists need to be created and resurvey done. This is not always glamorous, as leads tend to be small in previously surveyed areas and resurvey itself is not generally as interesting as surveying virgin cave. However, this is what it takes to create a completed quadrangle map, and new cartographers are always needed for these long-term projects.

Cave Hollow–Arbogast Cave Survey

September16, 2017

Dave West

Back in 2007, we made an effort to begin surveying the Cave Hollow–Arbogast Cave System. An agreement was nearly reached when WNS hit the state, bringing the effort to a halt. In 2013 the West Virginia Association for Speleological Studies (WVASS) convinced the Monongahela National Forest to hold a meeting on establishing a means for cavers to assist the Forest in documenting the caves in their area. I took part and became a member of a working group that began hammering out the details of a process that the Forest could support and defend against any potential challenge by the Center for Biological Diversity (CBD), who had been submitting Freedom of Information Act (FOIA) requests for various types of information on Forest Service caves throughout the country. A procedure was established in early 2017, and I submitted a proposal for the project, knowing I had support from all involved agencies. After various meetings and discussion, September 16 was established as our first actual trip into the cave,

After a few meetings throughout the week prior to the trip to finalize the details in the Operations and Management Plan for the survey, we had a fully executed and signed plan and a signed authorization letter, along with keys for the various gates. Bob Hoke, Dave Socky, Karen Willmes, and I spent Friday night at the Alpine Lodge in Alpena.

In the morning we opened up the restaurant at 8:00 a.m. and were joined by Aaron Bird, Rachel Bosch, and Wayne Perkins. On arrival at the parking area across from the Showalter driveway, we selected two trees near the edge of the woods and set up an instrument course for standardization of each set of instruments to be used in the day's survey. After changing into our cave clothing we headed off to the cave, arriving about 11:30 a.m. We installed a new sign about WNS on a tree inside the fence.

Dave Socky opened the gate, and while he and the others waited, Bob Hoke and I made a quick trip to the Bat Room to determine whether the maternity colony was still in place. We saw only one pip and an unidentified flying bat. We decided to begin the survey in the Bat Room, with one party going back to the entrance to tie in to the existing surface survey from 2007 while the other would proceed south toward the Golden Spike Room. We planned to meet back at the Bat Room at 5:30 p.m. for our departure.

I was joined by Karen, Aaron, and Rachel to head towards the entrance. Our plan was to knock that out and then return to the Bat Room and survey out the northwest

Karen Willmes at the Arbogast Cave entrance. *Aaron Bird*

corner until the meeting time. The passage was more complex than we thought, and the survey out took more time than we had hoped. When we reached the Entrance Room, I realized we did not have enough time for me to sketch it and still tie in, so we put the sketch on hold and got the tie in first. On the way back into the cave, I had Aaron give me a number of splays so I could get the drip line and get the gate properly positioned on the sketch. As 5:30 approached, Aaron went back to the Bat Room to meet the other team. We had 620.4 feet of survey, but about 100 feet of that were splay shots. I continued sketching until it was time to depart for dinner at the Alpine.

Dave S., Bob, and Wayne surveyed south in a nice walking canyon for 619.9 feet before they reached their turn around time. Before departing, they looked ahead a bit, and were surprised to encounter two clusters of Virginia big-eared bats, each about a foot in diameter. They immediately retreated to the end of their survey, where Bob got his camera to get a picture of the bats. The bats did not await his return and moved further into the cave. We will not return to this passage this winter unless requested to do so by the Forest Service. Fortunately, it is part of a loop and can be reached from the other direction in the summer, although it will be quite a trip.

Our plan for next month is to finish the sketch of the Entrance Room and then continue to radiate away from the Bat Room so that any passages in the area can be reached from the other end without disturbing the maternity site.

Hamilton Valley Operation Report

Pat Kambesis

Hamilton Valley Operation Manager

2015–16

The Hamilton Valley Maintenance team (Roger McClure, John Fiel, Daniel Gregor, Joyce Hoffmaster, Elizabeth Winkler, and Pat Kambesis) continues to do general repairs and maintenance on the buildings and property and keep the grounds mowed. Hamilton Valley (HV) work weekends have been few and far between, and the last time we scheduled one, only two people showed up. We depend on the work weekends for more thorough cleaning of the facility, a necessary action since users aren't expected to do major cleaning, just enough to accommodate their use. We will try scheduling two work weekends for the upcoming year and make a better effort at promoting it amongst our membership.

In October 2015 CRF was a co-host (along with Mammoth Cave National Park and Western Kentucky University) of the biennual Cave and Karst Management Symposium, which was held at the Cave City Convention Center. The event saw about 60 participants and a few of them stayed at Hamilton Valley during the 5-day event. This event provided good public exposure for CRF and highlighted their partnership with Mammoth Cave National Park and Western Kentucky University.

Earlier this year, assessors from the Hart County showed up to measure the footprint of the new house for tax purposes. Fortunately, we convinced them that we were indeed a registered non-profit. A large-sized lock box has been installed on the front porch of the new house for HV users to drop off paperwork and payments. HV purchased and paid for kitchen appliances for the new house in Fall 2015.

A new lockbox for key access has been installed at the door of the main building at HV. This takes the place of the bucket-covered lockbox at the second gate. All gates are now kept closed (except during CRF expeditions) to discourage random visitors to the property. This has also cut back on outside use of our dumpsters (which will be a money-saver in the longer run.) The gates are no longer kept locked unless the HV Manager is away from the property for more than a couple of days at a time.

Elizabeth Winkler did crowd-funding projects to purchase a new sofa for the main room and to purchase a commercial electric stove and extra metal prep table. The new stove eliminates the need for future propane purchases though it is uncertain how it will affect the electric bill. We did have to make one more propane purchase during the stove crowd-funding project, but that should be the last one. The propane tank is about 80% full at this point, and it will remain on the property either as a potential source for a fireplace reconfiguration or may be set up as a backup at the new house. We will sell the old stove, probably on Craigslist.

Trailer sale has been on hold until we get a copy of the title. The HV Manager has applied for a replacement title and is waiting for it in the mail. We are getting ready to try and sell the trailer (Plan A). As soon as we receive a copy of the title, advertising will start. If we can't sell the trailer, we will try to "give" it away (Plan B). In both cases, purchaser/taker will have to assume the expense of moving it off CRF property. If we can't sell or give away, then we will dismantle it ourselves and dispose accordingly (Plan C).

During the Fall 2015 fire suppression inspection, we were informed that we needed to replace all of our fire extinguishers since they were out of date and no longer meet code. New equipment was purchased, installed, and inspection completed (see summary for cost). Hopefully it will be another 10 years before we have to replace all fire extinguishers and the fire suppression system in the kitchen.

HV Land income, handled by Roger McClure, provides a steady source of income to the facility and property. This year Roger raised the cost of the Peers hunting lease to $800. Hunting season is upon us now, and the hunters put up the gate sign whenever they are in the valley.

We continue to schedule more than one small-to-medium group at a time, and occasionally schedule small research groups during CRF expeditions with approval from the expedition leader. We have also rented out just the main hall of HV and will likely continue this in the future. There are occasional renters of Hoffmaster House

by members of Pat Peers Hunting Club, but they have not used it as much as in the past. So HV rental income has increased a little (would have been more had we not had several groups cancel during January and February of this year because we were snowed in). Expenses at HV continue to be reasonable, and we also pay a much greater part of repairs and purchases which in the past had been paid for by Cave Books. We will continue to take on repair and purchase expenses without the help of Cave Books. Table 1 is a summary of HV accounting for 2015–16.

In December of this year, the Mammoth Cave Learning Center will close. This was a decision made by the Superintendent of Mammoth Cave National Park. One of the services that the Learning Center provided was to lead geologic field trips in Mammoth Cave and surrounding area. Many of the school groups that use HV were among the users of this resource. Now, if a group wants a field trip, they may have to pay the Park for the time of a guide. This is an unfortunate situation for many of the groups who are on tight budgets. However, MACA will allow qualified volunteers to lead the geology tour trips. The HV Manager has volunteered to provide this service to school groups who use the HV facility (otherwise we lose rental income!).

Future Plans

Sometime in 2017, we will add two stacked ovens to our kitchen. The second refrigerator will be moved to the pantry and ovens installed next to the new stove.

October 2017 is the 60th Anniversary of CRF. HV will host an anniversary celebration in conjunction with the 2017 October Expedition. Details will be announced after the first of the year.

On Cave Books, most of the Cave Books book inventory now resides in the Archive Building. The HV Manager fills book orders for Cave Books that are delivered to Mammoth Cave National Park Hotel and Visitor Center. At some point in the future, all Cave Books operations may run out of HV.

This past summer our neighbors (the people who bought Peers' property) put a permanent (no entryway) gate on Dogwood Cave. We are not sure why they did this since they said we would continue to have access. The gate is easily breeched and is not bat friendly. The HV Manager plans to talk to them to see if they would be interested in letting us install a gate and take on management of access.

We had a number of "one-time" major purchases that were made this year, but HV was able to pay for them all. Hopefully next year, facility income will continue to grow. That, along with another fee increase in January 2017 (to $13.00/night) will assure that HV finances continue to stay in the black and that HV can fully support itself.

EXPENSES	
Propane	566
Phone/Internet	997
Electric-KU (main, 2 bunkhouses, archive bldg)	6401
Electric RECC (safety light-Hoff house)	303
County water	576
Bank fees	158
Gasoline (mowing)	145
Dumpster/monthly	474
Dumpster/empty	252
HV supplies (includes Sams Club membership)	376
Fire suppression	1175
Misc. repairs	327
New hot water heater	397
NEW HOUSE EXPENSES	
Appliances (stove, fridge, dishwasher)	1876
Snow shovel; hose reel; salt; edge trimmer	150
TOTAL MONTHLY EXPENSES	14173
INCOME	
2015 Balance	9919
HV Land Income	5719
Rental Income	10119
TOTAL 2015–16 INCOME	25757
BALANCE AS OF OCTOBER 1, 2016	**11584**

Table 1. Draft 2016 Financial Report for Hamilton Valley Field Station.

2016–17

The Hamilton Valley Field station has been fairly busy during 2016–17. We provided space for several big events including Mammoth Cave National Park's (MACA) Bat Bio Blitz, Southeastern Cave Conservancy's Daleo Entrance Acquisition event (they bought one of the Roppel entrances to the Mammoth Cave System), and of course CRF's 60th Anniversary.

Since education and outreach is one of our initiatives, we provide not only bunkrooms and space for university, high school and select middle school level field camps and field trips, we have also been working with the professors, instructors and teachers in helping them assemble custom itineraries for local karst/cave related trips that are outside of the national park. The HV director also leads geology field trips in Mammoth Cave when MACA division of resource management does not have sufficient personnel (4 this past year). The more personalized interaction with university/school groups is resulting in the scheduling of repeat users—many who now use our facility for their annual field trips.

We provide space/internet access for a number of researchers who are now becoming HV regulars (they like it better than Maple Spring). We have had researchers who are working on local archeology, mussel rescue, Mammoth Cave restoration, and plant inventories.

We have rented our main room for local neighbors for family reunions/dinners and for local caver-related activities. And, of course, we host the Hamilton Valley work weekends which happen 2–3 times per year. If we had a third bunkroom, I think I could put it to good use.

John Feil and Roger McClure negotiated a new hunting lease with our new neighbors. The original charge for annual hunting lease was $600. Fair market value is $3500, and that is what we now get. The new lease rate significantly bumps up the HV land income. We also have a written agreement with the neighbors for CRF to manage and lead trips to Dogwood Cave. They gated it because there was a lot of traffic that was not us. We will be installing a new gate at some point next year (2018).

The new electric stove, double convection oven, and extra metal tables have now all been installed in the kitchen. We have moved the smaller refrigerator into the pantry. This seems to have opened up more kitchen work space, and so far, the cooks like the new arrangement.

Renter activity has been up, and we have seen more large groups than ever this year—and hope that this trend continues. EO income will be reflected in some other part of the Annual Financial Report that Bob Hoke generates.

Expenses from last year are similar—up in some cases, down in others. We did have a major water pipe break in the trailer and though they eventually turned the water off (it happened while I was at work) that jacked up the water bill for March. Since we now have an electric stove, we no longer have the propane expense. And with our new hunters, they don't use the Hoffmaster House, so our electric costs there will drop as well.

I spoke with several different banks to add Bob Hoke on the HV account, but no one will do it unless Bob shows up in person. I have put Elizabeth Winkler, a member of the Finance Committee, on the account since she is local. I can provide monthly bank statements to Bob if he wishes, but that seems redundant since I do provide a full accounting every year.

Table 2 is a draft financial summary for Hamilton Valley expenses/income. I still have a few outstanding invoices that have not been paid yet, for HV use prior to October 1st. I will update the report once all of the 2016–17 income is received.

Plans for next year include putting more signage in the parking area to prevent people from parking their cars on (and off) the road. We have a party interested in the trailer (since we are giving it away—they pay to have it removed). Moving the trailer will be challenging as we don't want to tear up the septic field near which it sits. Our HV maintenance team will work with the person when they are ready to remove the trailer.

2017 Hamilton Valley Financial Report	
EXPENSES	
Phone/Internet	1193
Electric-KU (Main, 2 bunkhouses, Archive Bldg)	6397
Electric RECC (safety light-Hoff house)	247
County water	976
Bank fees	168
Gasoline (mowing)	179
Dumpster/monthly	496
Dumpster/empty	248
HV Supplies (includes partial Sam's Club membership, shared with EO)	532
Fire suppression	616
Repairs	1270
TOTAL EXPENSES	12322
INCOME	
2016 Balance	11584
HV Land Income* (reconcile with Roger)	8550
Rental Income	10462
TOTAL INCOME	30596
BALANCE AS OF OCTOBER 1, 2017	**18274**

Table 2. Draft 2017 Financial Report for Hamilton Valley Field Station.

Lava Beds Operations

Report to Cave Research Foundation Board of Directors

John Tinsley

Manager, CRF-LABE Operations

2016

The Lava Beds Operation of the Cave Research Foundation operates year-round and consists of 10 projects active in and around Lava Beds National Monument in northern California. A Principal Investigator heads each project and is responsible for the timely completion of the activities enumerated in the proposal. Each proposal, in turn, has been approved by either the pertinent governmental agency, usually the National Park Service or the Forest Service. The cartography and inventory projects are loosely organized around the geology, with principal investigators respectively taking on areas that are mapped by U.S. Geological Survey volcanologists as distinct flow events or phases of flow events. The idea is to eventually be able to compare aspects of cave occurrence and morphology in terms of the geology of this part of Medicine Lake volcano.

In 2016 to date, CRF has conducted at least 8 expeditions attended by 38 people. In 2016, 45 different people invested at least 301 person-days at LABE expeditions. This figure does not account for cartographic activities conducted outside of the on-site field mapping activities, per se. About 79 caves were mapped, or were linked by surface surveys, or were sampled. Eight caves are new to the Monument's database. In short, it has been a most productive year, with substantial amounts of work done by CRF JVs who mounted 3 expeditions that lasted at least a week. Most of these folks traveled substantial distances from across the country and made their time on site count, in terms of caves mapped.

The specific projects and Principal Investigators are summarized briefly below.

1. Elmer's Trench Cartography (Ed Klausner)

Continuing under the 2015 RP, we continued the survey of caves in Elmer's Trench, which is a distinct lobe of the 35,000-year-old Mammoth Crater flow that is situated east of Gillem fault. There were two approximately week-long trips to LABE, one in late April and one in late July following the 2016 National Speleological Society's annual convention in Ely, Nevada. Some 24 caves were surveyed or linked.

2. Cave Loop: complete cave resurveys (Liz Wolff)

The Cave Loop surveys of principal caves have been completed and the mop-up work linking various surveys and dealing with a few persistent magnetic field perturbations continues. More than 16,000 feet of surveys have been compiled on a base map of the Cave Loop area, and the results demonstrate the complexity of these distributary conduits relative to prior understanding of the Mammoth Crater flow system. Liz Wolff shared a preliminary version of this compilation at the Annual Meeting in June, to great acclaim. Additional field checking of data and a few cave connections, and additional surveys are needed to resolve a few questions, but the main surveying and cartography tasks are nearing completion.

Total Cave Loop system length is now greater than 16,224 feet with much remaining to be done prior to pronouncing "final" totals.

3. Modoc National Forest CRF Project (Bill Broeckel)

This project addresses caves of the Modoc National Forest, federal land that adjoins the Monument which contains a number of significant caves and vent areas for several of the principal late Pleistocene and Holocene lava flows that extend into the Monument from Medicine Lake Volcano. While some caves are small, the signature lava tube feature is the principal distributary feature dubbed Steamboat Frank Cave, named for the famous Modoc warrior from the Modoc War.

4. Caves of the Valentine Cave Flow (Heather McDonald)

The Valentine Cave flow is geologically illuminating because the basalt of Valentine Cave (bvc) as mapped by Julie Donnelly-Nolan of the U.S. Geological Survey, is a basaltic andesite and has a chemical composition in terms of silica content that is near the limit of viscosity required to form significant lava tubes. This study aims to reconnoiter, locate, and map the caves of this distinctive geologic unit. The results will enable comparisons of cave numbers and morphological characteristics of the bvc deposits to the more fluid basalt of Mammoth Crater (bmc). During 2016, fieldwork has been primarily reconnaissance but also included increasing amounts of surveying as significant lava caves are located. Reconnaissance involves systematic search and documentation of lava tube and flow features. Notable features have been recorded with digital photographs and GPS-locations obtained. Recon Cards have been filled out for the new lava tubes found, and cultural resources have

been noted, photographed, and GPS coordinates taken and passed on to Monument resource management. Parts of 4 expeditions addressed this RP so far this year.

5. North Castle Flow, South Castle Flow, Inventory and Monitoring Cave Surveys (Scott House)

In mid-April, folks flew in from Missouri, Iowa, Arkansas and environs with the goals of continuing work on the documentation of features of the North Castle Flow and of initiating work on the South Castle Flow. These flows are located a few kilometers north of Schonchin Butte and present a distinctly different geology than does the bulk of the Monument's caves that are located in the basalt of Mammoth Crater. During the week-long expedition, 21 caves were surveyed and/or linked by surface survey. This work is progressing nicely.

6. Balcony Flow System (Dave West)

The Balcony Flow system is another distinct lobe of the ~35,000-year-old Mammoth Crater flow. Two approximately one-week-long expeditions (late April, late July 2016) have resulted in significant progress in the mapping of at least 13 significant caves of this remarkable arm of the basalt of Mammoth Crater's lava tube systems.

7. Ice Cave Monitoring (Bill Devereaux)

In 2016, one trip in May recorded ice levels in Upper Ice Cave, Heppe Ice Cave, Incline Cave, and Merrill Cave. We recorded temperatures inside and outside the caves. We also recorded moisture and ice deposits that we monitor each year for quality, deposition, or declination of deposits. In general, during the past decade, ice volumes appear to be decreasing in all caves but Skull Cave.

8. Craig Cave Cartography and Inventory (John Tinsley)

Surveys of the principal parts of Craig Cave are complete, and map, profile, and sections are being drawn as time permits.

9. Mammoth Crater Flow Lobes and Chemistry (John Tinsley, Julie Donnelly Nolan)

This is a new RP that is attempting to learn which of the 6 lobes of the Mammoth Crater flow, if any, are younger than the other Mammoth Crater flow lobes, using the content of potassium as measured in whole-rock analyses as a relative

Iceberg Cave entrance. *Ed Klausner*

age indicator. The concept is that initial eruptions will vent lavas that have had the most prolonged contact with continental rocks and thus will tend to be more enriched in potassium compared to later-stage eruptives that are more "primitive" in composition, as these are derived from mantle-based melts that did not assimilate significant volumes of potassium-rich rock and thus are depleted in potassium. Samples have been collected from all but one of the Mammoth Crater flow lobes, and we hope to have enough data by this time next near to learn if this approach will offer any additional insights into the eruptive history of the flow that as produced nearly 90% of the Monument's tubes.

We look forward to another productive year at Lava Beds National Monument in 2017.

10. Photo-monitoring of selected lava tubes (Peri and Bill Frantz)

This is a long-standing effort that since 1989 periodically re-occupies the camera positions of past or historical photographs with the idea of making comparisons among photographs to assess conditions or impacts of traffic on lava caves of Lava Beds National Monument. The principal investigators work with Resources Management at LABE to select the caves or other features to be monitored, and to establish the interval at which to re-occupy photographic positions. Caves are selected for their sensitivity of features to be monitored.

Elizabeth Miller at a lava tube entrance. *Ed Klausner*

2017

Summary

The LABE Operations Area enjoyed another highly productive year. The Cave Loop Resurvey by Liz Wolff is approaching completion; her digital compilation of all the cave maps on a Google Maps photobase is one of the more thought-provoking documents I've seen in recent times. The "Easterner" folks (PIs Klausner, West, and House) mounted two long expeditions in April and early May, one following the other, and much was achieved in the Elmers Trench, Balcony-Boulevard, and Castle Flow system surveys. Tinsley completed sampling of proximal and distal pahoehoe flows in lava tubes within each of the principal lobes of the Mammoth Crater flow; lab results are anticipated by early spring, 2018. Efforts to improve the radiometric dating of the Mammoth Crater flow using modern argon/argon techniques did not succeed. Bill Broeckel mounted two expeditions and assisted with others as surveys of the boundary caves continue, including surveys in Steamboat Frank Cave. Ice level surveys continued in May (Bill Devereaux), with ice diminishing visibly in all caves except Skull Cave. Heather McDonald and crew mustered three expeditions to the Valentine Flow cave survey; several known caves and a few new caves were located and surveys are ongoing. Bill and Peri Frantz continue their photo-monitoring of NPS-selected caves; they presently await guidance as to the next caves that NPS wants to re-photograph. NPS is exploring the idea of using new software such as "Structure from Motion" to obtain more easily quantitative information about selected monitoring sites. This could be much more important for projects like the ice level studies. Tinsley should finish the map of Craig Cave and Craig Temple Cave shortly, assuming lingering software issues can be resolved.

At Lava Beds this year, 36 CRF joint venturers invested 84 days in traveling to and from the remote venue. There were 180 person-days expended on-site for a total of 264 person-days expended, excluding off-site activities like data processing, map drafting and the like. There were at least 4148 feet of cave survey obtained, tied together by at least 7869 feet of surface survey. At least 35 caves were surveyed in whole or in part.

PI Roster

Frantz, Tinsley, House, Klausner, Broeckel, West, McDonald, Wolff

Future Opportunities

The International Vulcanospeleological Symposium convenes at Lava Beds next July 21–27. I've yet to receive a solicitation for papers, but Googling "International Vulcanospeleological Symposium 2018" brings up the website. CRF should have a distinctive presence, as several of our projects are far enough along to report on. I'm thinking of my geochemical work on Mammoth Crater Flow with Julie and Liz's compilation of Cave Loop stuff, at a minimum.

Mapping of Craig Cave

Lava Beds National Monument, California, USA

John Tinsley

During 2017, mapping at Craig Cave consisted chiefly of exploring and mapping the maze of breakdown that marks the terminus of the main trunk passage. The area is not stable and great care must be exercised in threading one's way through the breakdown.

Work was also conducted on profiles and sections along the main passage. Completion of the map and sections is anticipated by mid-2019.

Cave Loop Survey Project

Lava Beds National Monument

Liz Wolff

Principal Investigator

May 25–29, 2017 Expedition

Personnel

Bill Devereaux, Steve Hobson, Beej Jorgensen (Brian Hall), Breanna Kisling, Matt Liessring, Rick Magnin, Heather McDonald, Bruce Rogers, Dave Smith, Doug Viner, Jim Wolff, Liz Wolff, and newcomers Jarrod Breuer, Neil Calmes, and Ernie Maier.

Expedition Objectives

Check-survey in Golden Dome to correct bad loops, etc; complete the survey of Hmm Bridges; take some ice levels; further document cave entrances previously found in the Valentine's lava flow. This report covers only Golden Dome and Hmm Bridges.

Findings

On Saturday, May 27, Liz, Bill, Breanna, and Neil entered Golden Dome Cave, one of the more popular caves on Cave Loop, to do a check of the 2007 survey and relocate the station where the passage divides. Many discrepancies were noted, mainly in the inclinometer readings. After lunch, they were joined by Jarrod when the check-survey continued to show discrepancies. A major blunder, which threw the surveyed loop closures off, was discovered. They exited the cave after 5 p.m. having checked about 400 feet of survey. Numerous groups of tourists crossed their path during the day, slowing the survey process. Most were curious about the survey and why it was being done.

Sunday, May 28, Doug, Liz, Jim, and Dave entered Hmm Bridges to complete the survey. The previous station was located and the survey begun. Hmm Bridges, in the Valentine's flow, is mainly low with either an inflated floor, raised and rafted floor plates, or up-ended, jagged floor plates. After a single shot plagued with magnetic problems and torturous travel through tight places with up-ended floor plates, they exited a skylight next to the road and broke for lunch. Following lunch in comfort, they returned to continue into the final section of the cave. After clearing a path through sticks and rat droppings, a lava seal at the end of the cave was reached. The cave end is approximately half way across the Valentine's road. They then measured to both roads and back to the Hmm Bridges pin from the final skylight. Total in-cave survey for Hmm Bridges was 280 feet. We encountered a black widow spider, gnats and flies, many butterflies in the skylights, and a lizard scurrying across the ceiling over an a'a floor; when it was over the pumice floor, it dropped down to hunt bugs. Delicate ferns festoon the skylights just under the overhangs, mosses and small plants carpet parts of the skylight floors. In the first section of the cave, a low and obviously man-made rock wall crosses the passage.

Modoc National Forest Project Report

2017 Update

Bill Broeckel

Principal Investigator

The most recent trip into Steamboat Frank Cave featured Joyce Hoffmaster, Mark Jones, and David Riggs on April 26, 2016. Steamboat Frank is the big cave that highjacked the project a couple three years ago. David Riggs (Lava Beds Cave Specialist) toured all the way back to cave's end, much of the passage being within the Monument. We also surveyed a small maze in the left wall, where Joyce discovered an interesting intrusion of creamy beige lava. The length of Steamboat Frank now sits at 4624 feet, with six leads still awaiting survey.

Bill Broeckel and Mark Jones at Crustose Lichen Cave.

Ed Klausner

Arkansas Cave is another Monument boundary cave but has tiny passages. When Jenn Ellis and Kayla Sapkota were ready to go, they looked like just the right team for this cave. After crawling along through flat rooms, Jenn and Kayla said it reminded them of some caves in Arkansas, and the cave was thus named. At the end of the day (July 26, 2016), they made a breakout into a bigger passage.

April 22, 2017: Bill and Judy Broeckel and Mark Jones returned to Arkansas to survey the new passage. Judy and I both injured ribs on the way in and were glad to find a surprise fifth entrance at the end of the survey. Three days later, Charles Fox agreed to help do some clean-up survey, tying in the tight discovery entrance. We figured out a way to map through the tight spot without actually having to get through it ourselves. Length currently stands at 540 feet, with some more to go in another bigger passage found by Mark Jones. This is an atypical lava cave and seems to be formed in layers inside a network of pressure ridges. As noted, Arkansas now has five entrances: two small ones, and three very small. As some of them are in Lava Beds, I was asked to submit a research proposal to the Monument for caves with entrances within the boundaries.

October 8, 2017: So it was back to the nether regions the other day with Claude Koch. We shimmied into Sphenoid Cave and surveyed a small 40-foot lava tube, disturbing a solitary day-roosting bat. Sphenoid is located quite near to Ethmoid Cave, and we continue to illuminate the internal anatomy of a large spatter cone known as Big Bertha. In this area, we also pulled a rusted crow bar out of a possible cave entrance. It was homemade from a spike welded to a length of pipe and may have been lost from a Bruce Rogers expedition some fifty years ago.

Ice Level Measurements in Selected Caves

Lava Beds National Monument, California, USA

Bill Devereaux

For the year 2017, I visited Lava Beds National Monument twice. During early May for the TimeLine event, I conducted measurements of ice in Cox Ice Cave. The ice was wet, the ice level was .16 feet closer to the pin than in 2015, and the temperature was .2°F colder than in 2015.

Later in May, during the Memorial Day weekend, I went to Upper Ice Cave and Heppe Ice Cave and made measurements and observations of ice levels. Upper Ice was .3 feet closer to the pin #2, and the temp was 1.5°F colder. Heppe Ice Cave had no ice compared to the previous year and was 0.2°F colder. The previous year (2016) the "pond"/lake was 38 feet × 30.8 feet × 4.1 feet (deep).

Photo-Monitoring of Selected Caves

Lava Beds National Monument, California, USA

Peri and Bill Frantz

The photo-monitoring study has been inactive in 2016–2017 because we are between the agreed-upon times when re-occupation of camera positions is scheduled to take place. This project is operated in conjunction with the needs of the Lava Beds Resources Management group to track changes in selected Monument caves. With an eye to the forthcoming International Vulcanospeleological Symposium in July 2018, we are preparing a paper for oral presentation, and hopefully a written contribution to the Proceedings that will document our efforts at Lava Beds since 1989, when the Cave Research Foundation initiated an active presence there under the leadership of Janet M. Sowers.

Castle Flows Project

Lava Beds National Monument

Scott House and Don Dunham

This project involves the location, reporting, surveying, and inventory of caves in the North Castle and South Castle Flows located north or west of Hardin Butte, a cinder cone. All caves are in the Basalt of the Castles. The two flows are slightly different in morphology, at the minimum. The study area is accessed by a two-mile hike, partially utilizing new trails or old roads. Drafting of cave maps is essentially up to date with surveys.

April 2016 Expedition

The primary objective of this expedition was to continue inventory and survey work on the South Castle Flow. A secondary objective was to complete a few surface ties in the North Castle Flow.

Don Dunham, Richard Young, and Scott House flew in from St. Louis, while Mark Jones drove from Chicago.

Battlefield (or Square Tube) Cave is one of the vents for the North Castle Flow. *Mark Jones.*

Bill Broeckel joined us for a day and came from Yreka, California.

Field trips with the same four individuals were taken into the project area on seven straight days, from Wednesday, April 13, through Tuesday, April 19. On the last day, we were joined by Bill Broeckel plus NPS tech David Riggs; this was the day that the surface ties on the North Castle Flow were accomplished.

Twenty-one caves were completely surveyed. One was started but shelved due to lack of time (the cave was much longer than the 70 feet advertised). The total surveyed in the caves completed was over 2700 feet.

The caves in the South Castle flow are slightly different than those in the North Castle flow. Much of our work was in the north end of the south flow where the flow was coming to an end, so the caves are smaller than those located further south (or upflow) in the flow.

All the South Castle caves surveyed were on the west side of Hardin Butte except for one. At the request of NPS, Ratty Loft Cave (S140) was surveyed to a length of over 600 feet). This cave is southwest of Hardin Butte to the south of the old Powerline Trail road.

Other caves surveyed included:

- Rhizoplaca Cave (S370) 41 feet
- Hypotenuse Cave (S299)* 146 feet
- Pepperjack Cave (S410) 141 feet
- Bufo Boreas Cave (S360) 153 feet
- Volpes Fulva Cave (S340) 50 feet
- Trapdoor Cave (S338)* 47 feet
- Rocky Horror Cave (S310) 123 feet
- Ahoyhoe Cave (S271)* 51 feet
- Cedar Fingers Cave (S259) 47 feet
- Grassy Hole Tube (S237)* 52 feet
- Summer Home Cave (S236) 70 feet
- Cobble Pot (S234)* 114 feet
- Mossy Coffin Cave (S420) 64 feet
- Whack A Mole Cave (S412)* 43 feet
- Breve Fisso Cave (S400) 40 feet
- San Marcos Cave (S380)[2] 196 feet
- Udongo Cave (S390) 84 feet
- Teton Perdu Cave (S350) 64 feet
- Dalmatian Cave (S330) 380 feet
- Vespertine Cave (S320) 169 feet

*= New Caves

All caves were examined for cultural materials and a separate report has been sent to NPS.

- People days: 32
- Field hours: ~232
- Onsite lab/support hours: ~30
- Miles driven by privately owned vehicle: ~4800

Looking north over the North Castle Flow from Hardin Butte. *Scott House*

Richard Young at the entrance of Cedar Fingers Cave. *Mark Jones*

Don Dunham at the entrance of Cobblepot Cave. *Mark Jones*

Richard Young gets a little help fitting into a tight entrance. *Mark Jones*

Scott House sketches in Pepperjack Cave. *Mark Jones*

May 2017 Expedition

The objectives of this expedition were to conduct an overland survey to tie in the caves in the North Castle Flow and to continue inventory and survey work on the South Castle Flow.

Field trips were taken into the project area on four straight days, from Sunday, May 7, through Wednesday, May 10. On Tuesday, Bill Broeckel joined us to help with surveying caves in the South Castle Flow. The overland survey of the North Castle Flow was conducted during the first two days. Cave surveys were conducted during the last three days.

Malibu Cave connects visually (not humanly passable unless we dig through debris) to another, new-found cave, which we did not have time to map.

The total overland survey was 5007 feet. Four caves were completely surveyed. The total surveyed in the caves was 769 feet.

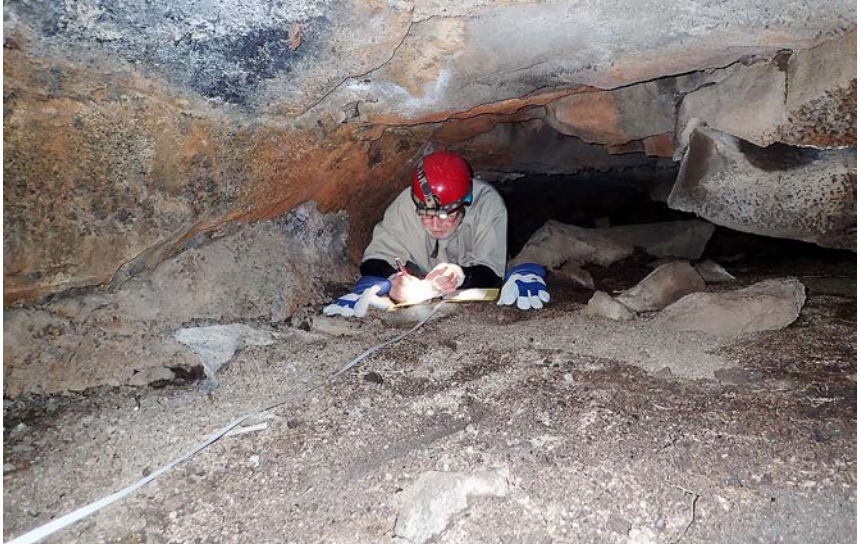
All caves were examined for cultural materials; none was found.

Caves surveyed included:

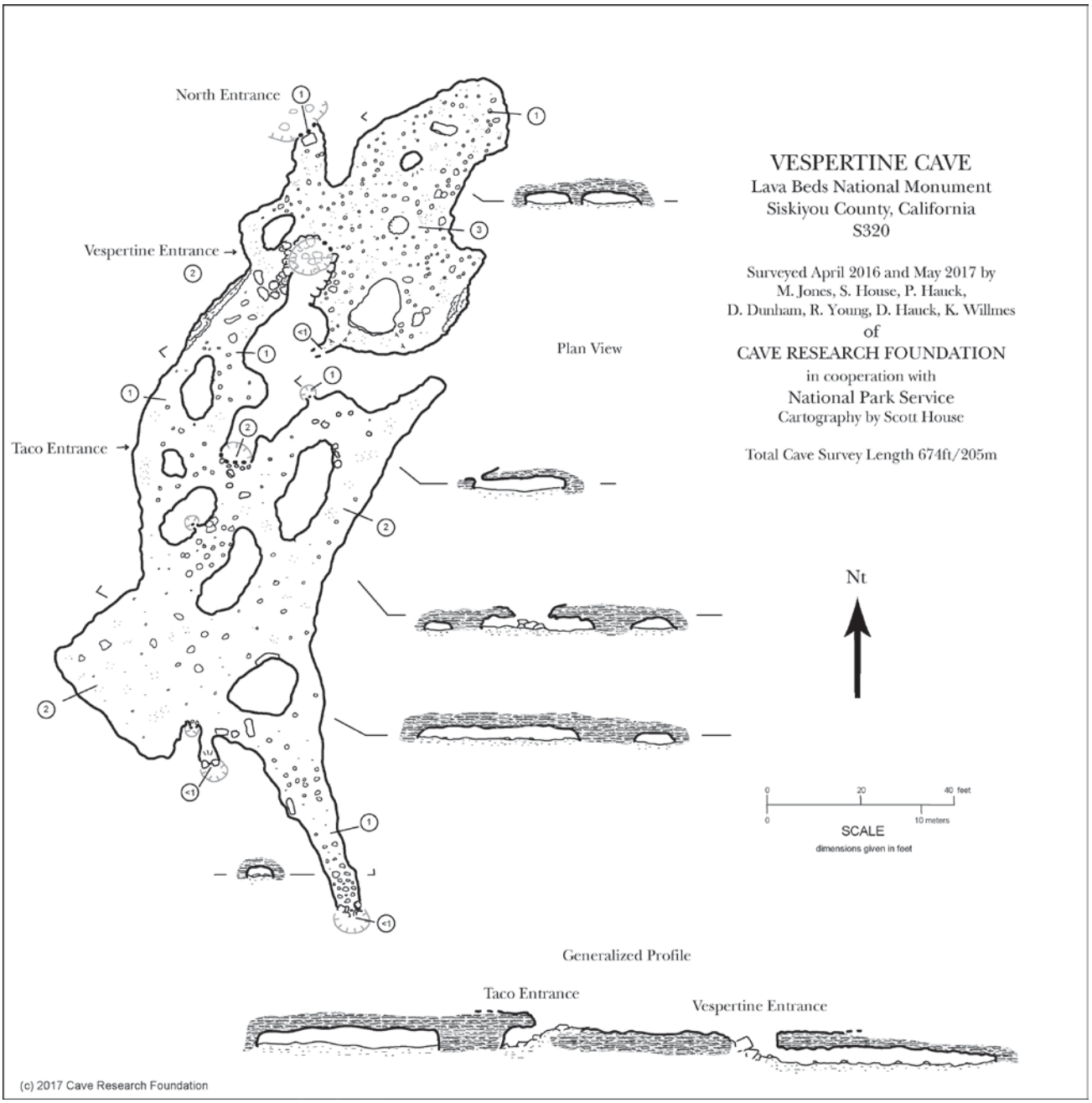
- Let's Get a Taco (S300) 121 feet: *Let's Get a Taco* is connected to *Vespertine Cave*, and therefore is a single cave. Suggest calling the cave *Vespertine Cave*, dropping the *Taco* appellation.
- Catbox Cave (S290) 163 feet
- Malibu (S280) 420 feet
- Orange Peel Cave (S240) 65 feet

- People days: 20
- Field hours: ~152
- Onsite lab/support hours: ~20
- Miles driven by privately owned vehicle: ~4000

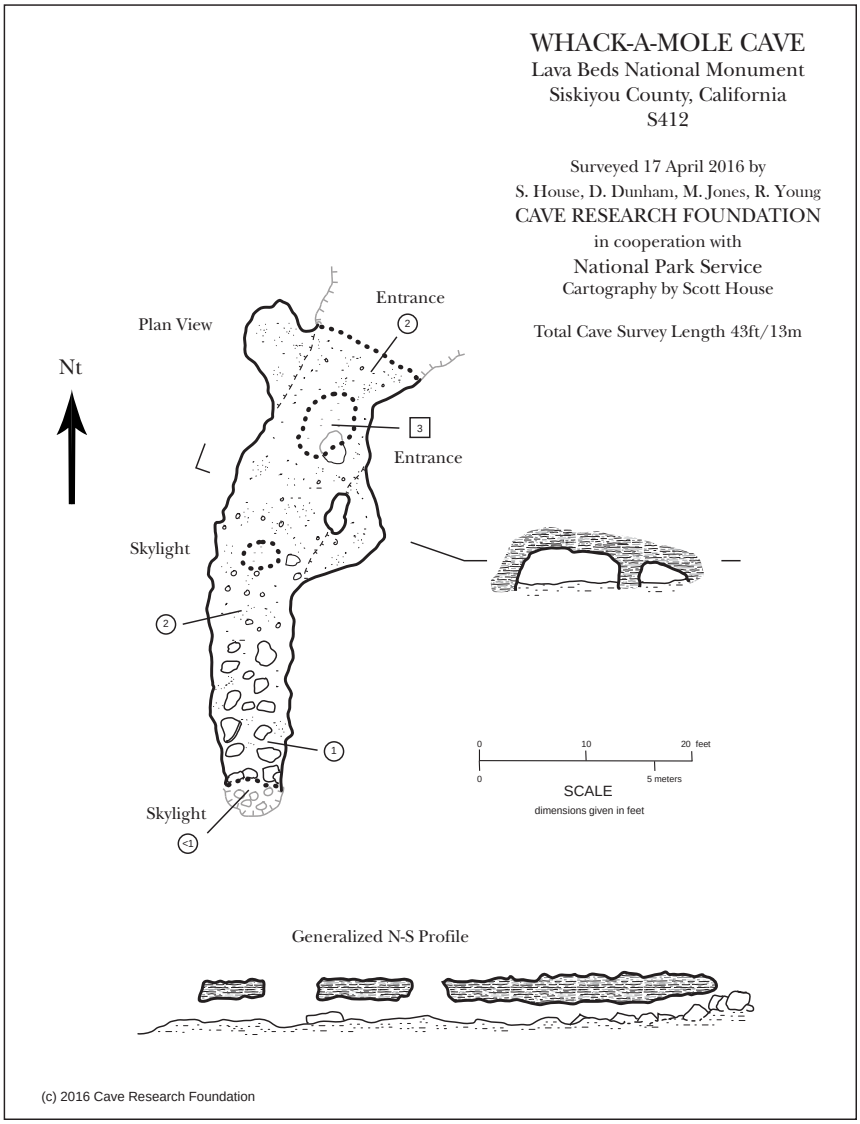
Richard Young reads instruments in Ratty Loft Cave.
Mark Jones

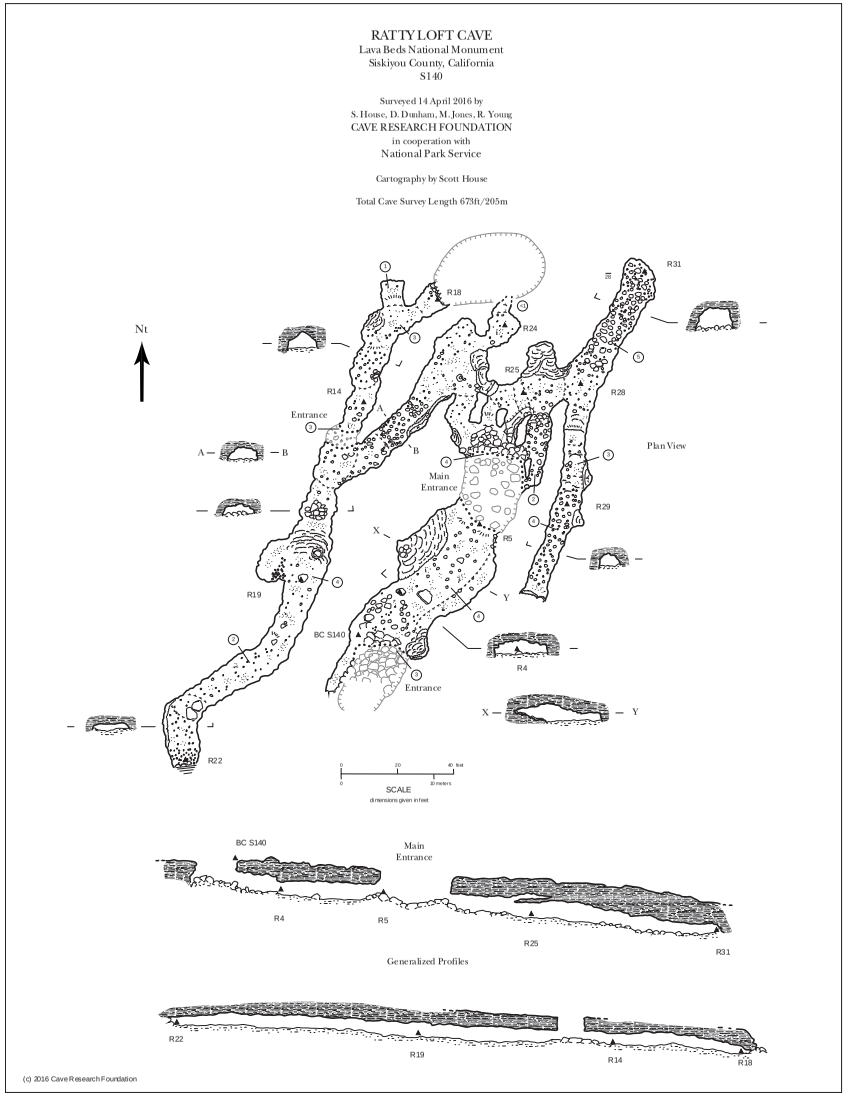


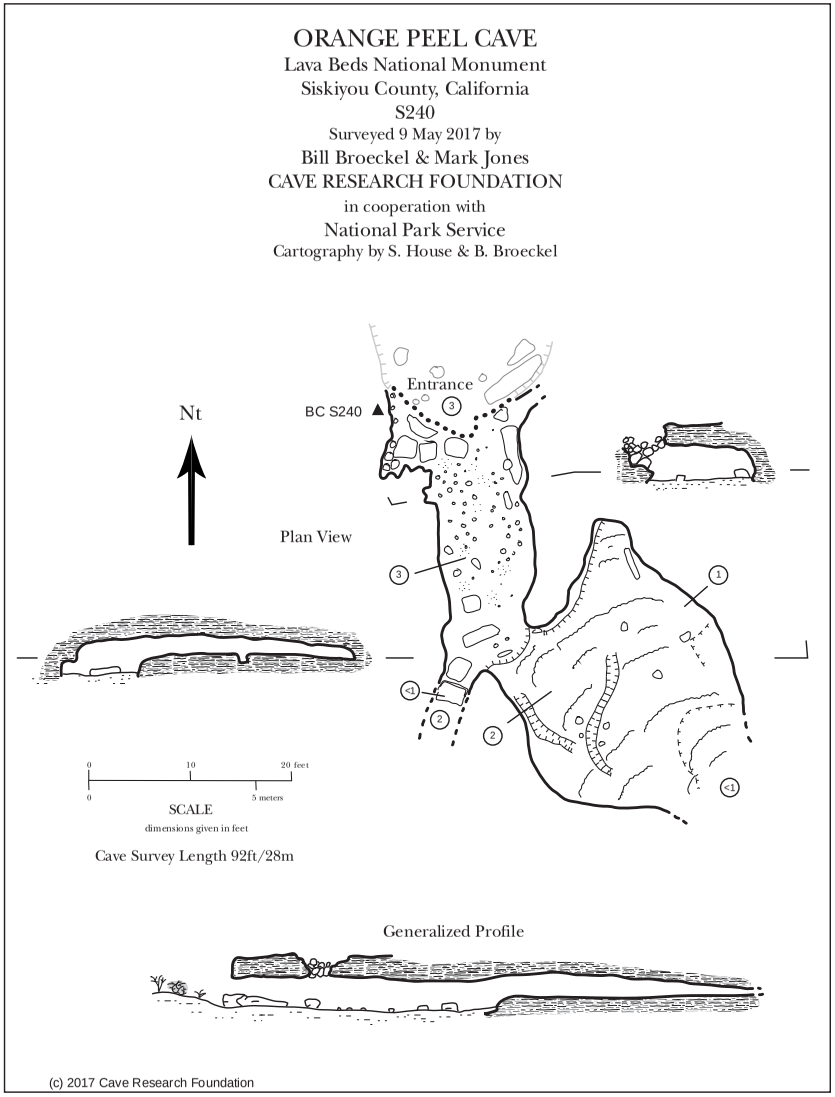
Paul Hauck sketching in Vespertine Cave. *Mark Jones*



Three surveyors popping out of entrances at Whack-A-Mole Cave.
Mark Jones




RATTY LOFT CAVE
Lava Beds National Monument
Siskiyou County, California
S140
Surveyed 14 April 2016 by
S. House, D. Dunham, M. Jones, R. Young
CAVE RESEARCH FOUNDATION
in cooperation with
National Park Service
Cartography by Scott House
Total Cave Survey Length 673ft/205m
Nt
Plan View
Entrance
Main Entrance
BC S140
R4
R5
R14
R18
R19
R22
R24
R25
R28
R29
R31
SCALE
dimensions given in feet
Generalized Profiles
(c) 2016 Cave Research Foundation


ORANGE PEEL CAVE
Lava Beds National Monument
Siskiyou County, California
S240
Surveyed 9 May 2017 by
Bill Broeckel & Mark Jones
CAVE RESEARCH FOUNDATION
in cooperation with
National Park Service
Cartography by S. House & B. Broeckel
Nt
Plan View
Entrance
BC S240
SCALE
dimensions given in feet
Cave Survey Length 92ft/28m
Generalized Profile
(c) 2017 Cave Research Foundation

Cultural Resource Assessment of Lava Caves

Lava Beds National Monument

Richard A. Young

Trap Door Cave (S338)

Trap Door Cave was surveyed by a Cave Research Foundation crew comprised of Scott House, Don Dunham, Mark Jones, and Richard Young on April 15, 2016. This tube is located on the eastern flank of a large collapse feature situated to the west of Hardin Butte. Drop-In Cave's northwest facing entrance is 3 feet wide and 1.5 feet high. This rather tight entrance drops into a passage in which one can comfortably stand. During the survey, we observed what appears to be a copper Gov't. 50–70 cartridge case. Surrounded by rubble blocks, this artifact lies in a pocket on the cave floor 15 feet west of survey station D1 and approximately 2.7 feet from the tube's northwest wall. The ceiling height immediately above the cartridge is 3.40 feet.

This rimmed case is 1.75 inches long and .50 inches wide. One quarter inch above its rim, the case is crimped to contain an internally primed Benet primer. Although the case was not disturbed, there appears to be no head stamps on its base. One can, however, see that the base has been completely pierced by the firing pin that discharged the weapon.

A cartridge for .45-70 load was used in the Modoc War.

Scott House

A brief Internet search regarding this case suggests it was designed for use in the U.S. Springfield Allen Conversion rifle adopted by the United States Army in 1866. It seems likely this particular cartridge case was manufactured at the Frankford Arsenal between 1868 and 1872. In addition to the army Allen Conversion, the Gov't 50–70 cartridge was also utilized by some Sharps rifles.

This cartridge case was photographed and left undisturbed in situ. No other cultural material or evidence of human activity was observed in the tube.

Summer Home Cave (S260)

Summer Home Cave was surveyed by Scott House, Don Dunham, Mark Jones, and Richard Young on April 16, 2016. During this survey, Richard Young conducted a pedestrian survey of the tube in order to evaluate its archaeological potential. Although no cultural material was observed, this cave certainly seems to offer promise as a site.

This tube contains a spacious chamber entered via two entrances. The east entrance is 10 feet wide and 4.5 feet high while the west-facing entrance is 15.5 feet wide and 4 feet high. Both of these entrances exhibit breakdown rubble slopes leading into the tube's single domed chamber. Between these two entrances, the cave is 35 feet long and approximately 6 feet high at its highest point. It exhibits a relatively flat floor that is generally dry but strewn with some breakdown blocks. Within the cave, only one intact deer cannon bone was noted along with a scattering of partially charred wood fragments. The surface area immediately surrounding the tube was also investigated for evidence of archaeological activity but nothing was noted.

Notwithstanding the lack of cultural material observed during this visitation, Summer Home Cave is perhaps worthy of closer investigation.

Elucidating the Eruptive History of the Basalt of Mammoth Crater at Lava Beds National Monument, California, USA

John Tinsley

The basalt of Mammoth Crater (map unit *bmc* of Donnelly-Nolan and Champion, 1987) was erupted about 35,000 years ago from several vents, the most prominent of which is the Mammoth Crater proper, on the north-northeast aspect of Medicine Lake Volcano, a major shield-shaped feature located east of the main Cascades volcanic province. The other *bmc* vents trend generally north from Mammoth Crater and occur along zones of fracture or weakness along and subparalleling the extensional structure commonly termed the Gillem fault. This fault scarp marks the western edge of the Tulelake basin, *sensu strictu*. The eruptive history is of interest because the *bmc* eruption produced 5 or 6 distinct lobes of cave-bearing basalt, many of which extend for miles downslope and in some cases reach the shores of Tule Lake or beyond. Probably 85–90 per cent of the lava caves of the Monument occur in the *bmc* flows. Two other major basalt eruptions are mapped by Donnelly-Nolan (2010) on Medicine Lake Volcano, these being the basalt of Giant Crater and the basalt of Yellowjacket Butte. These basalt flows are located on the south side of Medicine Lake Volcano, in contrast to the *bmc*, and these flows, the *bgc* and *byb* units contain a plethora of lava tubes. This intriguing aspect of the *bmc* eruption is that it was emplaced in a matter of a few decades, as the earth's non-dipole field direction is effectively identical no matter where the flow is sampled. The paleomagnetics and analysis supporting a short eruptive history for these basalt flows can be found in Champion and Donnelly-Nolan (1994).

To determine if any distinctive geochemical trends could be identified in the *bmc* flows, we sampled proximal and distal pahoehoe flows that comprised the bottoms of principal trunk passages that fed the various lobes of the *bmc* flow complex. These pahoehoe flows were the last *bmc* eruptives to have come through those flow systems, as they had solidified in place as the bmc eruption abated, thereby forming the floor of the distributary trunk passages. As 2017 winds to a close, we are awaiting the laboratory data that will give us the major element chemistry from 16 samples of lava from the *bmc* unit. The present geochemical data base for Medicine Lake volcano lacks subsurface samples of lava flows, in general. We anticipate that these additional samples will augment the existing surface sample set and provide lobe-specific data that will improve our understanding of the history of the eruption of the Mammoth Crater flows.

References Cited

1. *Geologic Map of Medicine Lake Volcano, Northern California*, by Julie M. Donnelly-Nolan. US Geological Survey Scientific Investigations Map 2927, 2010, scale 1:50000. [This is the definitive geologic map of Medicine Lake Volcano; best single rendition of the volcano, including ages of various geologic units.]

2. *Geologic Map of Lava Beds National Monument, Northern California,* by Julie M. Donnelly-Nolan and Duane E. Champion. Miscellaneous Investigations Series Map I-1804, Scale 1:24000 (1987). [This is a larger-scale map showing just the Lava Beds National Monument's geology.]

3. *Duration of eruption at the Giant Crater lava field, Medicine Lake volcano, California, based on paleomagnetic secular variation.* Duane E. Champion and Julie M. Donnelly-Nolan. Journal of Geophysical Research, Vol. 99, No. B8, pps. 15, 595–15, 604. August 10, 1994. [This paper emphasizes the paleomagnetic techniques and analysis employed by Champion and Donnelly-Nolan to show that the secular variations are so small that the eruption spanned but a few decades in duration.]

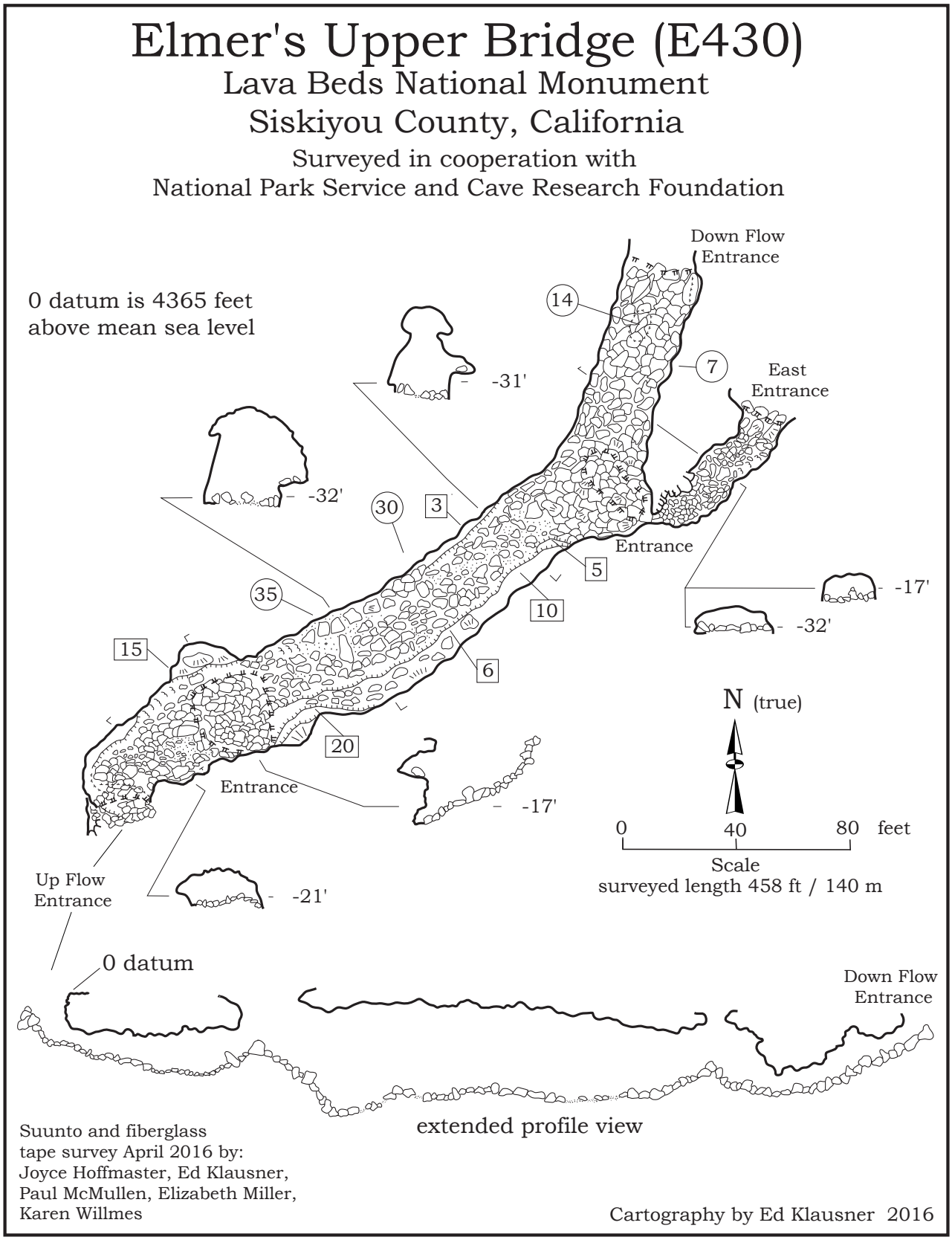


Figure 1. Elmer's Upper Bridge.

Elmer's Trench

Lava Beds National Monument

Ed Klausner

Principal Investigator

2016

Elmer's Trench is a 35,000-year-old lava flow in Lava Beds National Monument. It is comprised of Basalt of Mammoth Crater. Several caves had been recently surveyed in Elmer's Trench as part of the Inventory and Monitoring program. I had applied for and received a research permit to survey the known caves in Elmer's Trench and survey any additional caves located within the flow.

In April of 2016, Elizabeth Miller, Karen Willmes, Joyce Hoffmaster, Paul McMullen, and I spent 8 days surveying in Elmer's Trench while Dave West worked on his project in the neighboring Balcony/Boulevard Flow.

Two caves were at the top of the priority list: Elmer's Upper Bridge and Hungry Dog Cave as they were also Inventory and Monitoring caves. Elmer's Upper Bridge had 458 feet of survey to complete the cave (Figure 1), and Hungry Dog Cave reached 99 feet.

The end of the flow is covered by the a'a lava of Devil's Homestead. There is a convenient parking spot near by, so we surveyed several caves in this area when thunderstorms were predicted. This would allow us to retreat to the car and avoid being caught out when there was a possibility of lightening. We were fortunate not to have had to retreat, but those working south of us in the Monument experienced rain and sleet.

One of many lava tube entrance in Elmer's Trench. *Ed Klausner*

Finale Cave was located and surveyed along with a nearby cave we found, Rock Cress Cave (Figure 2). These caves are probably connected, but you have to be the size of a small rodent to make the connections.

In addition, Amber Dome, Emerald Star, Concert Hall, and Progress Caves were surveyed.

Later in the year, Elizabeth Miller, Dave West, Karen Willmes, Mark Jones, Kayla Sapkota, Jenn Ellis, and I made a second trip to the monument. Dave continued to work on neighboring Balcony/Boulevard Flow while I continued mapping in Elmer's Trench. We were joined by a number of park employees and interns (Chelsea Collins, Genomé Rodriguez, Lauren Van Fleet, and Mary Sullivan) during our stay as well as Bill Broeckel, another principal investigator at the monument.

Lucky Star Cave (Figure 3) was surveyed for a length of 635 feet and turned out to be connected to Meta Stella Cave. The caves are different in character with Meta Stella Cave having a large area with sediment on the floor. Lucky Star Cave had a wet area in the back, and we noticed some small, calcite stalactites. Lucky Star / Meta Stella Cave proved to be a difficult cave to teach people how to survey as some of the passages were small and contorted. Other caves that we surveyed were better suited and the interns and park seasonal employees were able to read instruments and set stations.

During our stay, Hat, Right Field, Glaesers 85, Pika Nests, Fumarole, and Coral Caves were also completed. We started Ohio Cave, but it is not yet complete.

Ed Klausner in Coral Cave. *Chelsea Collins*

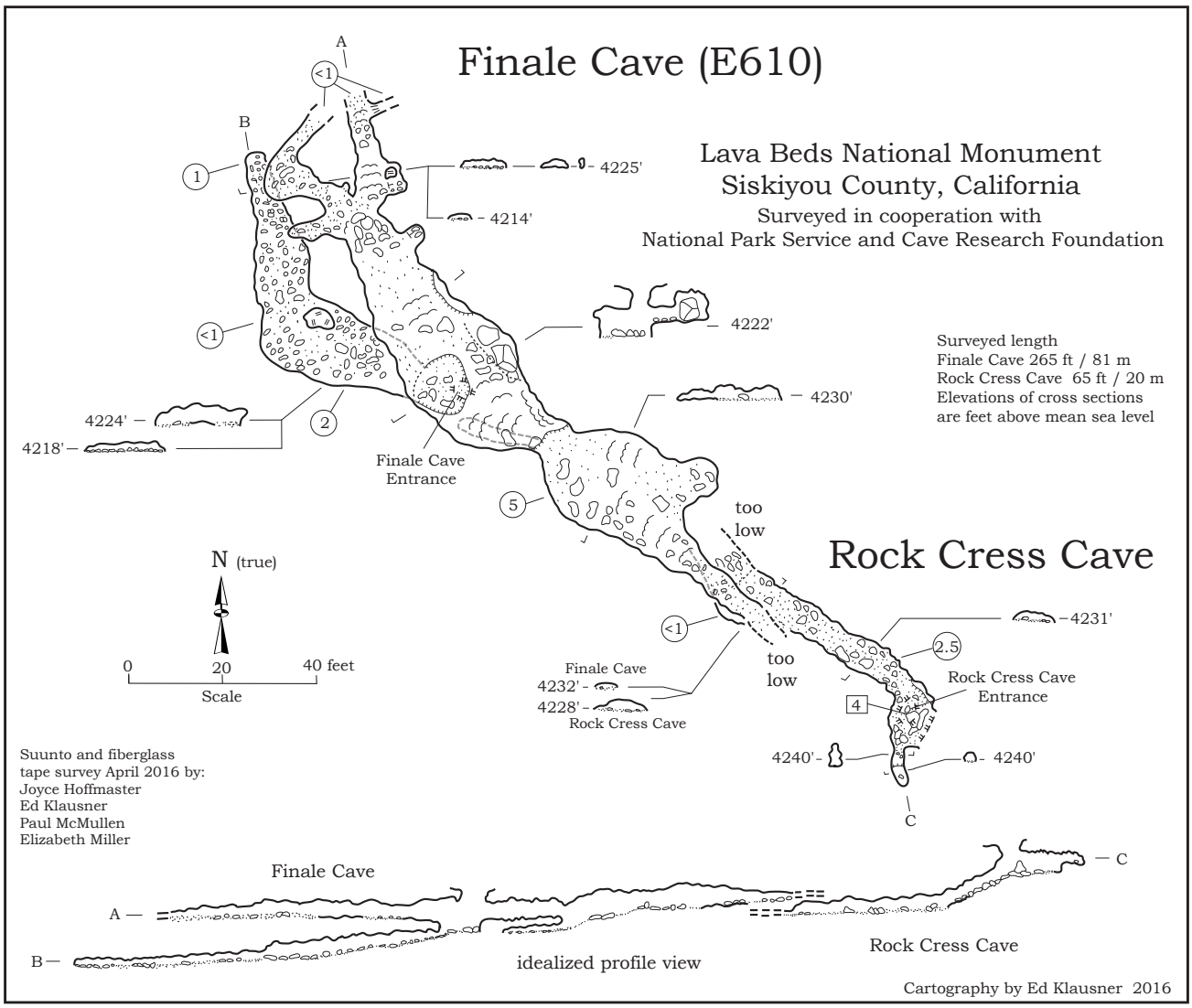


Figure 2. Finale Cave and Rock Cress Cave.

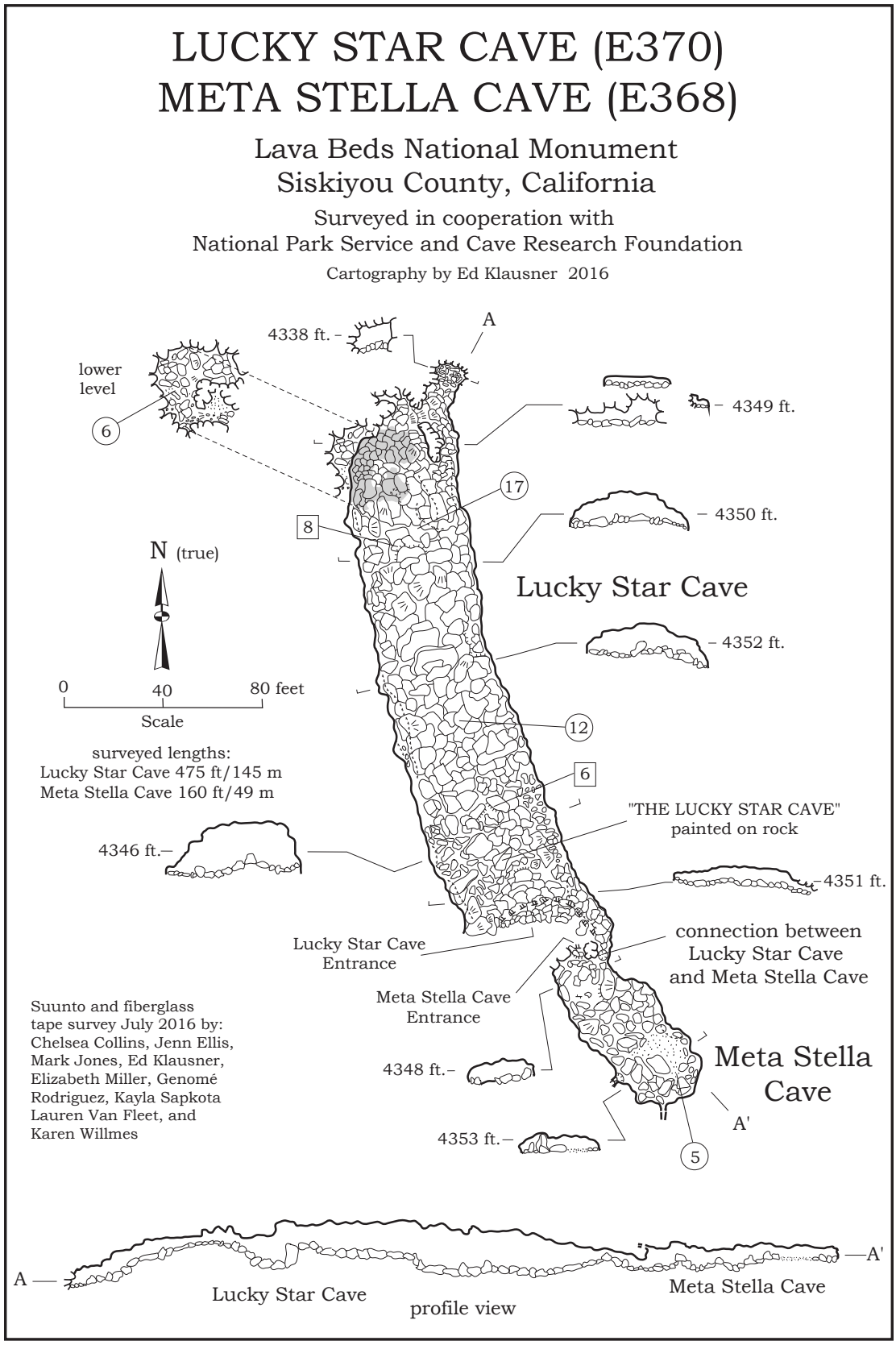


Figure 3. Lucky Star Cave.

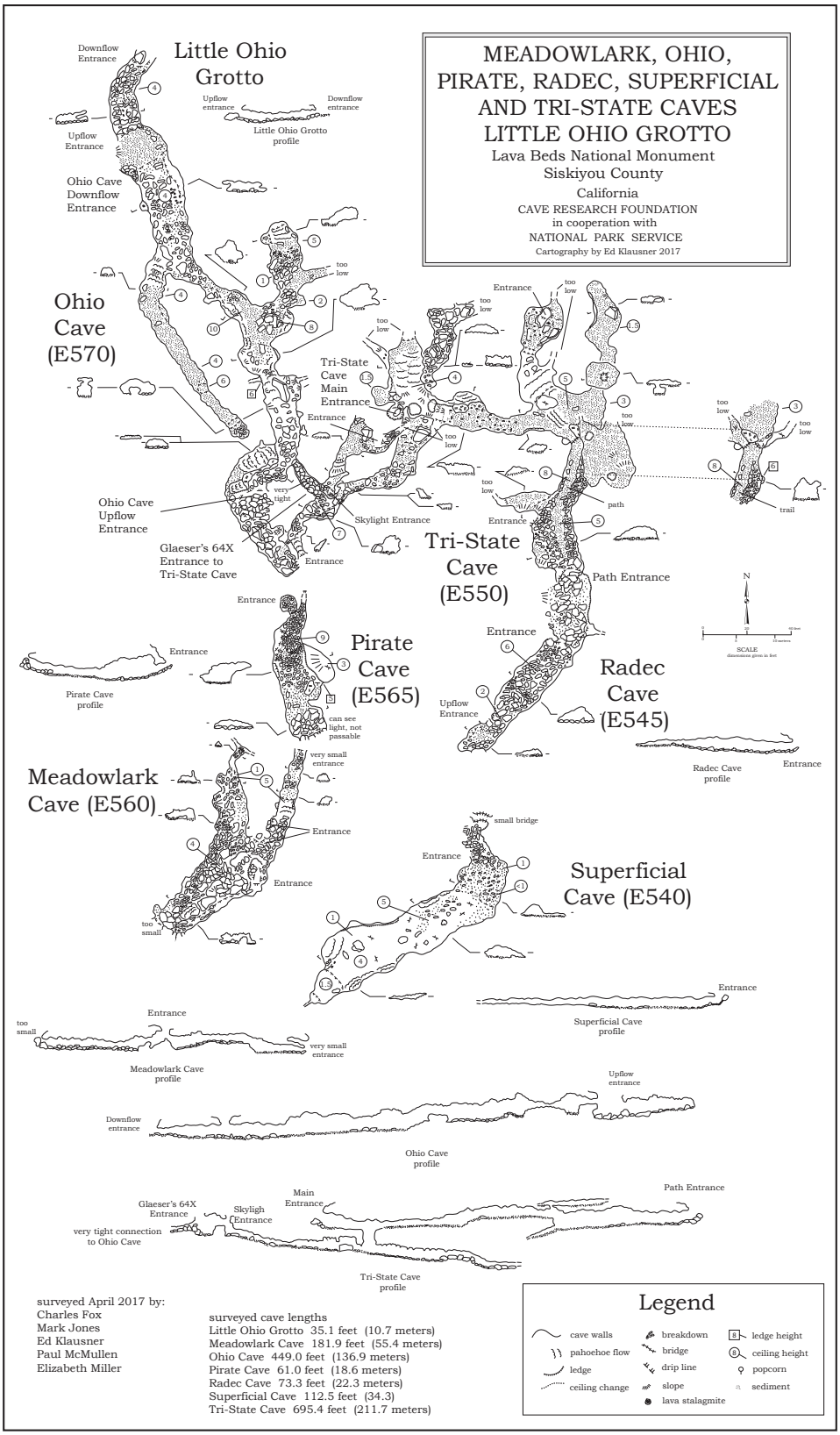


Figure 4. Meadowlark, Ohio, Pirate, Radec, Superficial, and Tri-State Caves and Little Ohio Grotto.

2017

The 2017 field season consisted of one long trip with 10 days of locating and surveying the caves in the 35,000 year old basaltic flow of Mammoth Crater known as Elmer's Trench. The flow is entirely within Lava Beds National Monument.

Dave West is responsible for the Balcony/Boulevard flow, and he joined me for the 2017 trip. Survey help for both Elmer's Trench and Balcony/Boulevard flow was provided by Bill Broeckel, Charles Fox, Mark Jones, Elizabeth Miller, Paul McMullen, David Riggs (Physical Science Technician / Cave Resource Specialist at Lava Beds National Monument), and Karen Willmes.

The northern end of the flow is the furthest extent downflow from the source (Mammoth Crater). The northern end and part of the western end of the flow is demarcated by the Devil's Homestead a'a flow. The monument road bisects the flow and makes for easy access on either side of the road. A pull off near the northern end makes parking convenient. Starting at the north end and systematically working south (upflow), we located and surveyed twenty-two known caves. In the same area, we found and surveyed nine additional new caves.

Using a GPS that tracks routes, we were able to systematically go back and forth from the road to the edge of the flow that is clearly demarked on the west side by a contrasting, non-cave bearing a'a flow. The east side of the flow is not as easy to distinguish from the Balcony/Boulevard flow. Morphology, and possibly mineralogic differences, will help determine which flow each cave belongs to.

The most complex of the caves surveyed this season was Tri-State Cave. Survey length of Tri-State was 695 feet and was found to connect to Ohio Cave, an additional 449 feet. Figure 4 shows Tri-State and Ohio in a cluster of an additional five caves.

Elizabeth Miller in Ohio Cave. *Ed Klausner*

Paul McMullen and Charles Fox at Superficial Cave.
Ed Klausner

The Plague Pit (Figure 5) only was known to contain the northern part of the cave, up to the squeeze (labeled in Figure 5). Elizabeth Miller squeezed through and found additional cave to survey, forcing Mark Jones and me to follow her. In all, the cave is 224 feet long.

At the Monument's request, Liberty Cave was surveyed because it is a bat hibernaculum. David Riggs accompanied us as he was familiar with where to rig the handline for the 12-foot drop into the cave. The 197-foot long cave was surveyed (Figure 6). As has become typical, we found a surface tube and a talus cave close by (Little Surprise Cave, 42 feet long, and Trench Collapse Cave, 44 feet long). The monument's minimum length to be considered a cave is 40 feet, so both of these counted.

Over the course of the 2017 field season, 2860 feet of cave survey and 725 feet of surface survey was accomplished in Elmer's Trench. The surface survey was done to tie new caves to the brass monuments of known caves. A future part of the project will involve getting differential GPS readings for each of the brass monuments in Elmer's Trench, so the exact relationship between caves can be plotted.

It's difficult to determine the exact percentage of the flow that we have systematically searched as I'm unfamiliar with much of the upflow section of Elmer's Trench. One third of the flow is a guess based on a map of the known caves of Elmer's Trench which don't show the upflow boundary nor the Balcony/Boulevard flow boundary. In any case, there appears to be at least several additional field seasons required to finish the study.

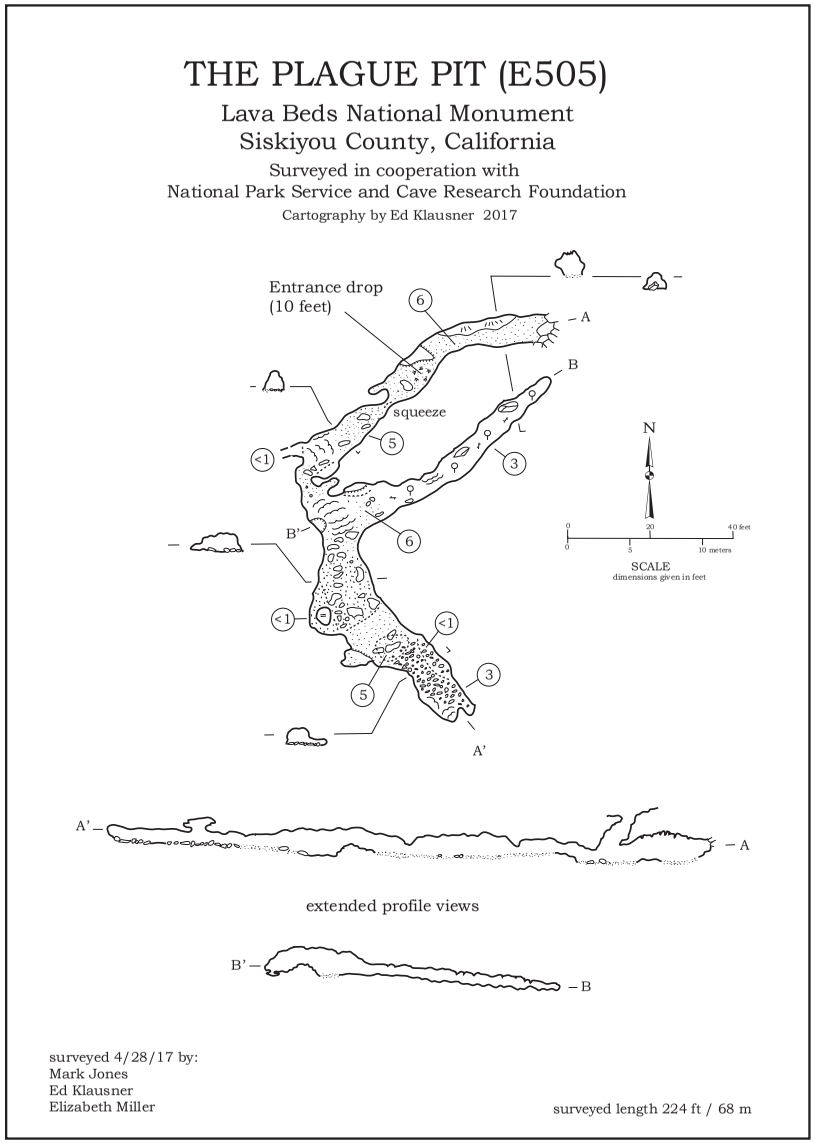


Figure 5. The Plague Pit.

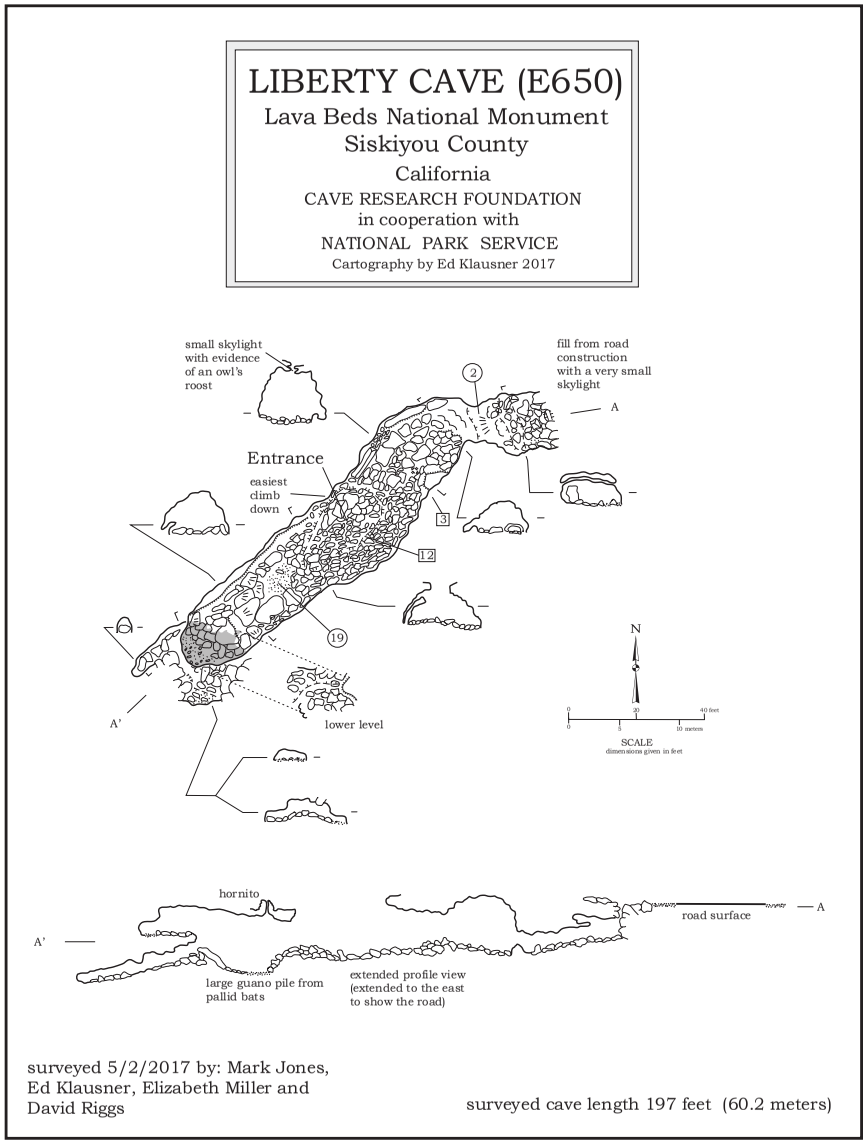


Figure 6. Liberty Cave.

Caves of the Valentine Flow

Lava Beds National Monument

Heather McDonald

Principal Investigator

During the 2017 field season, there were three trips conducted to work on the Valentine Flow within the Lava Beds National Monument (LABE). Trips have consisted of both reconnaissance and cave survey. Reconnaissance has involved systematic search and documentation of lava tube and flow features. All cave survey notes have been filed with Resources Management at LABE.

May 27–28, 2017

Personnel: Heather McDonald, Matthew Leissring, Brian (Beej) Hall, Ernie Maier, Colby Collins, Steven Hobson, David P Smith, Liz Wolff, and Doug Viner.

Conducted reconnaissance on foot on part of the Valentine Flow. Recon personnel: Colby Collins, Brian (Beej) Hall, Steven Hobson, Matthew Leissring, Ernie Maier, Heather McDonald, and Dave Smith.

a) The group returned to an area where a cave requiring a recon card had been located by Matthew Leissring and Heather McDonald in September 2015. This cave has a nuisance-drop vertical entrance. In order to make this drop, a rope was borrowed from the Monument. Several people rappelled in and discovered there was a lead at the bottom, which turned out to be a through-trip to a horizontal entrance with a brass pin. The cave is China Shop (V 170), discovered in 1997 and 1999. Possible seasonal ice was observed as ice stalagmites, chunks of ice in the floor amongst the rocky breakdown, and frost. Recon card information was completed and provided to the Monument.
b) A second cave worthy of a recon card, tentatively named Colby Jack, was located between China Shop and Upper Thicket (another cave with a pin that we did not enter this trip). Colby Jack may also prove to be a known cave, but we did not find a pin.

During the trek the team located, photographed, and obtained GPS readings on what seems to be a known archaeological site; the principal feature consisted of a scattering of relatively large chunks of obsidian (photographs provided to the Monument). The team also encountered some bundles of fire hose, photograph provided to the Monument.

c) Cave survey of Hmmm… Bridges. (Liz Wolff reported on this project activity).

Survey Personnel: Dave Smith, Doug Viner, Liz Wolff, and Jim Wolff.

Doug, Liz, Jim, and Dave entered Hmmm… Bridges to complete the survey. The previous station was located and the survey begun. Hmmm… Bridges, in the Valentine's flow, is mainly a low-ceiling, with either an inflated floor, raised and rafted floor plates, or up-ended, jagged floor plates. Total in-cave survey for Hmmm… Bridges is 280 feet. In the first section of the cave, a low and obviously man-made rock wall crosses the passage. (Photographs of the rock wall have been provided to the Monument.) The survey reached preliminary completion. Survey notes provided to the Monument. Doug Viner has volunteered to draw the map.

September 3, 2017

Cave survey of Hmmm… Bridges. (Doug Viner reported on this project activity.

Personnel: Jim Wolff, Rick Magnan, and Doug Viner.

The survey of Hmmm Bridges Cave was completed. GPS coordinates were taken of the three skylights to assist in closing the survey loop, and surface survey shots were done to tie the survey to a nearby road. The running profile was completed.

October 7, 2017

Personnel: David Riggs and Randy Paylor

Dave and Randy discovered a cave they have named Silicosis Crawl and completed a recon card. They described the cave as follows:

Entrance was chock-full of pumice, and squirming into the cave kicked up so much silica dust that they coughed the whole time. This is a low, broad surface tube of kneeling height. Pumice feeds in from the ceiling at one point, and you can skirt around a low point into continuing passage. No definite end was found on the recon trip.

Balcony Flow

Lava Beds National Monument

Dave West

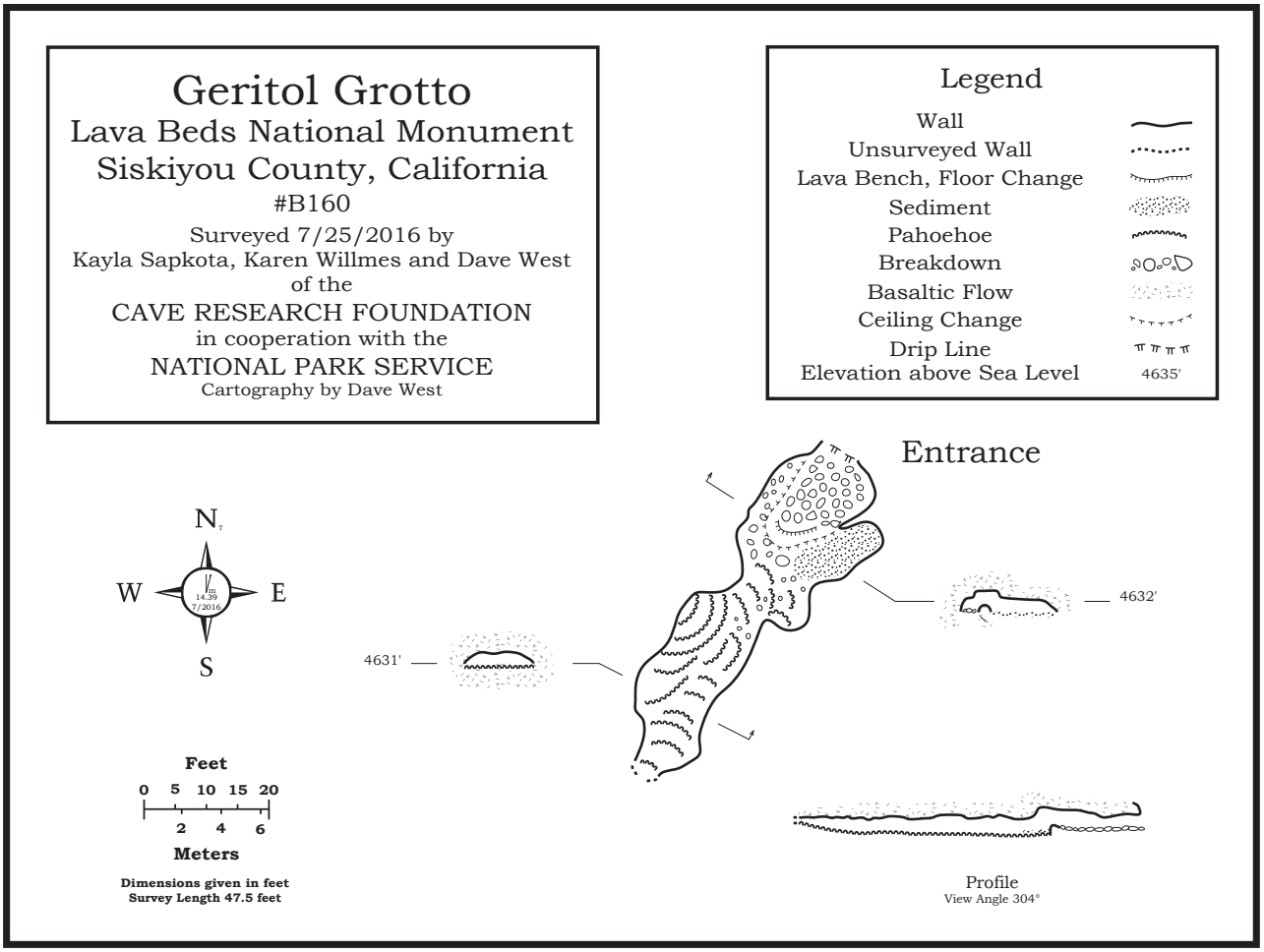
Principal Investigator

2016

We made two week-long trips to Lava Beds this year, the first in April and the second in July. We were joined by Ed Klausner, Elizabeth Miller, Mark Jones, and Bill Broeckel on both trips. In April, Kayla Sapkota and Jenn Ellis assisted, as well as Lindy Cain, a Monument intern. In July Paul McMullen and Joyce Hoffmaster were out to help.

In April we wanted to take advantage of the cooler temperatures and complete surface survey. We put in 7,377.7 feet of surface survey, drawing up the collapsed tubes that connect the remaining tubes. We obtained numerous GPS readings of various caves. We spent one day in Himmel Cave in an effort to finish it. The week's work took a total of 222 hours.

During our July week at the monument, surveys were completed in ten caves, of which six were previously undocumented. Surveys were begun in two other caves, of which one was previously undocumented. Two undocumented grotto features were also mapped. A surface survey from the Shark's Mouth monument to the Nirvana monument was accomplished to improve loop closure. A resurvey between Balcony and Boulevard Bridge on the surface was done for the same reason. Other surface survey was



accomplished to tie in the cave surveys to the survey net. The survey of Geritol Grotto indicates that its length had been underestimated, and that it meets the Monument's criteria to be categorized as a cave. A total of 3,164 feet of survey was accomplished. 148.09 volunteer hours of field work, and an additional 14 volunteer hours entering data and reports were expended during the week. The hours provided by Monument personnel Lindy Cain are not included in these figures.

- Last Call Cave—104.75 feet
- Closing Time Cave—72.25 feet *
- Geritol Cave—47.53 feet
- Obsession Cave—77.65 feet (unfinished)
- Monster Midden Cave—86.6 feet *
- Tiny Bridge Cave—74.3 feet *
- Bandshell Cave—99.0 feet *
- Arroyo Cave—272.25 feet
- Pummel Cave—62.41 feet *
- Damocles Cave—31.3 feet (unfinished) *
- Pancake Cave—183.1 feet *
- Last Gasp Cave—69.8 feet *
- 1 ICU Grotto—20 feet *
- Last Gasp Grotto—14.5 feet *
- Surface surveys—1,810.26 feet
- Surface resurvey—138.3 feet

*—Previously undocumented

Future work will include finishing the two unfinished surveys, although Obsession may prove to be a bit difficult due to a constriction. A few undocumented features remain in the northwest segment of the flow. Although we thought we had finished Himmel, a few cross sections are needed before the map can be considered finished. In the event a differential GPS and post-processing software become available, more precise locations for the various cave monuments will be obtained, as it has become clear that previous measurements were not necessarily taken at the actual monuments.

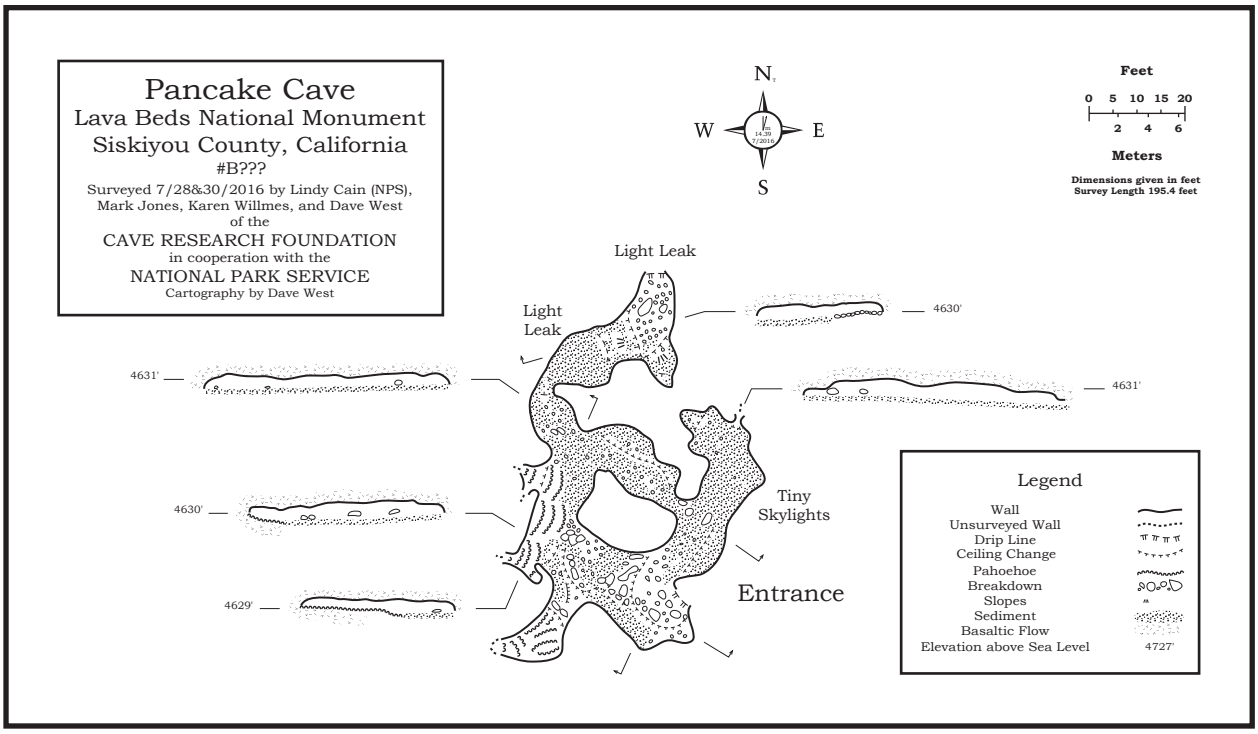
As always, we greatly appreciate all the help from Monument personnel in making our efforts a pleasure and a success. We look forward to our next visit.

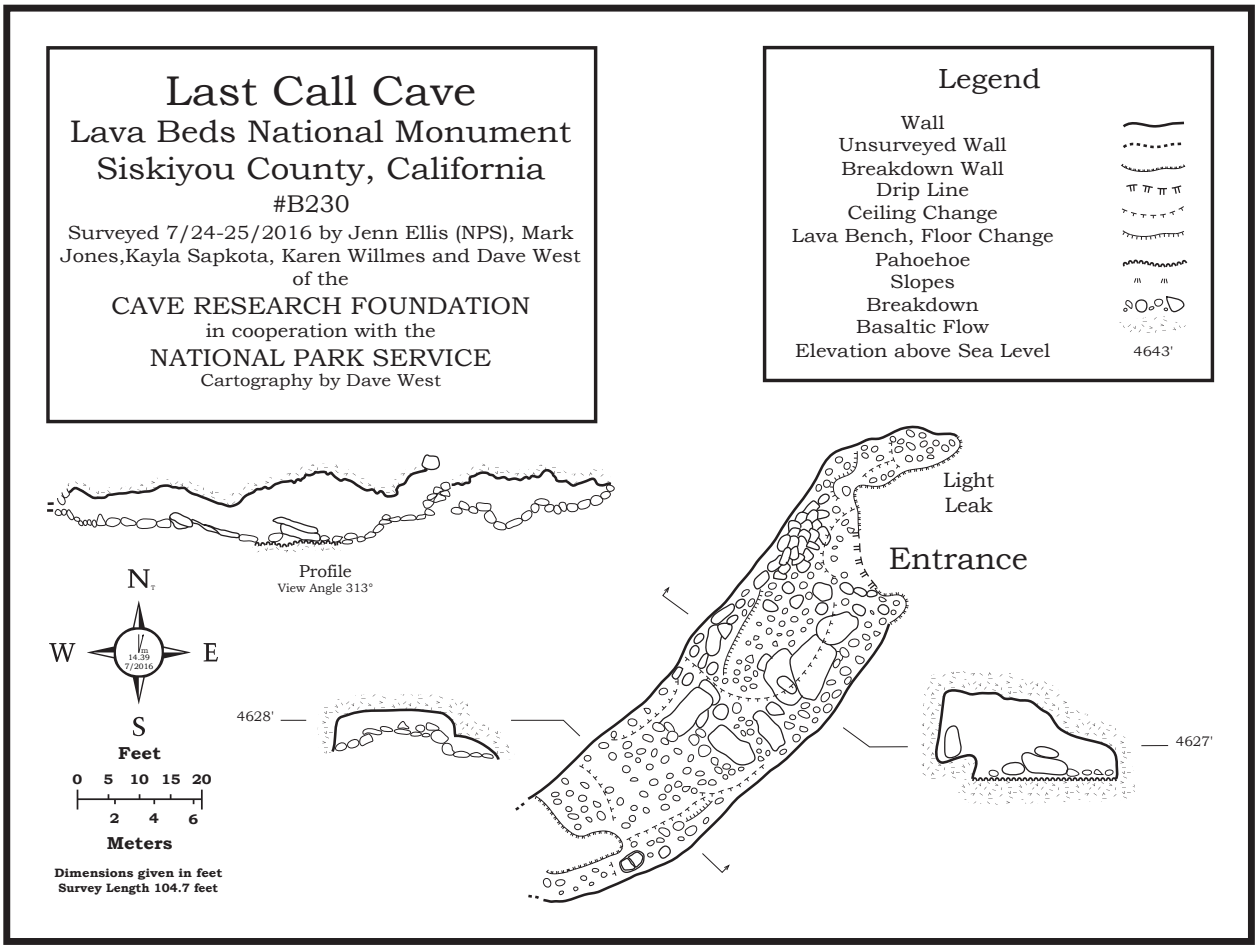
April 21–May 12, 2017

Karen Willmes and I arrived at the Lava Beds Research Center Friday evening, April 21, with Ed Klausner, Elizabeth Miller, Charles Fox, Mark Jones, and Paul McMullen. We quickly settled in and began preparations for the upcoming three weeks. My plan was to get the caves included in the current surface survey also surveyed, and then continue further upflow towards Bearpaw Butte.

New cave entrance: Joyce Hoffmaster entering a newly discovered cave entrance *Ed Klausner*

Karen, Paul, and I went to investigate a small cave near the Himmel pit entrance. Determining that it was indeed long enough to be an actual cave, we surveyed it, naming it Kleine (German for small) Cave due to its size (46.53 feet long) and proximity to Himmel. Another similar feature nearby was determined to be only a body length in size, and it was written off. We then went to Upper Balcony Cave to continue the survey there. The original USGS map of the cave stated it ended in a ceiling collapse filled with breakdown, and Scott House had ended his earlier survey at that point. When asked to retrieve any flagging left in the caves and being unaware at the time that the cave was supposed to end, I observed a rather tight but passable crawl that continued through the breakdown. We intended to survey through this and determine how close we might get to Sharks Mouth Cave, the next cave downflow. The passage split just beyond this initial squeeze, and we first surveyed straight ahead to a terminus in breakdown. Returning to the split and continuing right, this passage first wrapped around the entrance passage before ending in a breakdown plug. It also paralleled the passage we had just surveyed, continuing down a slope that would extend past where the other had terminated. Karen reported a large


Pancake Cave
Lava Beds National Monument
Siskiyou County, California
#B???
Surveyed 7/28&30/2016 by Lindy Cain (NPS), Mark Jones, Karen Willmes, and Dave West of the
CAVE RESEARCH FOUNDATION
in cooperation with the
NATIONAL PARK SERVICE
Cartography by Dave West
N
W
E
S
Feet
0 5 10 15 20
2 4 6
Meters
Dimensions given in feet
Survey Length 195.4 feet
Light Leak
Light Leak
4630'
4631'
4631'
4630'
4629'
Tiny Skylights
Entrance
Legend
Wall
Unsurveyed Wall
Drip Line
Ceiling Change
Pahoehoe
Breakdown
Slopes
Sediment
Basaltic Flow
Elevation above Sea Level
4727'


Last Call Cave
Lava Beds National Monument
Siskiyou County, California
#B230
Surveyed 7/24-25/2016 by Jenn Ellis (NPS), Mark Jones,Kayla Sapkota, Karen Willmes and Dave West of the
CAVE RESEARCH FOUNDATION
in cooperation with the
NATIONAL PARK SERVICE
Cartography by Dave West
Legend
Wall
Unsurveyed Wall
Breakdown Wall
Drip Line
Ceiling Change
Lava Bench, Floor Change
Pahoehoe
Slopes
Breakdown
Basaltic Flow
Elevation above Sea Level
4643'
Profile
View Angle 313°
N
W
E
S
Feet
0 5 10 15 20
2 4 6
Meters
Dimensions given in feet
Survey Length 104.7 feet
Light Leak
Entrance
4628'
4627'

room ahead, but we were out of time and returned to camp. After entering the data, we determined that the first leg of the survey ended approximately 8 feet away from the southernmost point in Sharks Mouth. Later in the week, we returned with Mark Jones and his wonderful new toy, a Disto X2 that had been calibrated at the monument. The room Karen had reported was over 50 feet long, 30 feet wide, and up to 14 feet in height. It passed to the east of Sharks Mouth. Unfortunately, it terminated in breakdown, and we could not find a way to continue. Overall, our addition to the cave nearly doubled its length.

Karen, Charles, and I went to Moldy Gold Bridge and Damsel Cave and surveyed them. The weather deteriorated, and we wanted to survey a cave that would occupy a full day. Crimson Cave seemed like our best bet to avoid the rain. Karen, Charles, Paul, and I began a survey here, noting the iron rich lava which gave the cave its name and also befuddled our instruments from time to time. We succeeded in staying underground all day and ended the day's efforts at the beginning of a large room to which we would need to return later. Mark again helped us complete the survey with his Disto X2. The following day Karen and I surveyed Zord and Zannies Caves.

The next day, Mark, Karen, and I decided to stay on the surface and be sure we could locate a few caves that are off the beaten path. I put the coordinates for Gooseberry of Death in my GPS, and we drove to the parking area, where the GPS advised me that we had arrived at our destination. Since the dot map I had been given suggested it was south of the road and well west of Upper Balcony, we set up a line at Upper Balcony and proceeded west paralleling the road. We went a considerable way, and decided we needed to go further south. We moved our line further south and proceeded back east. On reaching the area where we had started, we again moved further south and again proceeded west. As we reached our turn around point, we finally found a cave. It had a monument which advised us it was Just Right Cave. Concluding we had simply missed Gooseberry, we started back to the car. Two hundred feet from Just Right, we found a small cave with a Gooseberry bush guarding the entrance, and it seemed to fit the description we had. The cave was much further from the road than the dot map had suggested. Next, we drove up to the Merrill parking area, and entered the coordinates for Genesis Chimney into my GPS. This time it took us right to it. The direct route through the forest is probably not the best. After admiring the chimney, we started down flow, finding a few features and ultimately Black Ice Cave. Pretty much out of time, we returned to camp.

Karen and I went to One Time Cave and Lichen Cave and surveyed them. We also went to Bat Bridge, and surveyed from the brass cap to the drip line, but ran out of time to actually survey the cave.

Two days later, I led Dave Riggs and Karen to Obsession Cave to survey the portion of the cave into which I would not fit. A plastic sheet was used to reduce the snagging of clothing going through the tight area. Karen still encountered difficulty, but Dave was able to get through the various constrictions and was able to solo survey the remainder of the cave, except for one portion reportedly accessible through breakdown. Although he searched, he was unable to locate the route that Chris Roundtree had used. Chris reported unstable breakdown. It may have shifted as he exited.

The next day Mark and I first went to Himmel Cave to obtain a few cross sections needed to complete the map. We then went to Damocles Cave to complete the survey there. After that we examined the three nearby leads found by Bill Broeckel last year. We did a full survey of one, calling it Cooler Cave. Another, T Drop Grotto, was measured

Paul McMullen checking a lead. *Ed Klausner*

and sketched, but not fully surveyed as it was only 19 feet long. The third was about 30 feet in extent, but was adequately obnoxious that we followed Bill's recommendation of not surveying it. Then Karen and I returned to the west trenches to continue the survey south, surveying the third of three consecutive collapses, and the next trench south of them. We also closed a loop with the east branch, locating the last station set in it.

Karen, Mark, and I surveyed Bat Bridge, Dorrii Cave, and Moldy Cast Cave. There was no enthusiasm for surveying through the breakdown in Bat Bridge to complete a through trip. Nice bridge for bats, not so much for humans. Karen, Mark, and I began the next day by continuing the survey of the east branch trenches south to Mossy Knoll

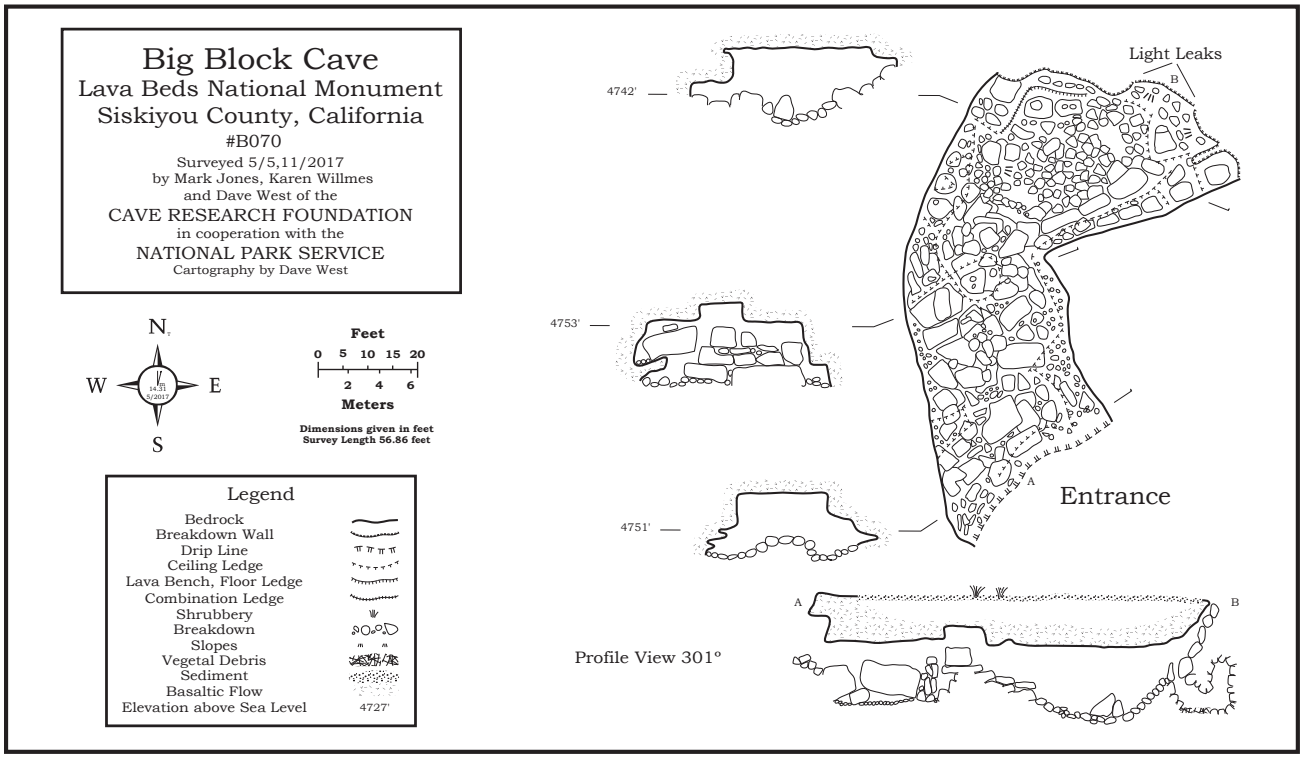
Cave. We had a lunch break and picked up the survey of the west branch trenches to Big Block Cave, also tying to a couple of points from the morning survey for loops.

The following day we parked at Merrill Cave and ridgewalked north from the Whitney Butte Trail along the trench to where we had left off the previous day and then surveyed Mossy Knoll Cave. After lunch we began the survey of Big Block Cave, finding the going slow with all the detail to be included. We took a beeline back to the parking area using Mark's GPS. We will never do that again. The terrain consisted of live and dead trees that forced one to walk on streams of unstable clinker. Not a good place to look for caves anyway, and we found none.

Paul and Dee Hauck arrived followed shortly by Don and Jan Dunham. Mark, Karen, and I worked with them on the North and South Castle flows. Jim and Liz Wolff, Bill Devereaux, and Ed Bobrow arrived to assist the Monument with a Timeline presentation for the local schools. Karen and I returned to Dorrii and Big Block Caves. In Dorrii we re-shot one bearing to correct a 10-degree backsight error I had missed while in cave. We then proceeded to Big Block and completed the survey of it. Unfortunately, I dropped my Bosch rangefinder into the breakdown and was unable to retrieve it. We then set off in search of Little Pillar and Just a Sec Caves, hoping that locating them would help us find the elusive Gooseberry of Death. Finding both, we again entered the coordinates for Gooseberry, and this time the GPS took us right to it, passing another undocumented entrance along the way. En route back to the car, we found yet another entrance not documented. Work for our next visit.

Our last day in the field consisted almost entirely of blunder repairs. First, Karen and I used the Monument's Trimble GPS to obtain locations for the actual pins at Himmel, Chalk Line, Balcony, Sharks Mouth, Lichen, and Big Block Caves, as well as for a 1954 USGS benchmark we had come upon the previous day. This went faster than expected, taking only about 10 minutes per location for the device to obtain the full set of readings. We also located yet another undocumented entrance while walking between caves, to be surveyed our next visit. Having also borrowed a Snake Snatcher device from Resource Management, we recovered my Bosch rangefinder from Big Block. Jim Wolff accompanied us on the data collection at Lichen and Big Block, as well as the Bosch recovery.

Our total survey in the Balcony Flow for the period was 4364.895 feet. We completed surveys of three caves that had been started previously, and surveyed an additional 12 caves, two of which were undocumented. Surveys of two smaller features were also done. We located an additional three apparent entrances of undocumented caves that will be investigated on our next visit. We also identified a possible site of prior use by the Modoc. Monument personnel, as always, were very helpful in accomplishing our goals.



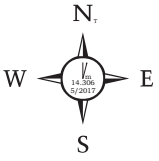
Cooler Cave

Lava Beds National Monument
Siskiyou County, California
#B304
Surveyed 5/1/2017
by Mark Jones, and Dave West of the
CAVE RESEARCH FOUNDATION
in cooperation with the
NATIONAL PARK SERVICE
Cartography by Dave West

Profile View Looking 305°

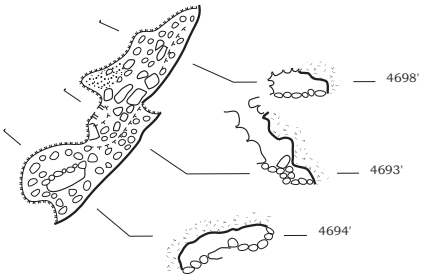
Feet
0 5 10 15 20
2 4 6
Meters

Dimensions given in feet
Survey Length 47.06 feet



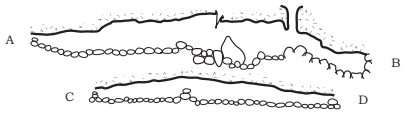
Legend

Bedrock	
Breakdown Wall	
Drip Line	
Ceiling Change	
Sediment	
Breakdown	
Slopes	
Basaltic Flow	
Elevation above Sea Level	4727'



Damocles Cave

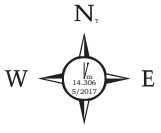
Lava Beds National Monument
Siskiyou County, California
#B303
Surveyed 7/2016 & 5/2017
by Mark Jones, Karen Willmes,
and Dave West of the
CAVE RESEARCH FOUNDATION
in cooperation with the
NATIONAL PARK SERVICE
Cartography by Dave West



Projected Profiles - View looking 308°

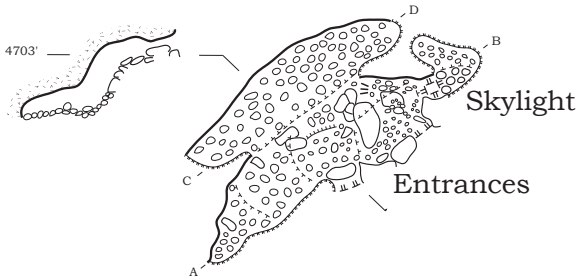
Feet
0 5 10 15 20
2 4 6
Meters

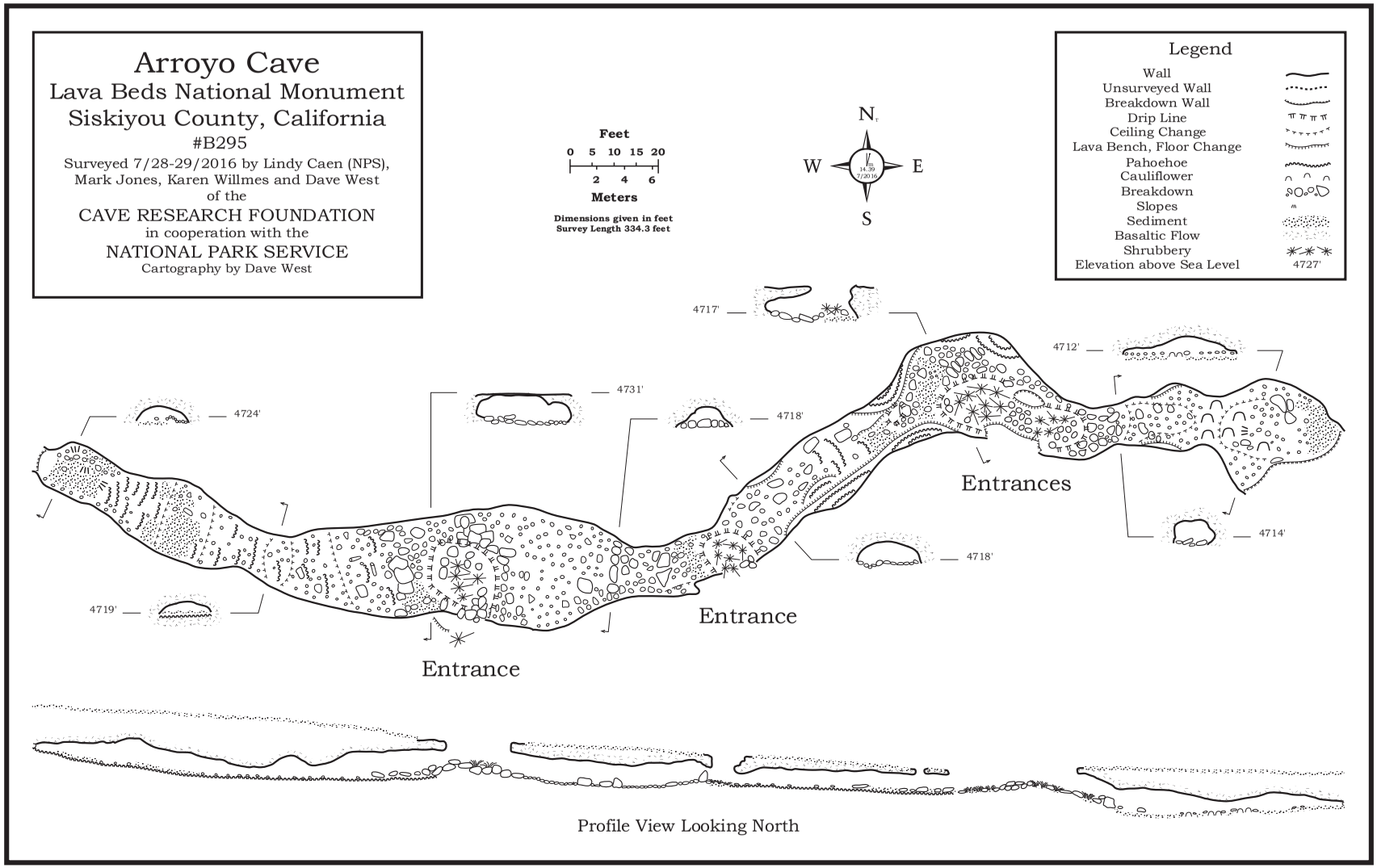
Dimensions given in feet
Survey Length 131.13 feet



Legend

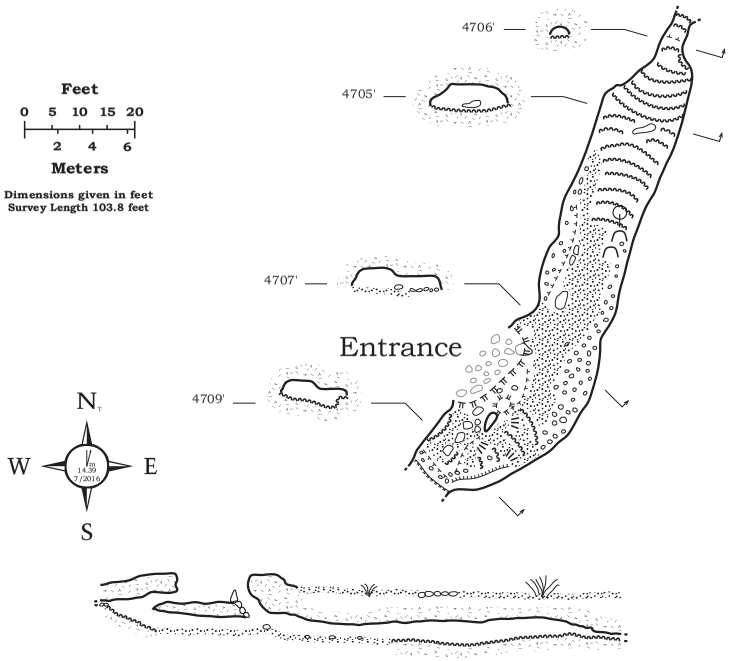
Bedrock	
Unsurveyed Wall	
Breakdown Wall	
Drip Line	
Ceiling Change	
Lava Bench, Floor Change	
Breakdown	
Slopes	
Basaltic Flow	
Elevation above Sea Level	4727'




Arroyo Cave
Lava Beds National Monument
Siskiyou County, California
#B295
Surveyed 7/28-29/2016 by Lindy Caen (NPS), Mark Jones, Karen Willmes and Dave West
of the
CAVE RESEARCH FOUNDATION
in cooperation with the
NATIONAL PARK SERVICE
Cartography by Dave West
Feet
0 5 10 15 20
2 4 6
Meters
Dimensions given in feet
Survey Length 334.3 feet
N
W
E
S
Legend
Wall
Unsurveyed Wall
Breakdown Wall
Drip Line
Ceiling Change
Lava Bench, Floor Change
Pahoehoe
Cauliflower
Breakdown
Slopes
Sediment
Basaltic Flow
Shrubbery
Elevation above Sea Level
4727'
4717'
4712'
4724'
4731'
4718'
Entrances
4714'
4718'
4719'
Entrance
Entrance
Profile View Looking North

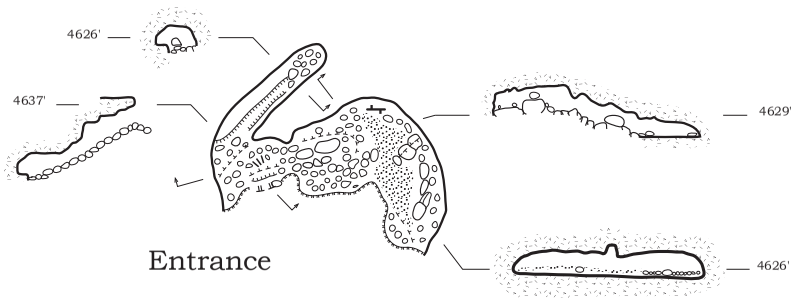
Bandshell Cave
Lava Beds National Monument
Siskiyou County, California
#B???
Surveyed 7/27/2016 by
Mark Jones, Karen Willmes, and Dave West
of the
CAVE RESEARCH FOUNDATION
in cooperation with the
NATIONAL PARK SERVICE
Cartography by Dave West

Legend
- Wall
- Breakdown Wall
- Unsurveyed Passage
- Drip Line
- Ceiling Change
- Lava Bench, Floor Change
- Pahoehoe
- Breakdown
- Slopes
- Sediment
- Basaltic Flow
- Shrubbery
- Elevation above Sea Level 4715'

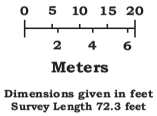


Profile View 295°

Closing Time Cave
Lava Beds National Monument
Siskiyou County, California
#B???
Surveyed 7/24-25/2016 by Jenn Ellis (NPS),
Mark Jones, Kayla Sapkota, Karen Willmes,
and Dave West of the
CAVE RESEARCH FOUNDATION
in cooperation with the
NATIONAL PARK SERVICE
Cartography by Dave West



Legend
- Wall
- Breakdown Wall
- Drip Line
- Ceiling Change
- Lava Bench, Floor Change
- Bedrock Floor
- Breakdown
- Slopes
- Sediment
- Basaltic Flow
- Elevation above Sea Level 4727'



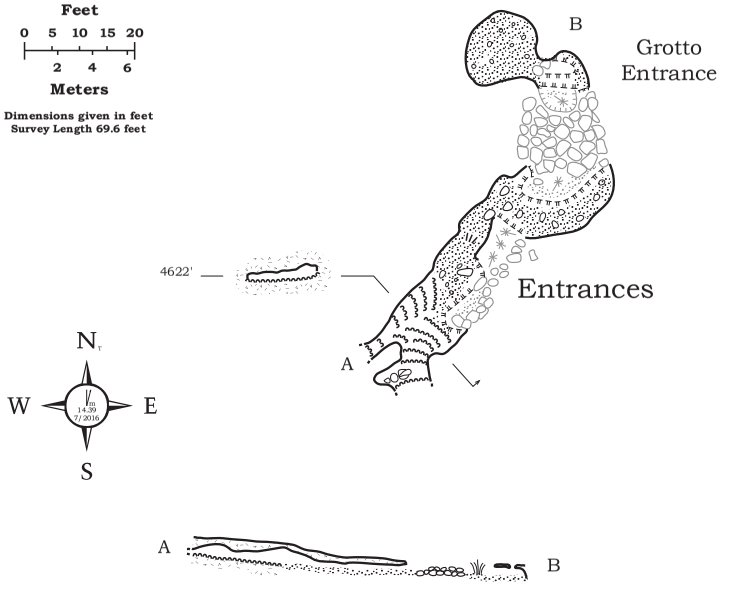
Last Gasp Cave

Lava Beds National Monument
Siskiyou County, California
#B???

Surveyed 7/30/2016 by
Mark Jones, Karen Willmes, and Dave West
of the
CAVE RESEARCH FOUNDATION
in cooperation with the
NATIONAL PARK SERVICE
Cartography by Dave West

Legend

- Wall
- Unsurveyed Wall
- Drip Line
- Ceiling Change
- Lava Bench, Floor Change
- Pahoehoe
- Breakdown
- Slopes
- Sediment
- Basaltic Flow
- Shrubbery
- Elevation above Sea Level 4622'



Profile View 310°

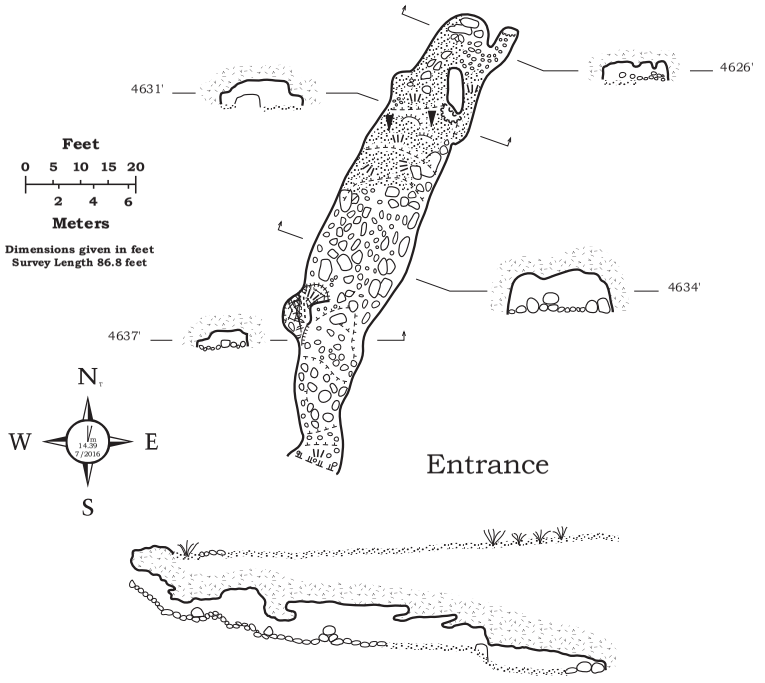
Monster Midden Cave

Lava Beds National Monument
Siskiyou County, California
#B???

Surveyed 7/26/2016 by
Elizabeth Miller and Dave West
of the
CAVE RESEARCH FOUNDATION
in cooperation with the
NATIONAL PARK SERVICE
Cartography by Dave West

Legend

- Wall
- Breakdown Wall
- Drip Line
- Ceiling Change
- Lava Bench, Floor Change
- Pahoehoe
- Lavacicles
- Vegetal Debris
- Breakdown
- Slopes
- Sediment
- Basaltic Flow
- Shrubbery
- Elevation above Sea Level 4648'



Profile View 288°

Pummel Cave

Lava Beds National Monument
Siskiyou County, California
#B???

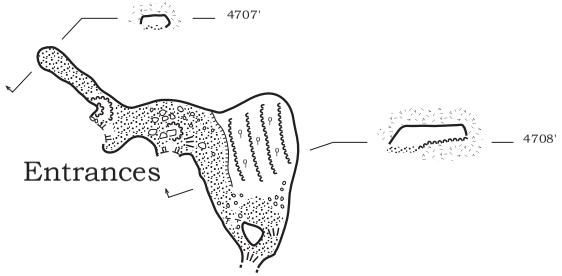
Surveyed 7/29/2016 by
Karen Willmes and Dave West
of the
CAVE RESEARCH FOUNDATION
in cooperation with the
NATIONAL PARK SERVICE
Cartography by Dave West

Legend

Wall	
Breakdown Wall	
Unsurveyed Passage	
Drip Line	
Ceiling Change	
Lava Bench, Floor Change	
Pahoehoe	
Breakdown	
Slopes	
Sediment	
Basaltic Flow	
Elevation above Sea Level	4711'

Feet
0 5 10 15 20
2 4 6
Meters

Dimensions given in feet
Survey Length 62.4 feet



Profile View 35°

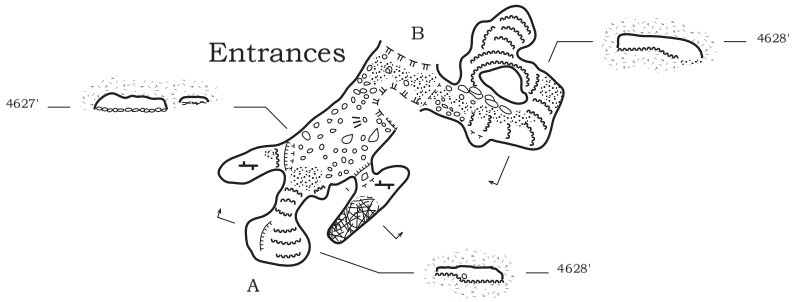
Tiny Bridge Cave

Lava Beds National Monument
Siskiyou County, California
#B???

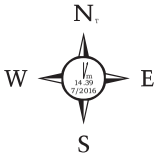
Surveyed 7/27/2016 by
Mark Jones, Karen Willmes, and Dave West
of the
CAVE RESEARCH FOUNDATION
in cooperation with the
NATIONAL PARK SERVICE
Cartography by Dave West

Legend

Wall	
Drip Line	
Ceiling Change	
Lava Bench, Floor Change	
Pahoehoe	
Bedrock Floor	
Vegetal Debris	
Breakdown	
Slopes	
Sediment	
Basaltic Flow	
Elevation above Sea Level	4727'



Profile View 306°

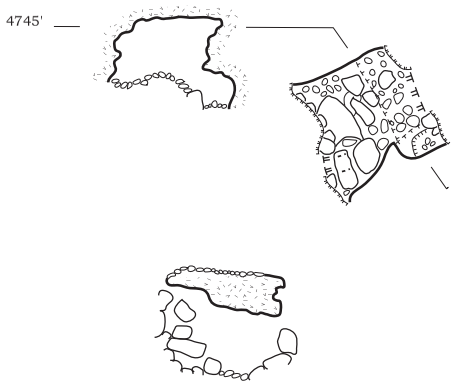


Feet
0 5 10 15 20
2 4 6
Meters

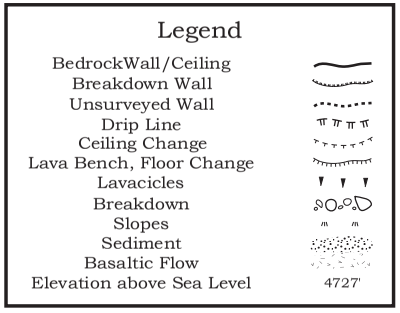
Dimensions given in feet
Survey Length 74.9 feet

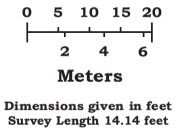
Bat Bridge
Lava Beds National Monument
Siskiyou County, California
#B250

Surveyed 5/3/2017
by Mark Jones, Karen Willmes,
and Dave West of the
CAVE RESEARCH FOUNDATION
in cooperation with the
NATIONAL PARK SERVICE
Cartography by Dave West



Profile View looking 320°

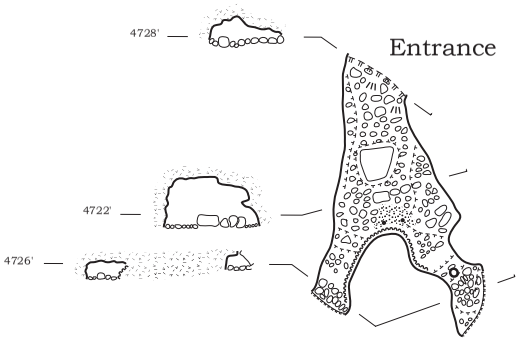


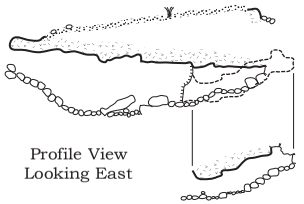


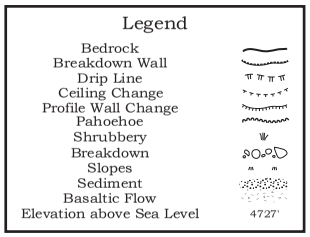
Dimensions given in feet
Survey Length 14.14 feet

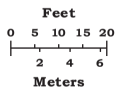
Dorrii Cave
Lava Beds National Monument
Siskiyou County, California
#B270

Surveyed 5/3/2017
by Mark Jones, Karen Willmes
and Dave West of the
CAVE RESEARCH FOUNDATION
in cooperation with the
NATIONAL PARK SERVICE
Cartography by Dave West









Dimensions given in feet
Survey Length 93.53 feet

Himmel Cave

Lava Beds National Monument
Siskiyou County, California

#B220

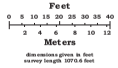
Surveyed 9/15, 4/16, & 5/17 by Rachel Bosch, Joyce Hoffmaster, Mark Jones, Karen Willmes, and Dave West of the

CAVE RESEARCH FOUNDATION

in cooperation with the

NATIONAL PARK SERVICE

Cartography by Dave West



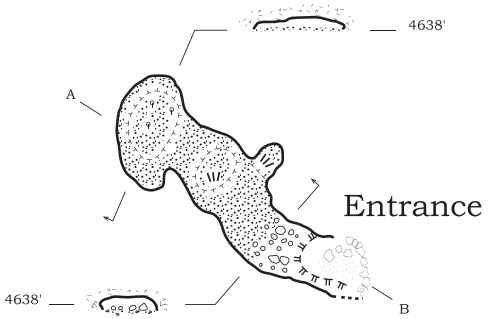
Cross Passage Profile - View Angle 318°

Main Passage Profile - View Angle 270°

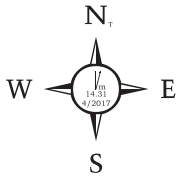
Kleine Cave

Lava Beds National Monument
Siskiyou County, California
#B???

Surveyed 4/22/2017
by Paul McMullen, Karen Willmes,
and Dave West of the
CAVE RESEARCH FOUNDATION
in cooperation with the
NATIONAL PARK SERVICE
Cartography by Dave West



Profile



Legend

Wall/Ceiling	
Unsurveyed Wall	
Drip Line	
Ceiling Change	
Shrubbery	
Popcorn	
Breakdown	
Slopes	
Sediment	
Basaltic Flow	
Elevation above Sea Level	4727'

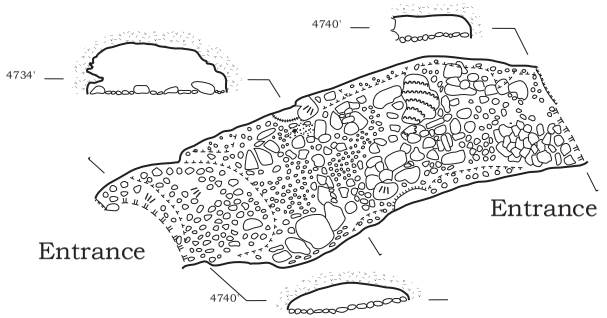
Feet
0 5 10 15 20
2 4 6
Meters

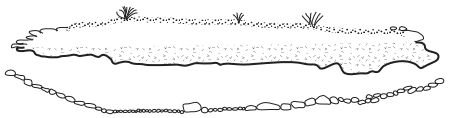
Dimensions given in feet
Survey Length 46.5 feet

Moldy Cast Cave

Lava Beds National Monument
Siskiyou County, California
#B260

Surveyed 5/3/2017
by Mark Jones, Karen Willmes
and Dave West of the
CAVE RESEARCH FOUNDATION
in cooperation with the
NATIONAL PARK SERVICE
Cartography by Dave West





Profile View 347°

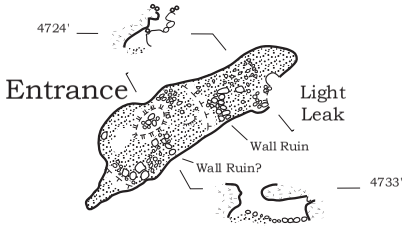
Legend

Bedrock	
Breakdown Wall	
Drip Line	
Ceiling Ledge	
Lava Bench, Floor Ledge	
Combination Ledge	
Pahoehoe	
Shrubbery	
Breakdown	
Slopes	
Sediment	
Basaltic Flow	
Elevation above Sea Level	4727'

Feet
0 5 10 15 20
2 4 6
Meters

Dimensions given in feet
Survey Length 89.75 feet

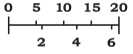
Zannie's Cave
Lava Beds National Monument
Siskiyou County, California
#B285
Surveyed 4/25/2017
by Karen Willmes and Dave West
of the
CAVE RESEARCH FOUNDATION
in cooperation with the
NATIONAL PARK SERVICE
Cartography by Dave West



Profile view 307°

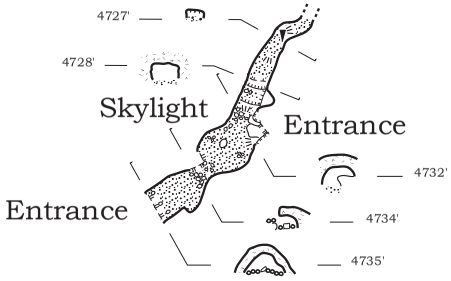
Legend

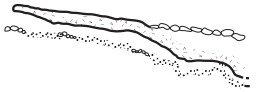
Wall/Ceiling	
Drip Line	
Ceiling Change	
Lava Bench, Floor Change	
Breakdown	
Slopes	
Sediment	
Basaltic Flow	
Elevation above Sea Level	4727'



Dimensions given in feet
Survey Length 44.93 feet

Zord Cave
Lava Beds National Monument
Siskiyou County, California
#B293
Surveyed 4/25/2017
by Karen Willmes, and Dave West
of the
CAVE RESEARCH FOUNDATION
in cooperation with the
NATIONAL PARK SERVICE
Cartography by Dave West

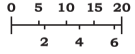




Profile view 307°

Legend

BedrockWall/Ceiling	
Breakdown Wall	
Unsurveyed Wall	
Drip Line	
Ceiling Change	
Lava Bench, Floor Change	
Lavacicles	
Breakdown	
Slopes	
Sediment	
Basaltic Flow	
Elevation above Sea Level	4727'



Dimensions given in feet
Survey Length 40.49 feet

Buffalo National River

Ozarks Operations, 2016–2017

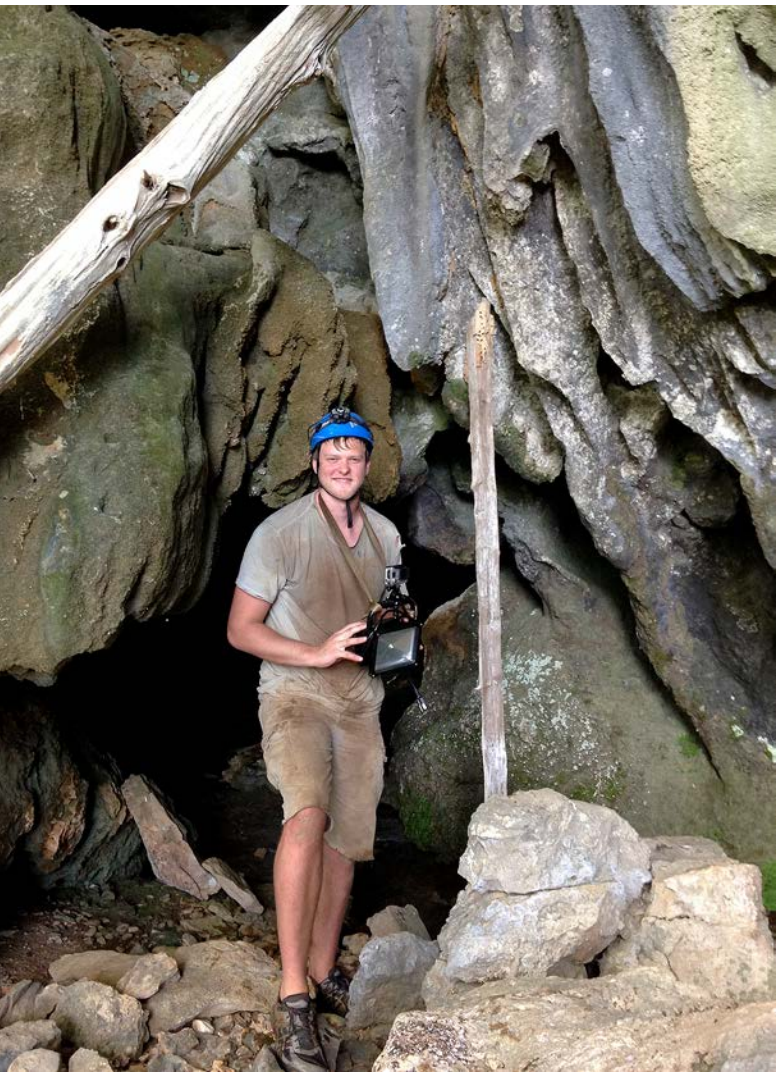
Kayla Sapkota

Eastern Tricolor Bat in Toga Cave. *Mark Jones*

The 2016 to 2017 period was a busy one for CRF–Buffalo National River. Highlights include increasing both the quantity of volunteers, as well as the capabilities of existing volunteers, which in turn yielded a greater productivity level over the previous two year period.

Figures:

- Total Mileage: 75,545
- Total People Days: 764
- Total Survey Footage: 20,017.5
- Total Hours: 5,663.4
- Total Trips: 200
- New Public Use Monitoring Records: 497
- New Faunal Records: 2,035
- New Maps Completed: 73
- New Caves/Shelters/Karst Features Located: 148



Joseph Jordan in Flowstone Facade Cave. *Pradeep Sapkota*

Facilities

CRF is fortunate to have regular use of the Steel Creek Research Center (SCRC) also known as the "rock house." This facility is located in the Steel Creek NPS complex (Upper Buffalo River) and contains a large kitchen area, a dedicated decontamination/laundry room, gear storage space, a large living room with Smart Board technology, three bedrooms (with one being an adjoining structure used as an office with one bed), and 2 semi-permanent, canvas tents with heavy-duty cots. Additionally, CRF may schedule use of the George Harp Field Station, located on the Lower Buffalo River, which proved invaluable in spring monitoring on the lower river.

Areas of Focus

The focus of our work continues to be biological monitoring, public use monitoring, and cartographic survey, with special attention being given to bat counts and WNS monitoring. CRF members receive recurrent small group training on biological identification and hosted Mike Slay, from the Nature Conservancy, to conduct a cave biology workshop in conjunction with the 2016 Annual Members Meeting.

In 2016 and 2017, additional members became proficient in vertical caving techniques, increasing the number of individuals who could perform biological monitoring and cartographic survey in caves requiring technical equipment to access drops. At the same time, a handful of individuals attended training sessions to learn how to draft digital cave maps, increasing the productivity of CRF Buffalo's cartography efforts.

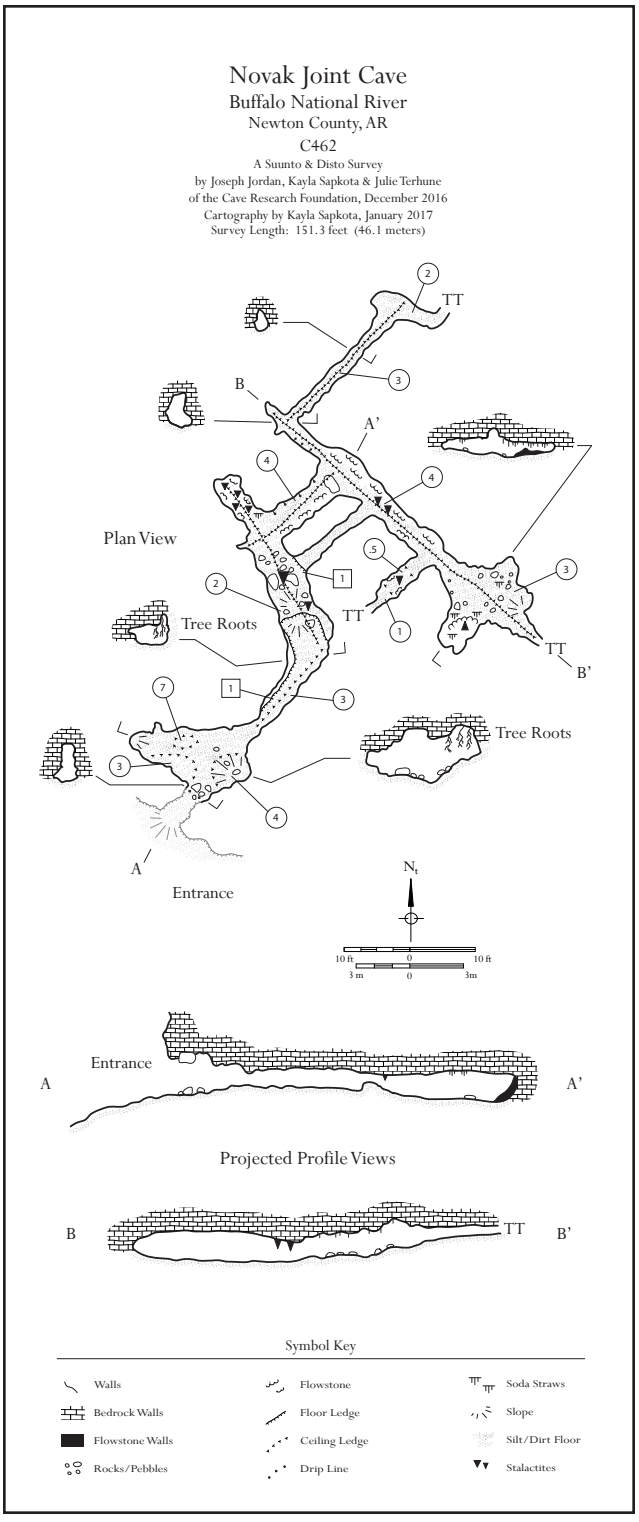
Ed Klausner in Wraparound Cave. *Mark Jones*

New individuals regularly joined expeditions from surroundings grottos, communities, and institutions of higher education. New "recruits" were paired with "seasoned" team leaders to learn about the purpose and culture of the operations. Additionally, as CRF endeavors to recruit and develop new members, presentations were made in 2016 and 2017 to special interest groups, such as local chapters of the Audubon Society and Rotary Club International, as well as the Buffalo River Partners group.

Field Trips

Expeditions were held each month, with some months having multiple expeditions, and some expeditions lasting longer than one weekend. In 2016 and 2017, lengthier expeditions were held in conjunction with the fall CRF Annual Meeting, Thanksgiving week, and the December holiday season. During the Thanksgiving expeditions in 2016 and 2017, a group of bio-speleology students from Texas A&M at Galveston assisted CRF members in biological monitoring and survey, yielding many new faunal records and updated database entries. As a standard practice, each site visited was subject to biological monitoring and public usage monitoring.

During the fall and winter months, teams focused on locating and monitoring caves that had not been visited in some time, as well as those smaller caves known to house bats. Additionally, ridge-walking was generally a focus in cooler weather due to the lack of pests (ticks, chiggers, poison ivy, etc.) and uncomfortably hot weather. Each spring (twice in 2016 and once in 2017), a monthly expedition was centered on a float trip in order to visit caves most easily accessed by river. Due to limited access (May 16–August 15), most summer expeditions were dedicated to continuing the survey of Fitton Cave—Arkansas's longest

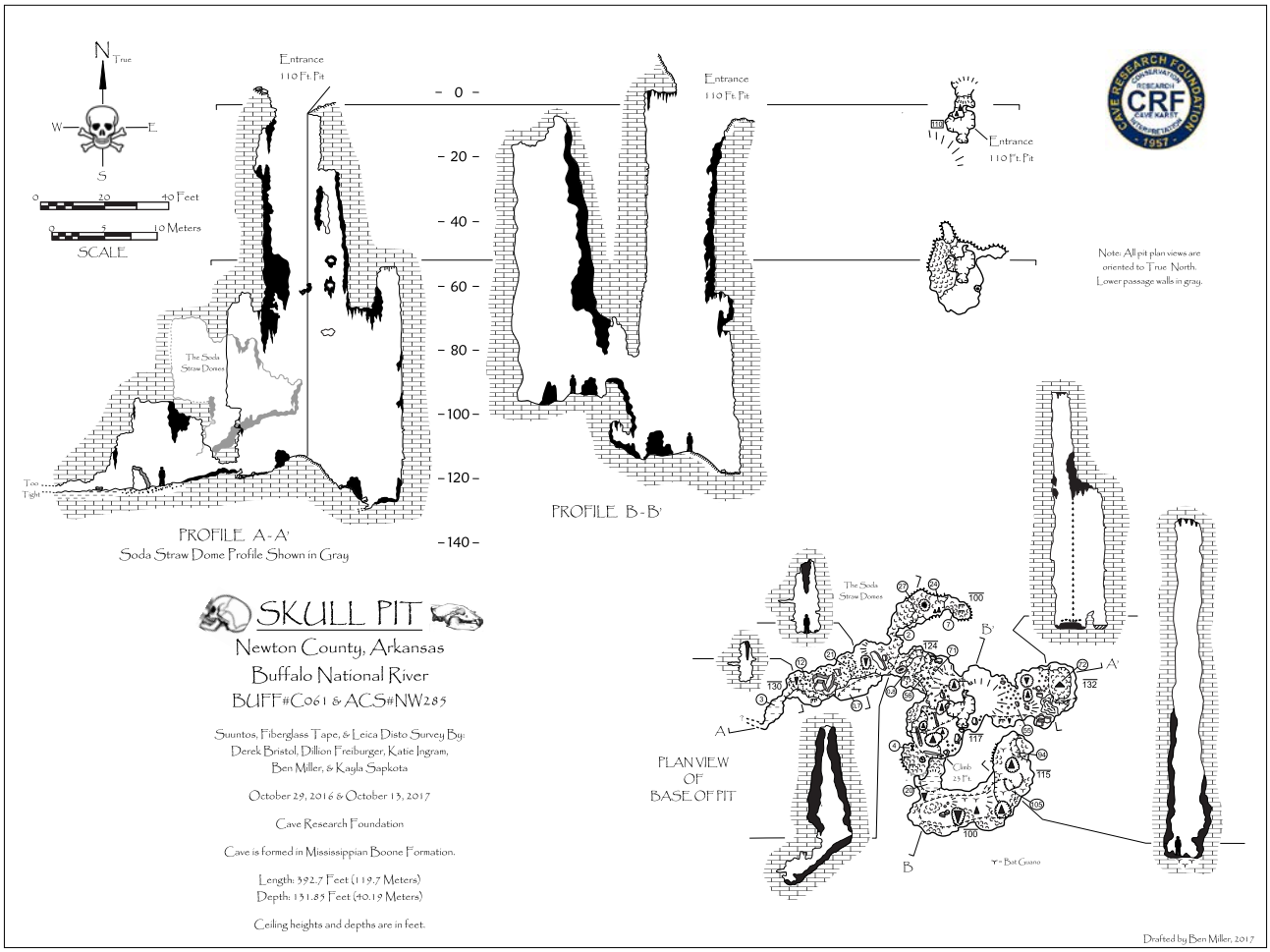


Chuck Bitting in Buffalo National River. *Scott House*

cave and consequently, an important bat hibernaculum. Tremendous progress has been made on the map sheets in Fitton Cave.

Future Work

Per CRF's research permit with the Buffalo National River, operations will continue to be focused on biological monitoring, public use monitoring, and cartographic survey. With each site visit, database entries and topographic map files will be updated, providing more accurate data to the NPS. Outreach will continue to local caving organizations, local educational institutions, and the current and past volunteer base. Trainings on survey techniques, in-cave sketching, and digital drafting of maps will continue in order to develop more survey leaders and cartographers. The Buffalo National River Cave Database holds over 725 records, including caves, shelters, karst features, and reported leads, and it is expected that there are many additional sites waiting to be discovered and documented.



Jenn Ellis in Toga Cave. *Mark Jones*

Cave Research Foundation Annual Meeting—2016

Harrison, Arkansas

The 2016 CRF Annual Meeting occurred in Harrison, Arkansas, which is the location of the Buffalo National River's Headquarters. The Board Meeting took place on October 28, and the Members' Meeting took place on October 29, both being hosted by North Arkansas College. On the date of the Members' Meeting, a general meet-and-greet took place during the first half of the day—complete with photo and map displays, software demonstrations, and research displays. In the afternoon, a series of speakers shared their cave-related research:

- "Modeling Ozarks Caves with Photogrammetry" by Joseph Jordan, University of Arkansas
- "Vadose Speleogenesis along the Eureka Springs Escarpment" by Jon Beard, CRF
- "Mayan Cave Art Discoveries in the Yucatán" by Dr. Dito Morales, University of Central Arkansas
- "Nine Days on the Buffalo" by Jon Beard, CRF

A dinner banquet followed the afternoon session, taking place across the street at the historic Hotel Seville. The next day, a CRF expedition at the Buffalo National River began, including biological monitoring and survey trips. Additionally, Mike Slay from the Nature Conservancy presented a workshop on Ozarks cave life.

Derek Bristol climbs up to lead in Skull Pit. *Dillon Freiburger*

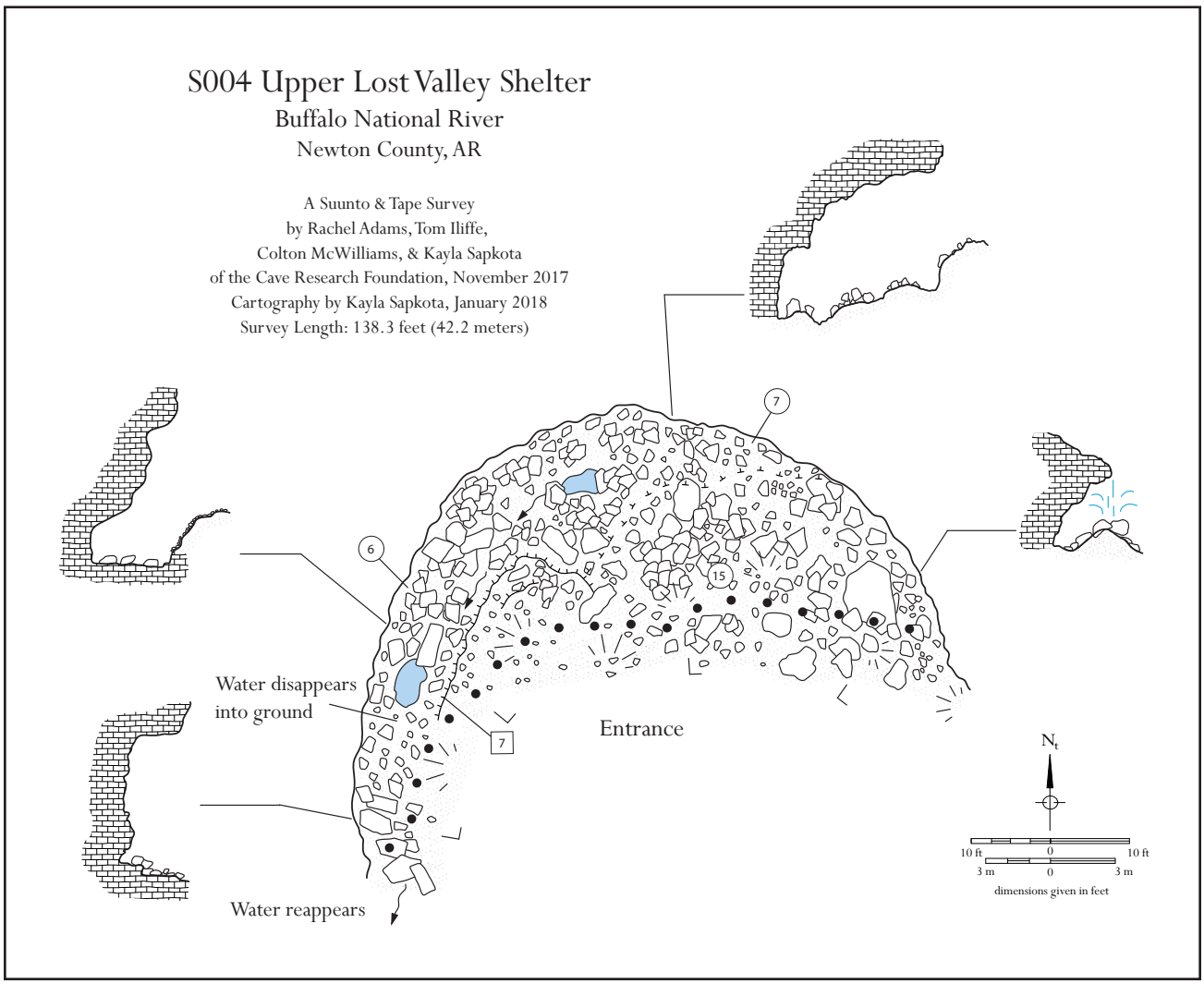
Seashell Dome Cave. Pictured are Derek Thompson, Meghan Gallo, Brandon Van Dalsem, and two unidentified cavers. *Chaz Angle*

Cave Research Foundation Annual Meeting—2017

Eureka Springs, Arkansas

The 2017 CRF Annual Meeting was also hosted in Arkansas, due to the scheduled National Cave and Karst Symposium (NCKMS) being successfully bid for Eureka Springs, Arkansas. The CRF Board Meeting was held on October 15, the day before the NCKMS festivities got underway. In lieu of a Members' Meeting, an informal dinner banquet was held at a local favorite Mexican restaurant on the same evening. Several individuals stayed in town to attend NCKMS. In contrast to the 2016 CRF Annual Meeting schedule, the associated caving monitoring and surveying expedition was held the week prior to the Board Meeting and included a few sites in Missouri, as well.

Kayla Sapkota in Pillbug Cave. *Mark Jones*



National Cave and Karst Management Symposium—2017

Eureka Springs, Arkansas

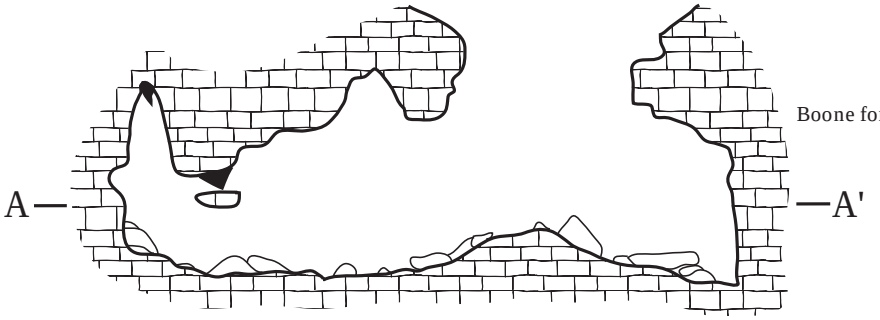
CRF functioned as a host for the 2017 National Cave and Karst Management Symposium, assisting in the planning of the event—especially with the finances and online registration/website processes. One hundred and five individuals attended NCKMS, representing multiple agencies, private companies, non-profit organizations, and individuals. Workshops in bat acoustic monitoring, dye tracing, road sediment control, and database development were held on Monday. On Tuesday, Thursday, and Friday, a variety of presentations and discussions were undertaken. On Wednesday, field trip options included a "Geology of the Buffalo River" float, a cave and springs tour of Eureka Springs, and a trip to the Ozark Underground Laboratory.

Ed Klausner surveys Leafy Crawl Cave. *Mark Jones*

Karen Willmes surveys in Y Cave. *Mark Jones*

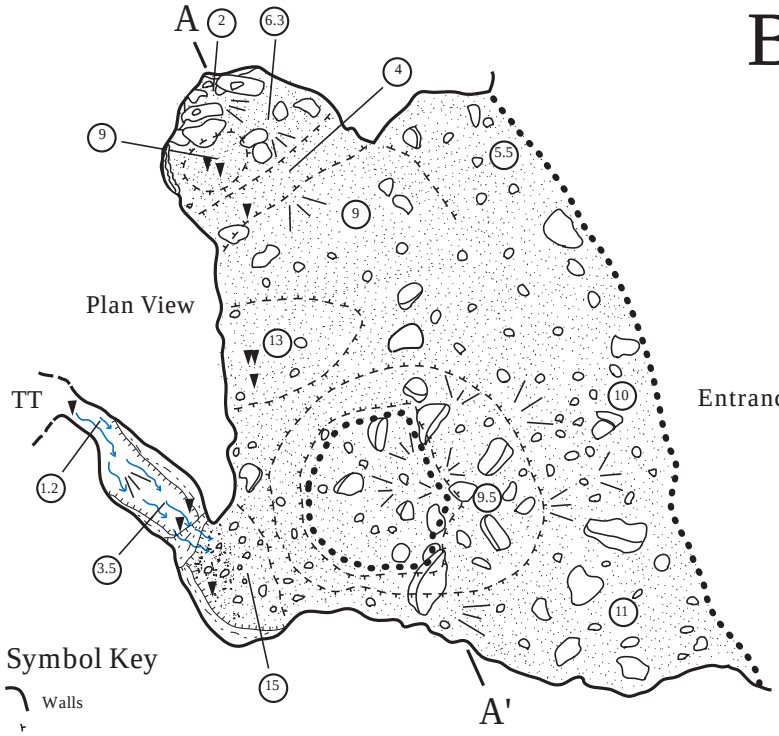
Mike Slay. *Scott House*

Chaz Angle at Needle's Eye Pit. *Kayla Sapkota*

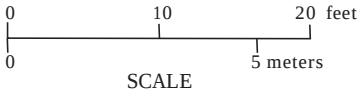


Bullseye Cave

BUFFALO NATIONAL RIVER
Newton County, Arkansas
C-466
Surveyed By Dillon Freiburger
and Kate McKalip, of
Cave Research Foundation
March 11, 2017
Cartography by Dillon Freiburger



Plan View

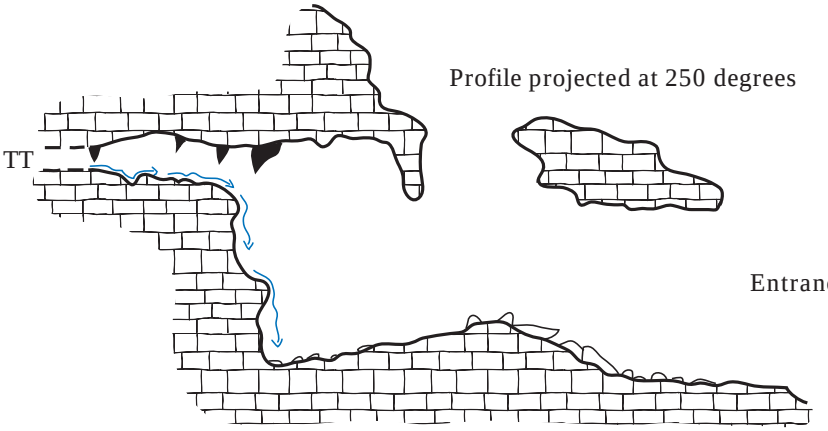


SCALE
dimensions given in feet

Cave Length 55.2ft/16.8m

Symbol Key

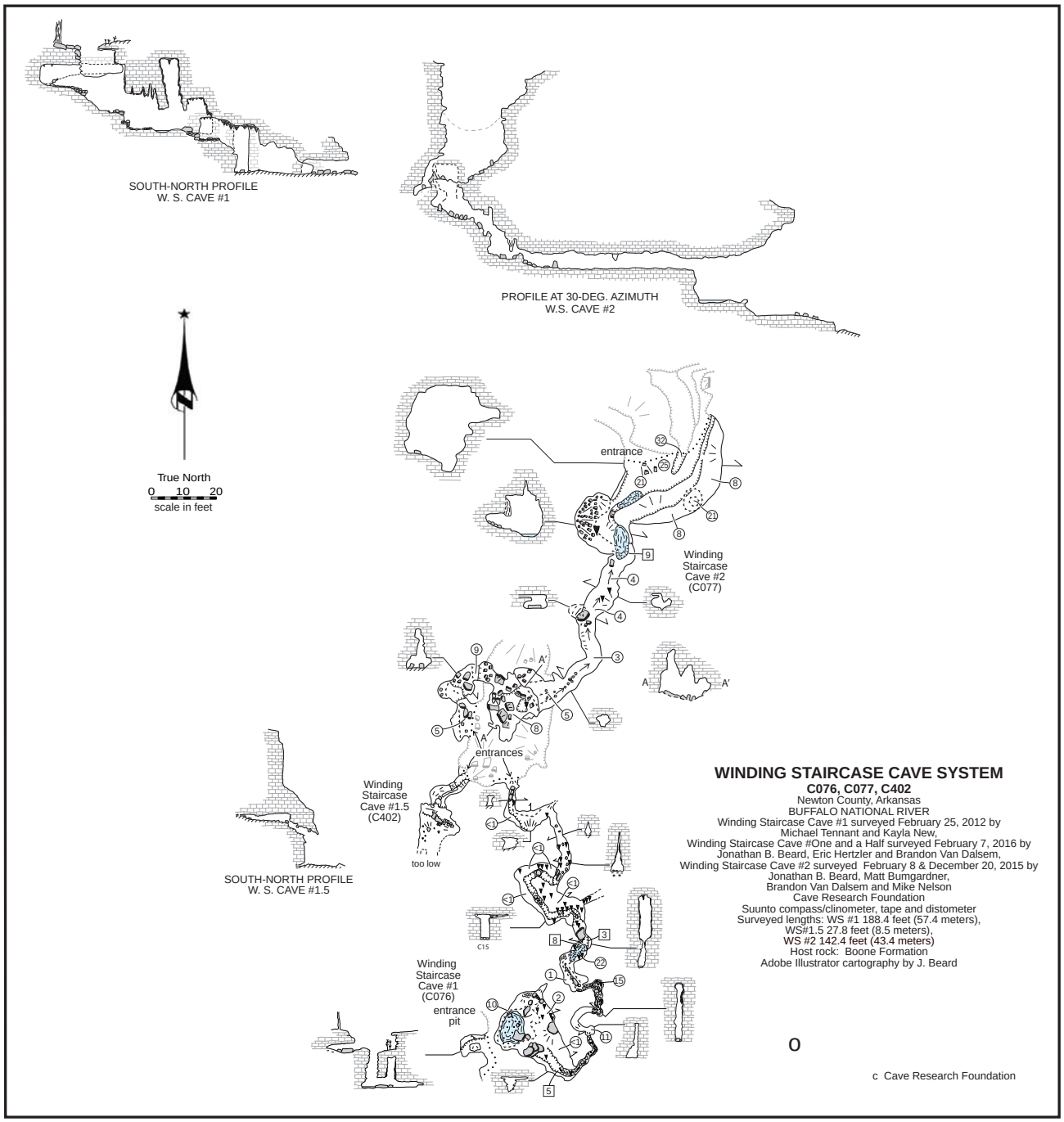
- Walls
- Ceiling Ledge
- Stalactites
- Floor ledge
- Bedrock
- Silt/Soil
- TT "Too tight"
- Rocks
- Slope
- Running Water
- Drip Line



Profile projected at 250 degrees

Eric Hertzler surveys in Milk Cow Cave. *Charity Hertzler*

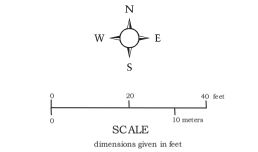
Elizabeth Miller taking inventory. *Ed Klausner*



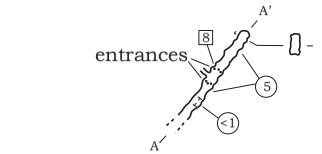
ROCK STEP CAVE (C488)
SHAG BARK CAVE (C487)
WILD FLOWER CAVE (C486)
ZIG ZAG CAVE (C485)
RAIN AND SHINE CAVE (C484)

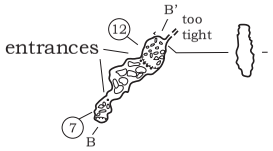
Buffalo National River
Newton County, Arkansas

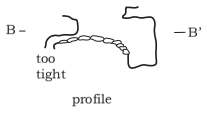
Surveyed by
Mark Jones and Sarah Heiser
of
CAVE RESEARCH FOUNDATION
in cooperation with
Buffalo National River

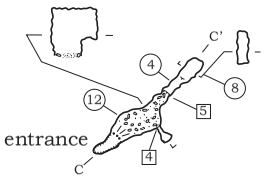


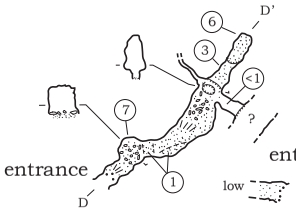
Rock Step Cave length 22.5 ft/6.9 m
Shag Bark Cave length 22.7 ft/6.9 m
Wild Flower Cave length 39.2 ft/11.9 m
Zig Zag Cave length 74.2 ft/22.6 m
Rain And Shine Cave lentgh 35.4 ft/10.8 m



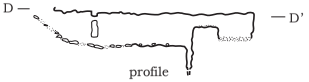


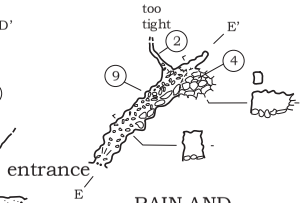




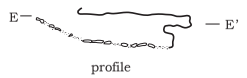


ZIG ZAG
CAVE ANNEX





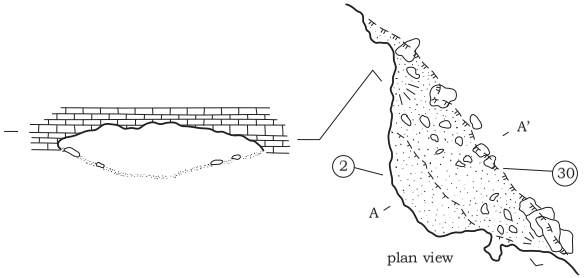
RAIN AND
SHINE CAVE

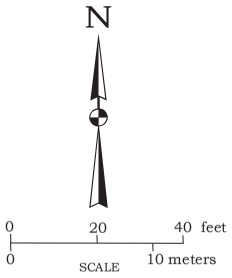


Map drawn by Ed Klausner

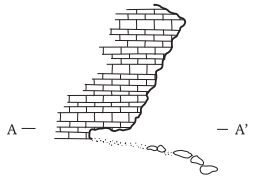
TOXICODENDRON SHELTER

Buffalo National River
Newton County, Arkansas
S044
Surveyed 2 November 2016 by
Mark Jones, Ed Klausner and Elizabeth Miller
of
CAVE RESEARCH FOUNDATION
in cooperation with Buffalo National River



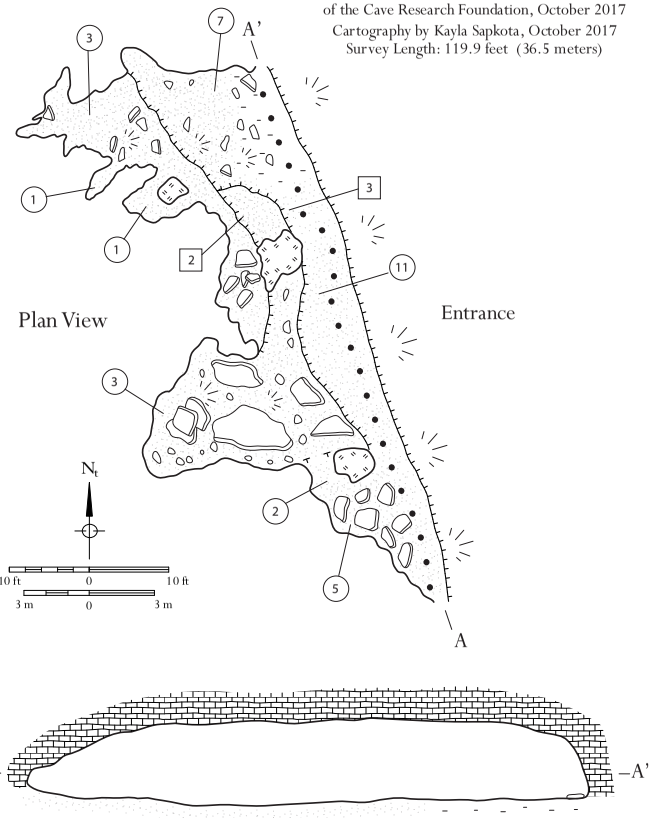


dimensions given in feet
Cave Length 21 ft/ 6 m



Map drawn by Ed Klausner

S047
Twin Shelter
Buffalo National River
Newton County, AR
A Suunto & Disto Survey
by Matt Bumgardner, & Mark Jones
of the Cave Research Foundation, October 2017
Cartography by Kayla Sapkota, October 2017
Survey Length: 119.9 feet (36.5 meters)



Ozark National Scenic Riverways

Scott House

2016

Operating under a cooperative agreement, CRF fielded over 60 trips on OZAR lands in calendar 2016. These trips resulted in 113 cave monitoring visits and over 410 new cave faunal records being added. In addition, a number of cave survey trips were taken, normally in conjunction with monitoring.

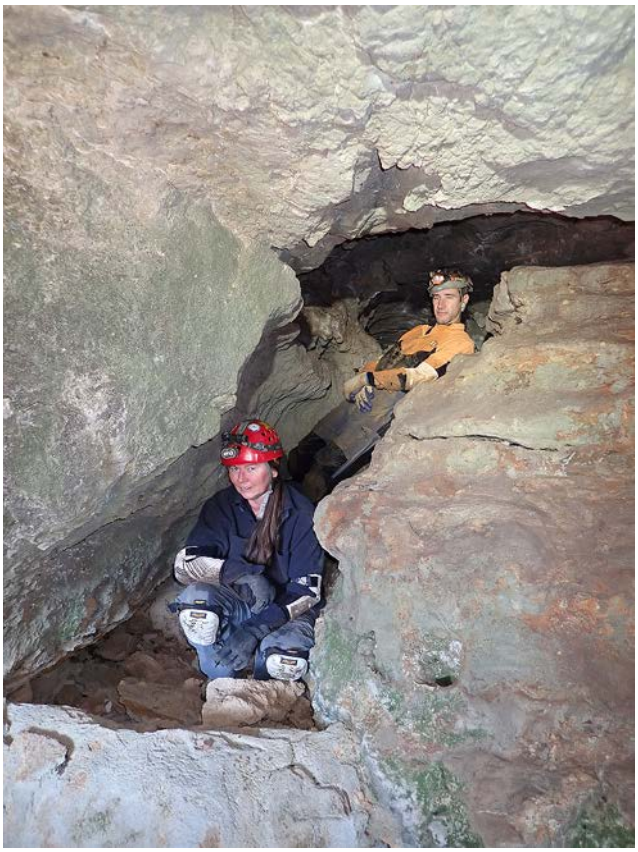
Highlights:

Much monitoring was done in areas that had not had much in recent times. We spent a lot of time making sure that cave areas were not ignored in the monitoring process. Help was given to bat-swabbing projects. A number of caves were monitored for archaeological surveys and/or checking for ARPA violations. When violations were found, rangers and resource management personnel were notified. Some monitoring trips were taken on adjoining (park-partner) agency or NGO lands adjacent to the park. Most of these were to check effects of WNS. Biological surveys were done in several park caves as part of a research project.

Surveys were continued on a large cave within the park boundaries but actually on state lands. This cave has passed one mile in length (7700 feet long). New caves were located on the upper Jacks Fork River.

Gate repairs were done on one park cave gate while a number of others were maintained (checked and locks oiled). Trail maintenance was done in Round Spring Cavern.

Three Entrance Cave. *Mark Jones*



Brenda Goodnight and Dennis Novicky at Tater Cave. *Mark Jones*

Ken Grush at Panther Spring Cave. *Mark Jones*

Restoration was done on one park cave that is very visible and available to visitors.

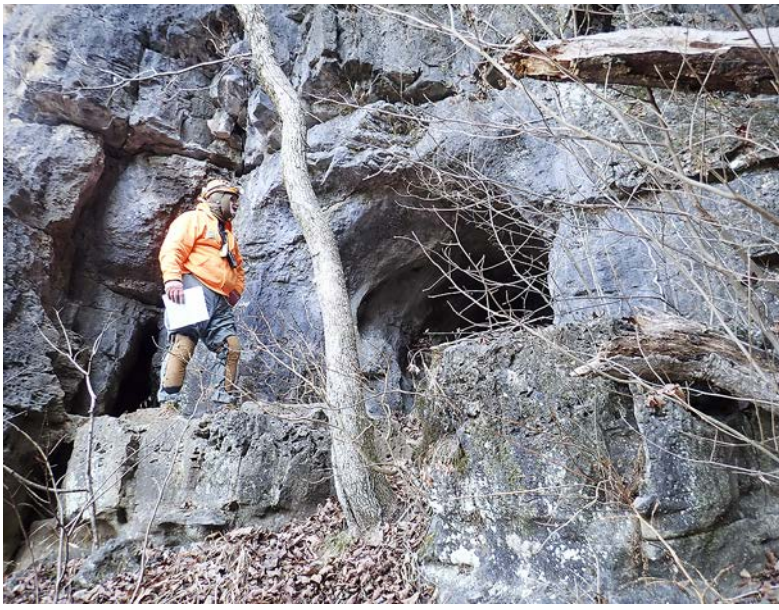
CRF crews spent time removing illegal/unauthorized climbing bolts and associated paraphernalia from a cave on the upper Jacks Fork. They were aided by NPS rangers.

2017

Continuing to operate under a cooperative agreement, CRF fielded 66 field trips in calendar 2017. These trips resulted in several new cave maps, nearly 500 new faunal records and 143 monitoring visits to caves.

Highlights:

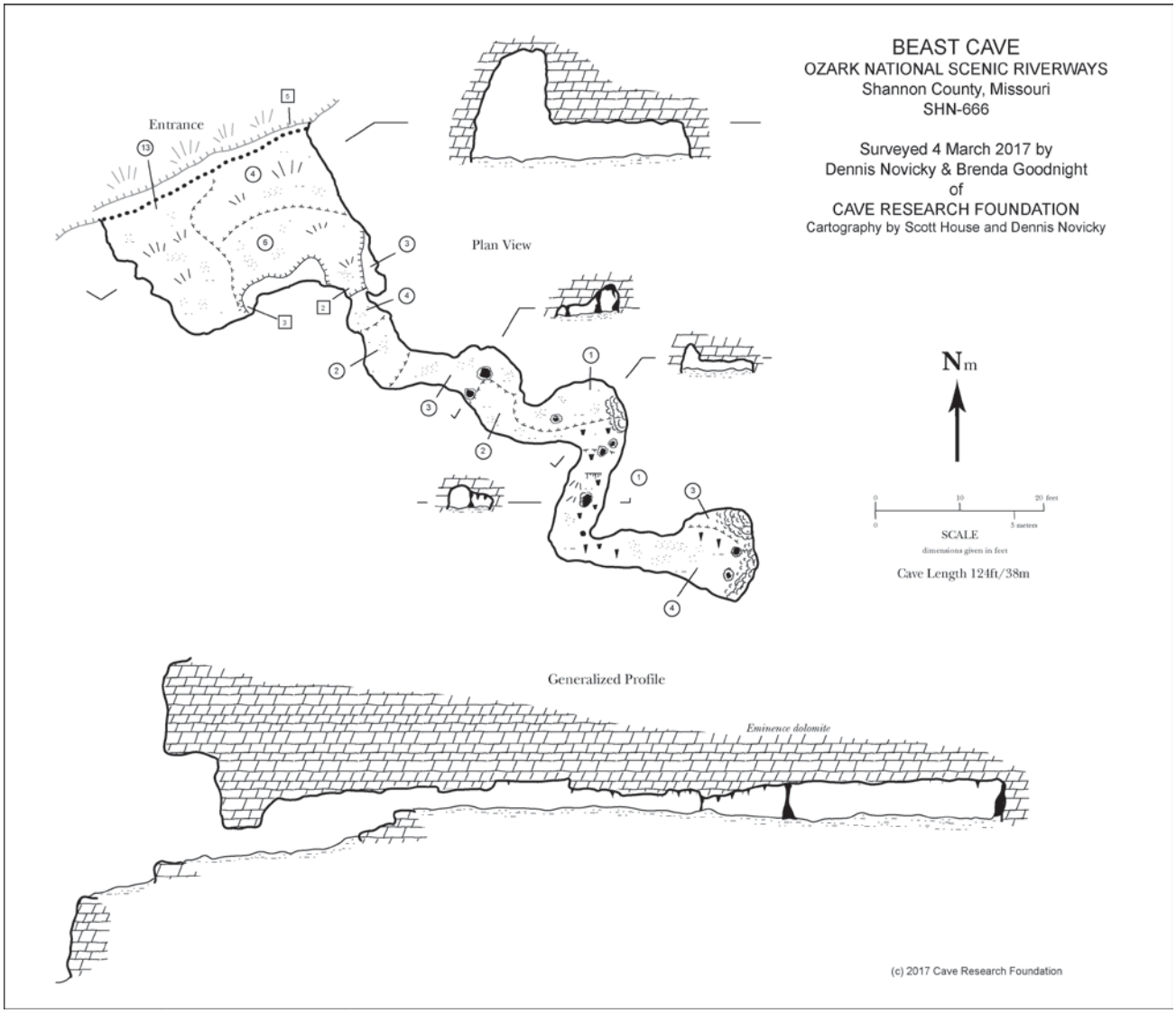
The bad highlight of 2017 was the historic, devastating flood of late April, resulting in the virtual destruction of the Powder Mill Research Center. Some materials were salvaged and cleaned but several computers, paper files, cameras, and other equipment were destroyed. Most field trips were suspended for some months until new housing became available at the USFS station at Winona, Missouri. During that time, cleaning, repair, and replacement of cave equipment was ongoing. Regular trips resumed in October

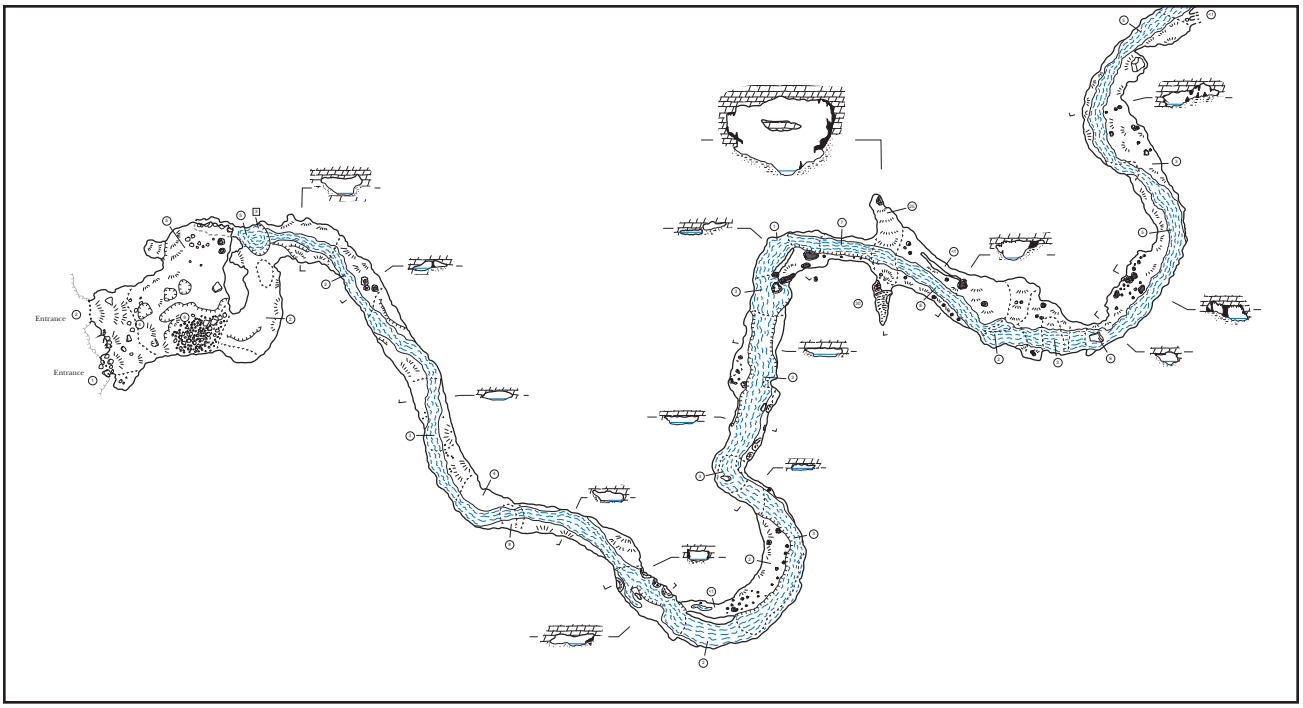


Jim Cooley monitoring cave archaeology site. *Mark Jones*

Canoe camping on Current River. *Scott House*

Black rat snake wintering in Sextus Mille Cave. *Mark Jones*





A detail from the Alphen Hollow Spring Cave map. Cartography by Scott House.

of 2017. The historic flood destroyed campgrounds, concession buildings, bridges, and other infrastructure in numerous places.

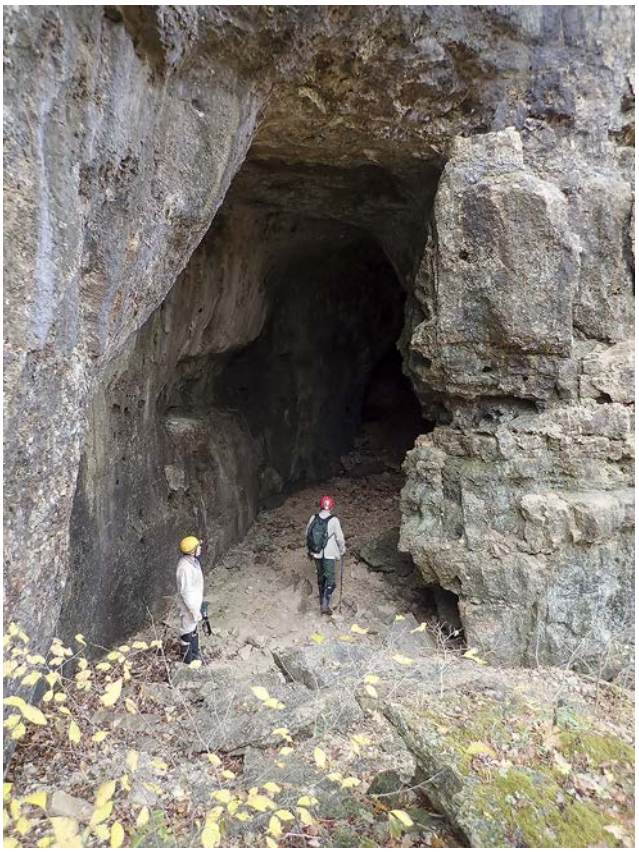
CRF volunteers discovered feral hogs inhabiting a small Indiana bat hibernacula. A number of caves were inspected for archaeological potential and/or to monitor any ARPA violations. In one epic day, a pair of crews inspected 20 caves for suspected violations.

A couple of older cave maps were resketched and redrawn to include profiles and other detail. Another 800 feet were surveyed in grim Bealert Blowing Spring which is now over one mile in length.

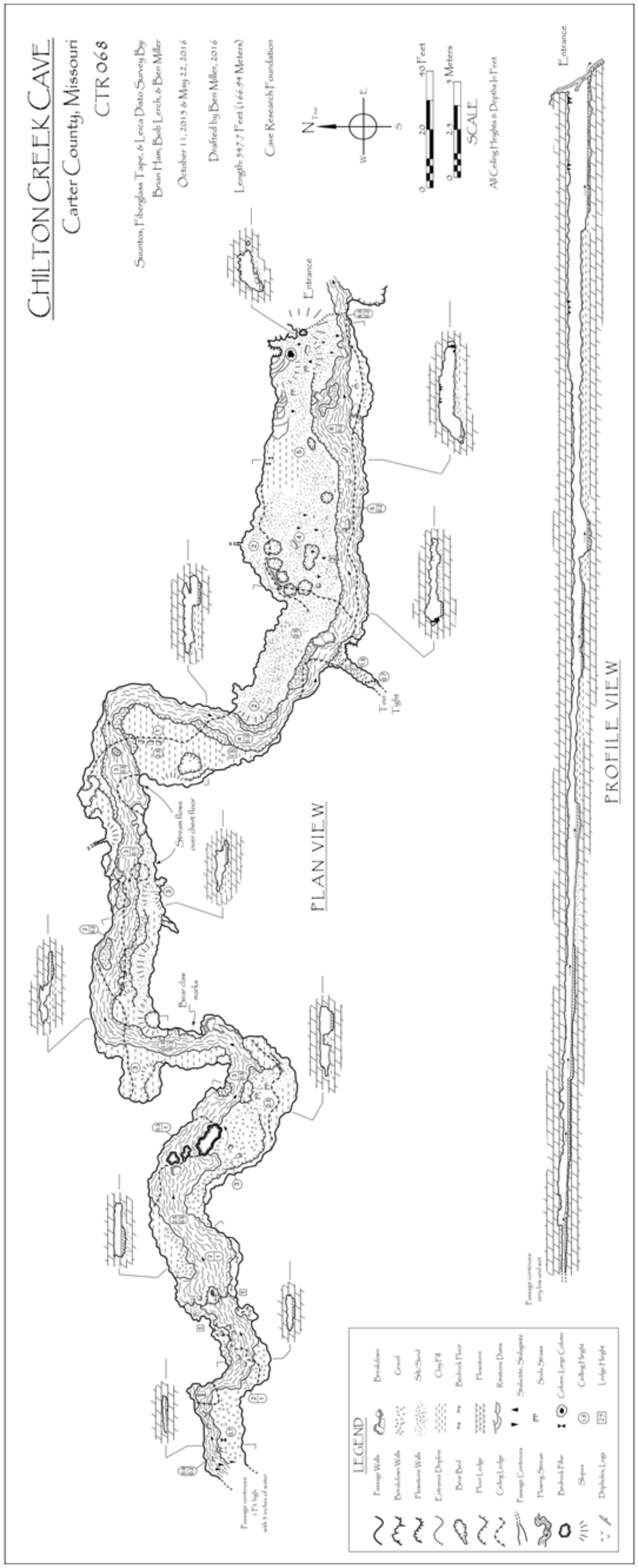
All major Indiana and gray bat hibernacula were monitored in conjunction with various agencies. Post-flood, several gray bat maternity colonies were examined, and results were that two of them suffered great losses while the two others were not severely impacted. In the two affected caves, low sections of the cave flooded first, trapping the bats. The entire caves filled up with water in a flood that saw river levels rise higher than ever recorded.

CRF volunteers continued to maintain the trails in the park's interpretive cave, Round Spring Cavern. One educational trip (a college class) was led by CRF.

The fence around Coalbank Cave, a gray bat maternity cave, was repaired and sections replaced. The gate on Lost Man Cave was repaired. The gate on Big Spring Well Cave was temporarily fixed; here the flood completely rearranged the entrance to this mostly-talus cave. Lock maintenance was performed on most of the park cave gates.



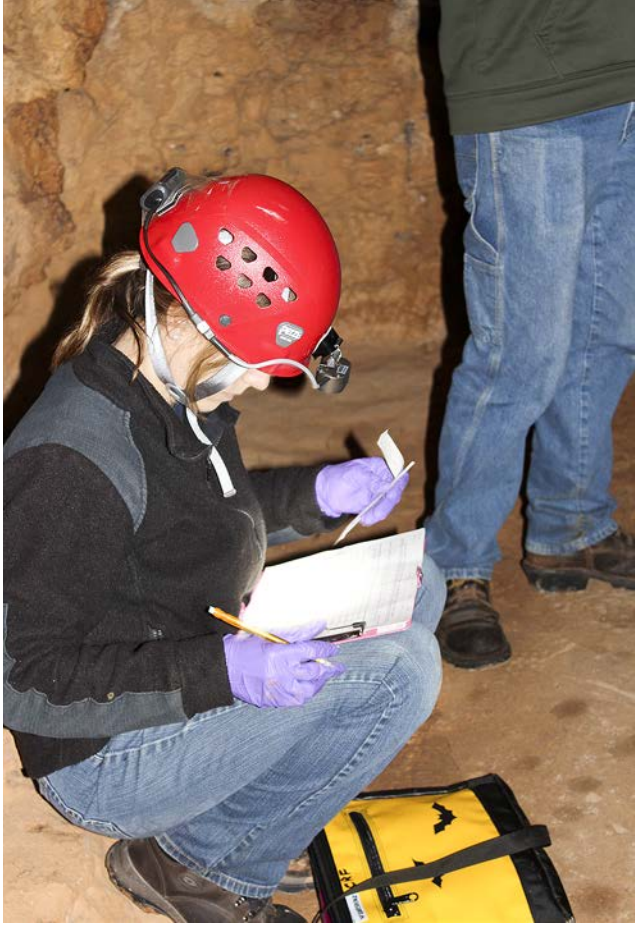
Don Dunham and Scott House at Three Entrance Cave.
Mark Jones


CHILTON CREEK CAVE
Carter County, Missouri
CTR 068
Suuntos, Fiberglass Tape, & Leica Disto Survey By:
Brian Ham, Bob Lerch, & Ben Miller
October 11, 2015 & May 22, 2016
Drafted by Ben Miller, 2016
Length: 547.7 Feet (166.94 Meters)
Cave Research Foundation
SCALE
All Ceiling Heights & Depths In Feet
Entrance
Too Tight
PLAN VIEW
PROFILE VIEW
LEGEND

Brenda Goodnight and guano measurement. *Mark Jones*

Ed Klausner entering Hidden Cave. *Mark Jones*

Karen Willmes exits Bear Cave, Barn Hollow. *Mark Jones*



NPS terrestrial ecologist Kim Houf recording bat data in Round Spring Cavern. *Scott House*

Doug Leer at the walled entrance of Whiskey Spring Cave. *Scott House*

Mark Twain National Forest

2016–2017

Mick Sutton

Work by CRF cavers on the Mark Twain National Forest continued at a fast pace. The Butler Hollow Project was a major area of focus, accounting for roughly 46% of all field work. This project originated with a need to gate five sites in the southwest Missouri Cassville sub-district which had seen mining activity during a localized fake "radium mining" obsession in the early to mid-20th century. The sub-district is a forested landscape of steep hills and deep valleys and includes the Piney Creek Wilderness.

Although all but one of the mining sites are natural caves, USFS policy mandates gating them as mines for public safety—and some of the mined passages are indeed unstable. Radium Cave had previously been secured with three gates; during the current period Carter Cave and Butler Hollow Mine were gated under the direction of Jim Cooley, after assessing the gate sites for cultural remains in collaboration with the Cave Archeology Investigation and Research Network (CAIRN). The mine gate was simple, but Carter Cave has four upper entrances, at least some of which are artificial, leading via a deep pit to a lower stream cave with a large natural entrance. CRF welders and Americorps volunteers were instrumental in getting the jobs

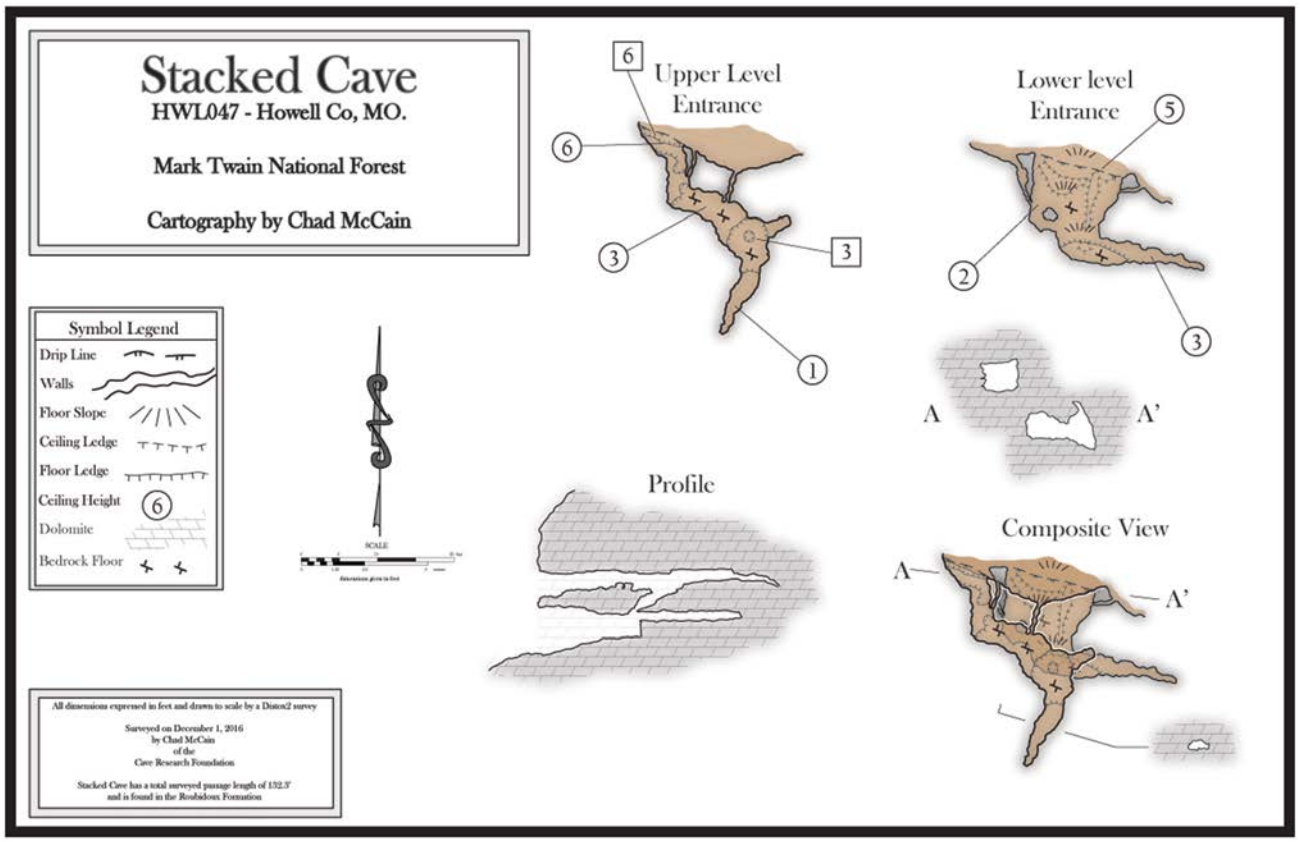
Big Spring. *Scott House*

done despite sometimes adverse conditions. During one session, lighting struck close enough to make participants' hair stand on end and take out a generator.

The Butler Hollow project also included an assessment of caves throughout the sub-district to see if other caves had seen mining activity and to generally document the caves with mapping and inventory, including an assessment of bat occurrences during the ongoing spread of white nose syndrome. Although no mining sites beyond the Butler Hollow / Radium Hollow area were found, 45 previously unrecorded caves were documented, nearly doubling the number of known caves on the sub-district, and maps were completed for a majority of them. New sites were documented for such creatures as western grotto salamander and *Stygobromus* amphipods.

Beyond the Cassville sub-district, a large amount of mapping, monitoring and inventory work happened throughout the Mark Twain. Thirty-one new caves were documented and mapped. A few caves were re-mapped to replace inadequate earlier maps. In the case of Rattlesnake Cave on the Ave sub-district, remapping led to more than doubling the cave's length. Assessment of historic and prehistoric cultural remains was conducted, mainly on the Rolla/Houston District, in association with CAIRN personnel. In addition to routine biological monitoring a number of trips and classroom sessions took place to train cavers in what to look for and the limitations of what can reasonably be identified in the field. The gates at Whites Creek Cave, a somewhat

Richard Young in an MTNF cave. *Scott House*



Don Dunham in Huffman Cave. Note the pipe; the cave provided a water supply for early residents. *Scott House*

Jon Beard at Mountain Maid Canyon Cave. *Scott House*

Stromatolite columns in Dead Man Estevalled. *Ken Grush*

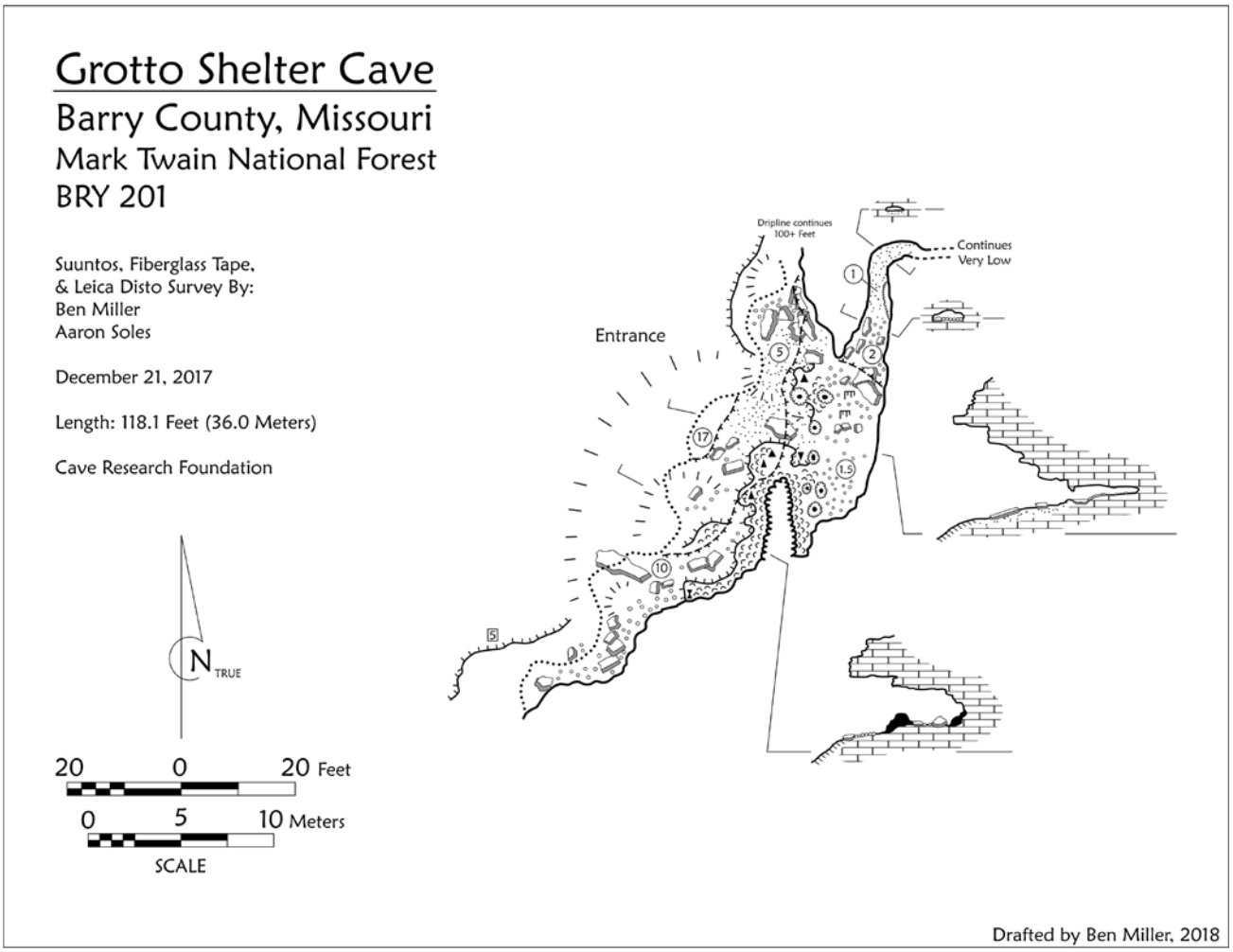
remote gray and Indiana bat site, and at McCormick Cave were repaired and other sites were assessed for possible gates or gate replacements.

Decline in bat populations continued to be tracked, with northern bats and pipistrelles being hit the hardest. On the other hand, the gray bat colony in Thrasher Ford Cave, and the Indiana bat colony in Big Brown Bat Cave remained stable.

CRF continued to provide scoping assessments of non-MTNF caves within or near proposed project areas.

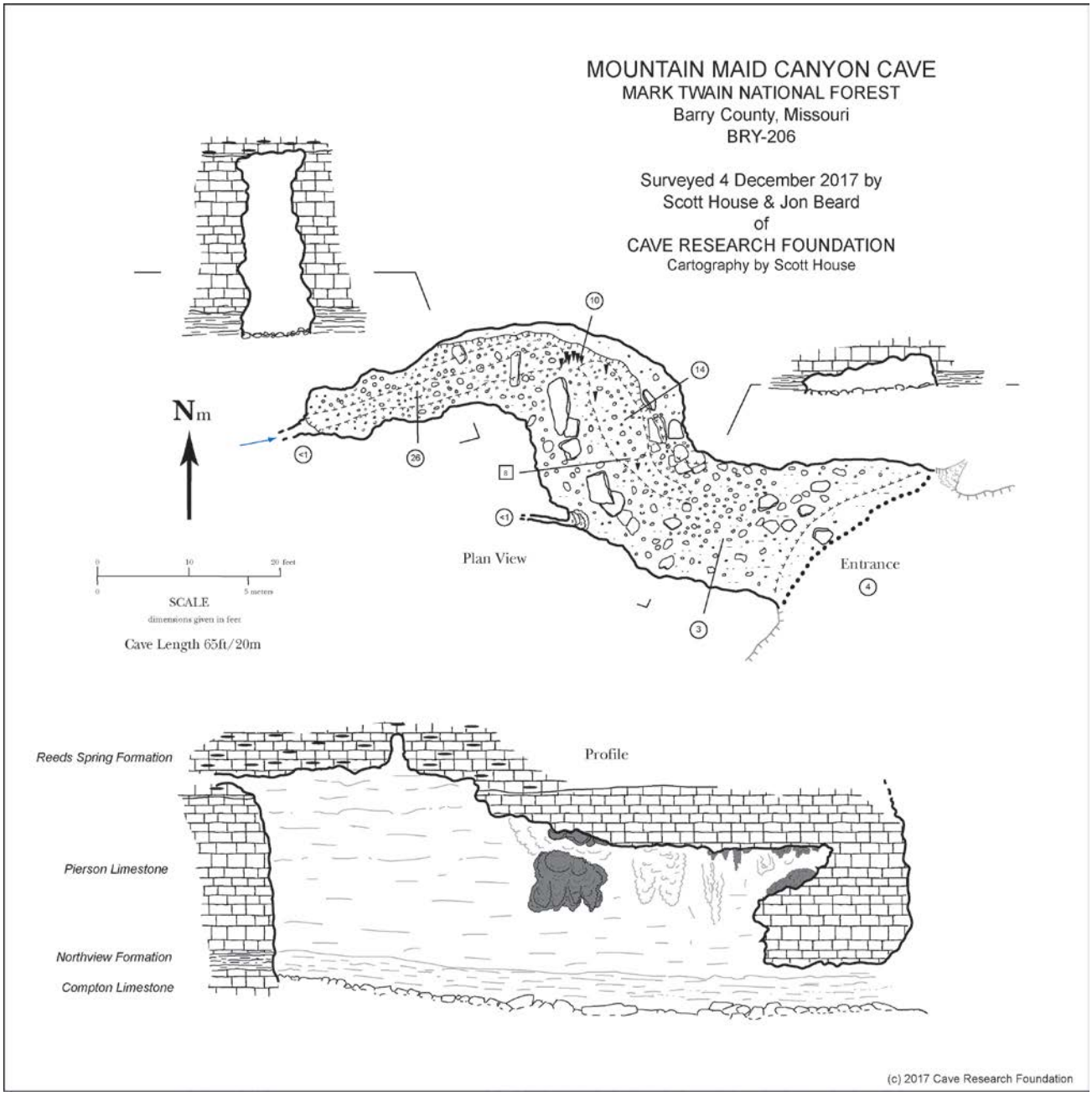
Some statistics:

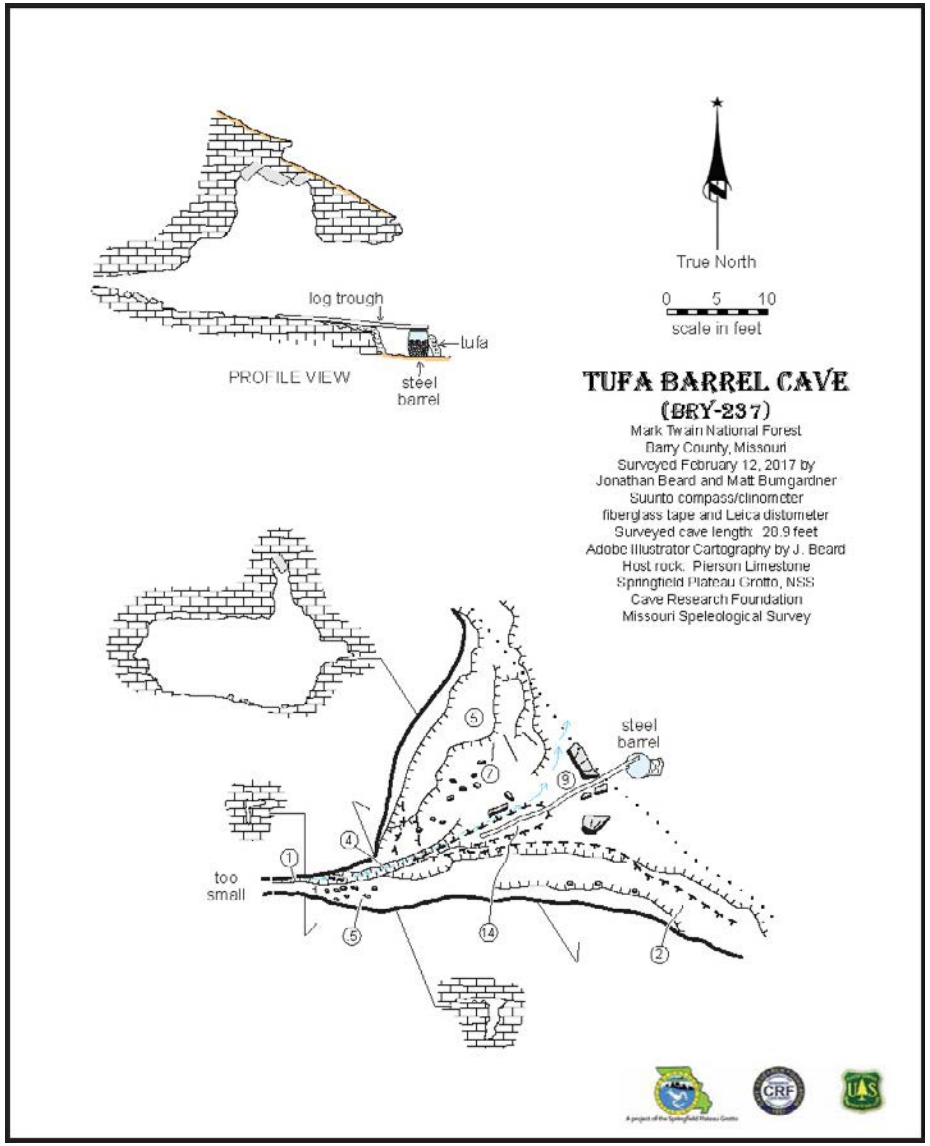
- Field trips taken: 170
- "New" caves located and documented: 76
- Maps completed: 51
- Biological records added to database: 896

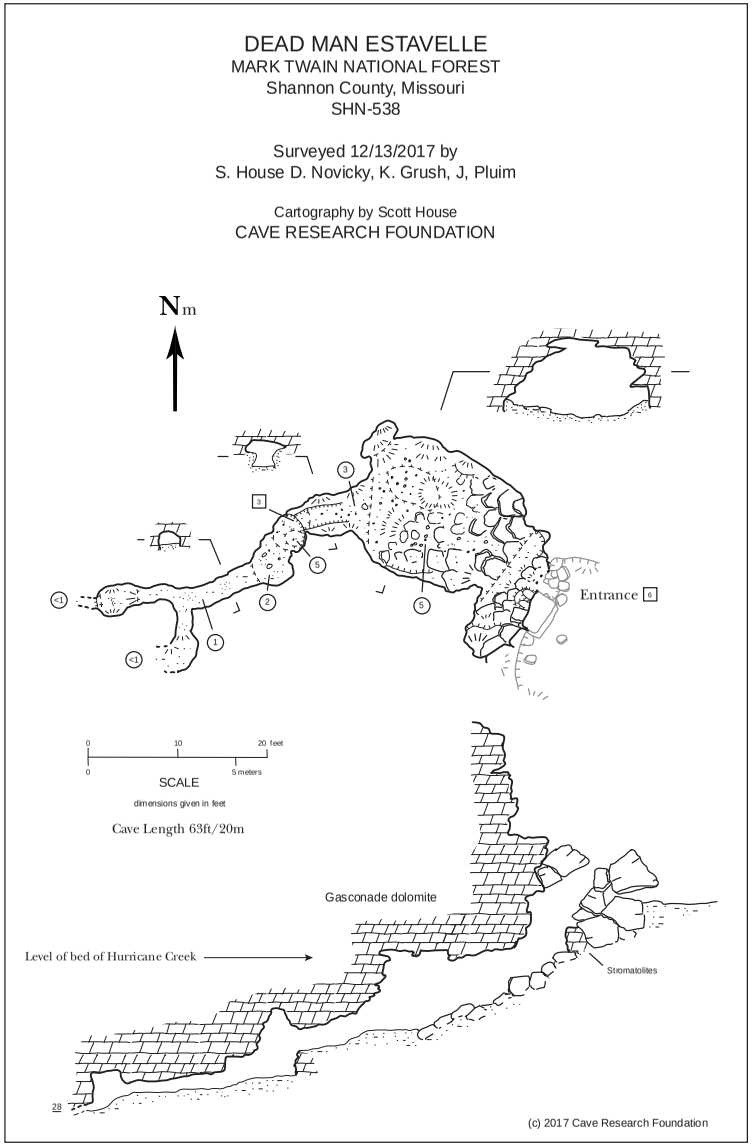


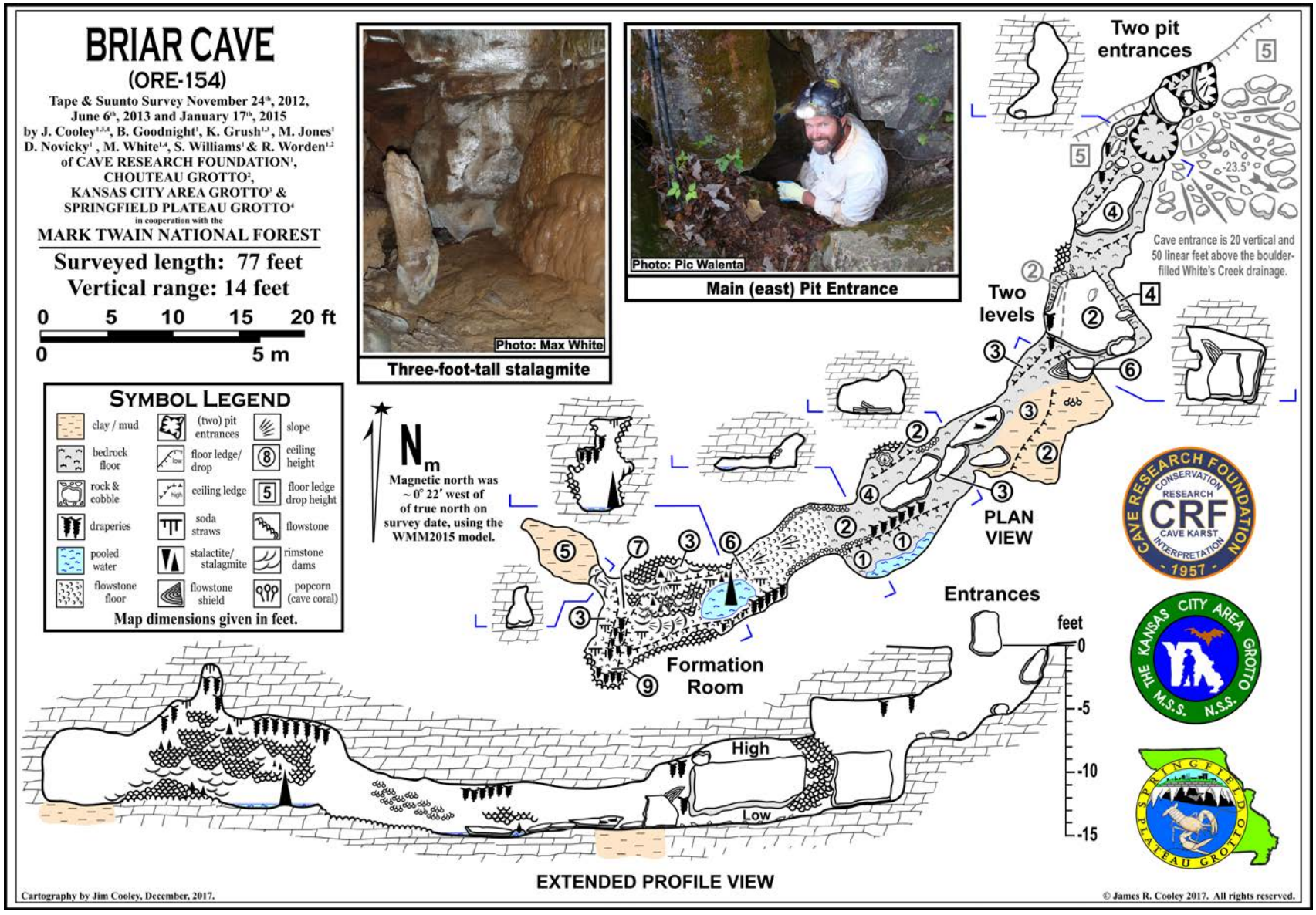
Along the Gladetop Trail. The rugged glade country of southwest Missouri sometimes looks more like Oklahoma or Texas. *Scott House*

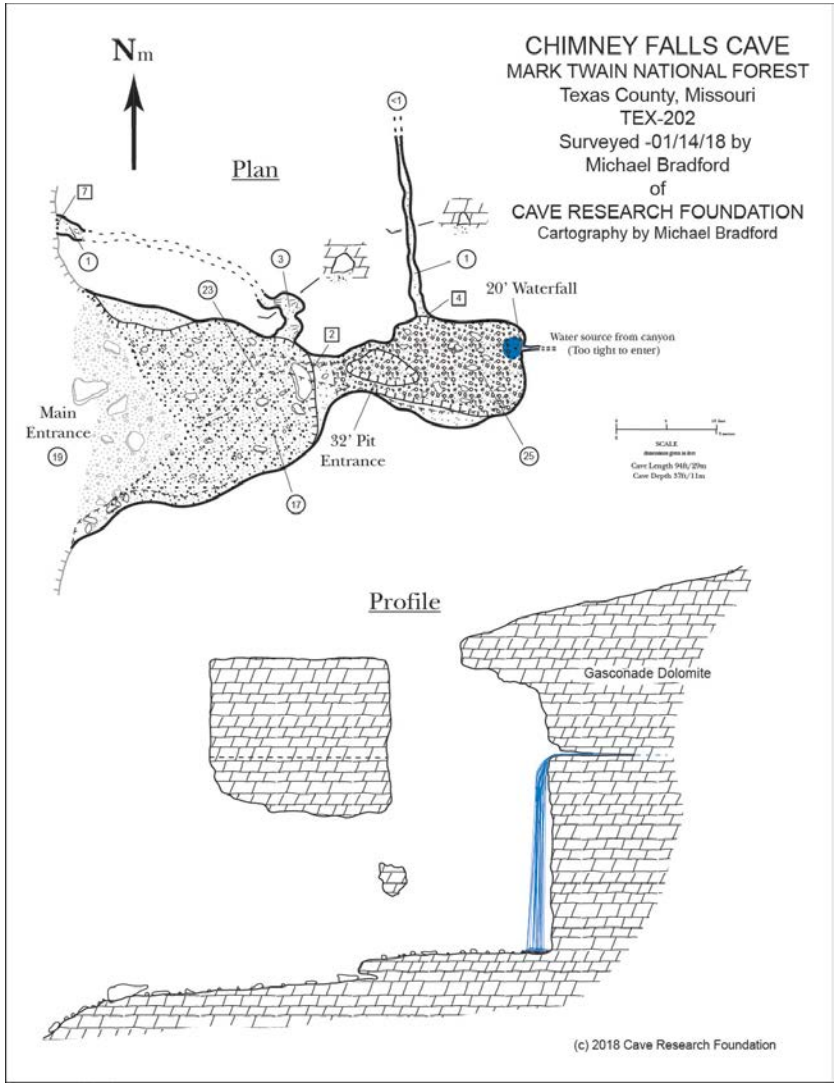
The Blue Hole (sink). *Scott House*

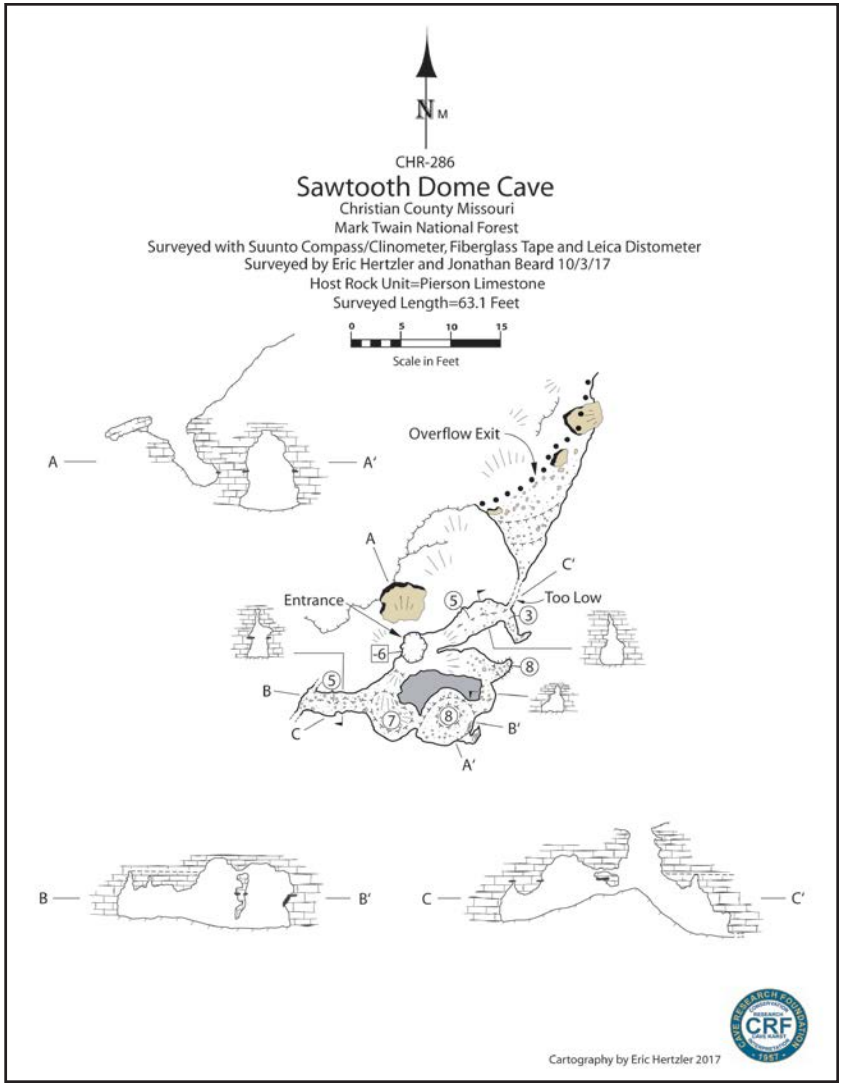

MOUNTAIN MAID CANYON CAVE
MARK TWAIN NATIONAL FOREST
Barry County, Missouri
BRY-206
Surveyed 4 December 2017 by
Scott House & Jon Beard
of
CAVE RESEARCH FOUNDATION
Cartography by Scott House
Nm
Plan View
Entrance
SCALE
dimensions given in feet
Cave Length 65ft/20m
Profile
Reeds Spring Formation
Pierson Limestone
Northview Formation
Compton Limestone
(c) 2017 Cave Research Foundation


log trough
tufa
PROFILE VIEW
steel barrel
True North
0 5 10
scale in feet
TUFA BARREL CAVE
(BRY-237)
Mark Twain National Forest
Barry County, Missouri
Surveyed February 12, 2017 by
Jonathan Beard and Matt Baumgardner
Suunto compass/clinometer
fiberglass tape and Leica distometer
Surveyed cave length: 28.9 feet
Adobe Illustrator Cartography by J. Beard
Host rock: Pierson Limestone
Springfield Plateau Grotto, NSS
Cave Research Foundation
Missouri Speleological Survey
steel barrel
too small


DEAD MAN ESTAVELLE
MARK TWAIN NATIONAL FOREST
Shannon County, Missouri
SHN-538
Surveyed 12/13/2017 by
S. House D. Novicky, K. Grush, J, Pluim
Cartography by Scott House
CAVE RESEARCH FOUNDATION
Nm
Entrance
0 10 20 feet
0 5 meters
SCALE
dimensions given in feet
Cave Length 63ft/20m
Gasconade dolomite
Level of bed of Hurricane Creek
Stromatolites
28
(c) 2017 Cave Research Foundation


BRIAR CAVE
(ORE-154)
Tape & Suunto Survey November 24th, 2012,
June 6th, 2013 and January 17th, 2015
by J. Cooley[1,3,4], B. Goodnight[1], K. Grush[1,3], M. Jones[1]
D. Novicky[1] , M. White[1,4], S. Williams[1] & R. Worden[1,2]
of CAVE RESEARCH FOUNDATION[1],
CHOUTEAU GROTTO[2],
KANSAS CITY AREA GROTTO[3] &
SPRINGFIELD PLATEAU GROTTO[4]
in cooperation with the
MARK TWAIN NATIONAL FOREST
Surveyed length: 77 feet
Vertical range: 14 feet
0 5 10 15 20 ft
0 5 m
Photo: Max White
Three-foot-tall stalagmite
Photo: Pic Walenta
Main (east) Pit Entrance
Two pit entrances
Cave entrance is 20 vertical and 50 linear feet above the boulder-filled White's Creek drainage.
Two levels
PLAN VIEW
Entrances
Formation Room
High
Low
feet
0
-5
-10
-15
EXTENDED PROFILE VIEW
SYMBOL LEGEND
clay / mud
bedrock floor
rock & cobble
draperies
pooled water
flowstone floor
(two) pit entrances
floor ledge/ drop
ceiling ledge
soda straws
stalactite/ stalagmite
flowstone shield
slope
ceiling height
floor ledge drop height
flowstone
rimstone dams
popcorn (cave coral)
Map dimensions given in feet.
Nm
Magnetic north was ~ 0° 22' west of of true north on survey date, using the WMM2015 model.
CAVE RESEARCH FOUNDATION
CONSERVATION RESEARCH
CRF
CAVE KARST INTERPRETATION
- 1957 -
THE KANSAS CITY AREA GROTTO
M.S.S. N.S.S.
SPRINGFIELD PLATEAU GROTTO
Cartography by Jim Cooley, December, 2017.
© James R. Cooley 2017. All rights reserved.


Nm
CHIMNEY FALLS CAVE
MARK TWAIN NATIONAL FOREST
Texas County, Missouri
TEX-202
Surveyed -01/14/18 by
Michael Bradford
of
CAVE RESEARCH FOUNDATION
Cartography by Michael Bradford
Plan
20' Waterfall
Water source from canyon
(Too tight to enter)
Main
Entrance
32' Pit
Entrance
Profile
Gasconade Dolomite
(c) 2018 Cave Research Foundation


NM
CHR-286
Sawtooth Dome Cave
Christian County Missouri
Mark Twain National Forest
Surveyed with Suunto Compass/Clinometer, Fiberglass Tape and Leica Distometer
Surveyed by Eric Hertzler and Jonathan Beard 10/3/17
Host Rock Unit=Pierson Limestone
Surveyed Length=63.1 Feet
0 5 10 15
Scale in Feet
Overflow Exit
Entrance
Too Low
Cartography by Eric Hertzler 2017

Missouri Department of Conservation

Dan Lamping

Jeremy Weih in Powder Mill Creek Cave. *Dan Lamping*

2016

In 2016 CRF Ozarks fielded 29 trips to Missouri Department of Conservation caves. In that time, we had no specific cooperative agreement with MDC, so all trips were either coordinated with regional natural history biologists or the MDC cave biologist. Trips included monitoring of certain MDC caves within the boundaries of the Ozark National Scenic Riverways, biological inventory of certain MDC caves in southwest Missouri, monitoring at the Fiery Forks Conservation area, and bat survey work in Lime Kiln Mine, Valle Mines, and other area mines.

An assessment trip was made into Powder Mill Creek Cave in order to familiarize a new generation of cavers with the cave and in attempt of reaching the back of the cave to

Jeff Crews and Joe Sikorski admire one of the many waterfalls in Powder Mill Creek Cave. *Dan Lamping*

Jon Beard, Scott House, and Chris Wessel examining a chert floor in Powder Mill Creek Cave. *Matt Bumgardner*

Survey crew hikes down to Shop Hollow Cave. *Josh Hafner*

Tony Schmitt in the stream crawl in Shop Hollow Cave.
Josh Hafner

Mike Tennant climbs a high lead in Shop Hollow Cave.
Josh Hafner

Dan Lamping sketches as Natalia Kolk Tennant reads clino in Shop Hollow Cave. *Josh Hafner*

retrieve a climbing pole left at the end of the survey project over a decade prior. High water, thin wetsuits, and uncertainty in navigation kept the team from reaching their goal.

Two trips occurred in the ongoing survey of Shop Hollow, a large MDC cave within the boundaries of ONSR. A team accessed a high lead in the far reaches of the cave within Terabyte Hall and then later returned to complete the survey of the high lead along with all of the remaining main passage, leaving only a very tight lead which would require an exceptionally small crew to finish the cave.

Survey work also began in Great Scott Cave, a significant MDC cave in the Meramec Valley. Great Scott is a gray bat maternity site and Indiana bat hibernaculum, which creates limited windows for access. CRF was contracted by MDC to do both an invertebrate biological inventory of the cave and to work towards replacing old survey in the cave that fails to meet modern standards.

2017

In 2017 CRF Ozarks fielded 36 trips to Missouri Department of Conservation caves. These trips were all arranged through the establishment of Wildlife Collectors Permits via the MDC, which were granted to 11 CRF cavers, one of whom had to be present on each trip. While we would not be collecting any wildlife, due to regulations written within their organizational policies, this was the only way we could get permits to do work in MDC caves. The permits were largely due to the efforts of MDC's cave biologist at the time.

Trips included continued monitoring of MDC caves within the boundaries of the Ozark National Scenic Riverways, as well as survey work in MDC caves within Ripley County and continued monitoring of MDC caves in Fiery Forks Conservation area.

In southwest Missouri, there was a single survey trip into Long Cave which netted 1,741 ft of survey by four cavers. In addition, there was a bio trip into Smittle Cave.

There were two mapping trips to Vanderman Cave in western Missouri's Hickory County, as well as surveys of Ladder Cave and Murphy Cave. A couple of these caves have signatures dating date to the 1890s along with unconfirmed reports of use by the Underground Railroad prior to the Civil War.

A biological inventory of Jefferson County Park's Pleasant Valley Cave was conducted along with MDC's cave biologist. Of anecdotal interest, the well renowned yellow bat sticker cavers use for identification, so often on our cars, was first created by Missouri caver Earl Biffle as a fundraiser to protect Pleasant Valley Cave.

Work also began on a collaborative project between CRF and MDC to find suitable habitat for the elusive Ozark Big Ear Bat. While field work was begun, complications over data ownership and inclusion in the Missouri Cave Database ultimately led to abandonment of the project.

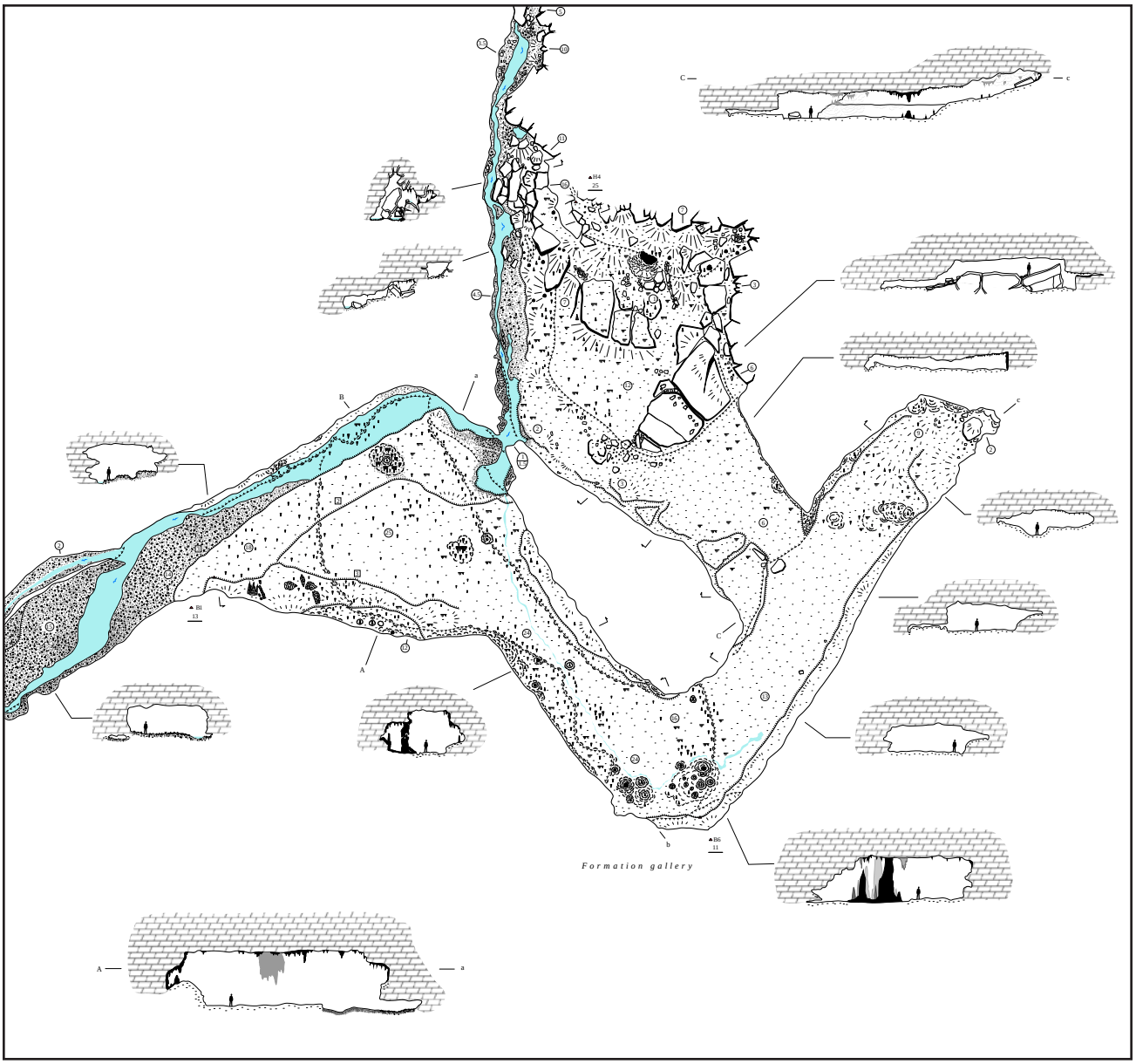
In conjunction with the spring Missouri Speleological Society meeting, 6 MDC caves were monitored, along with bio inventories in the Huzzah Wildlife Area.

Survey work continued in Great Scott Cave along with continued invertebrate biological inventory. There were two mapping trips and two bio trips with MDC biologists to check on bats. In addition, Mick Sutton did an exceptional job integrating the modern resurvey which started at the entrance, to older survey which he had originally done,

Dan Lamping sketches in Mossy Spring Cave. *Derik Holtmann*

Large room in Mossy Spring Cave. *Matt Bumgardner*

Tony Schmitt reading instruments in Mossy Spring Cave. *Matt Bumgardner*



A detail from the Mossy Spring Cave map. Cartography by Dan Lamping.

Henry Lamping and Joe Light enter to begin survey of Scotia Furnace Cave. *Dan Lamping*

with others, back in the 1970s and replaced the old 1960s survey which the map was primarily based on. Interestingly, this cave was Mick's first project when he initially moved to Missouri and it is where he and Scott House first met decades ago.

The survey of Mossy Spring Cave, a 3,000-foot-long gated cave in the Meramec valley was completed in a total of three trips with the help of 15 cavers. This was part of a funded project along with the Great Scott Cave project to do invertebrate biological inventory as well as survey. The two caves are a short distance from one another. Mossy Spring had been surveyed in the 1970s though the map was woefully lacking and did not give justice to the cave's spectacular character. The cave is gated and has had limited access for the past few decades. The final map has been drawn and submitted to MDC.

Approximately 15 years ago cavers with the Meramec Valley Grotto frequented a gnarly cave which they called Mouse's Ballroom. The "Ballroom" required a section of low air that was a couple of body lengths and got down to less than 1 inch of airspace, but opened into walking passage for over 1,000 ft. Going through it became somewhat of a rite of passage for some. The cave location was never turned in and a survey was done but no map ever completed. The Missouri Speleological Survey had two leads in the vicinity, one called Six Cave and the other called Scotia Furnace Cave. The area was checked and a cave was found. It was determined that the two leads were the same cave and a

Sunset Cave. *Mark Jones*

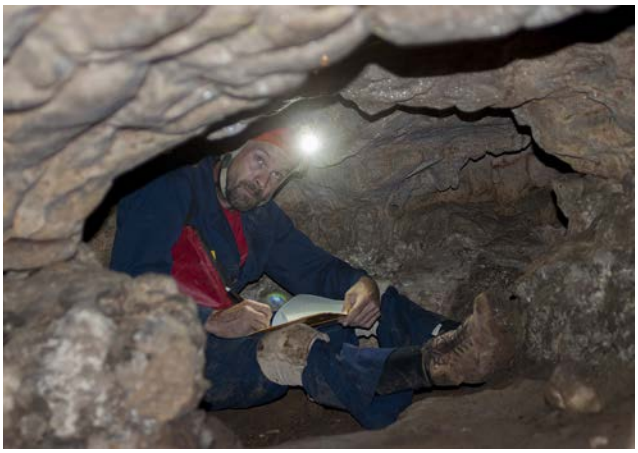
Richard Young of CRF, Susan Farrington of MDC, and AmeriCorps crew at the entrance of Peter Cave, Shannon County, Missouri. *Scott House*

Shelly Colatskie and Shawn Williams at the entrance of Saloon Cave. *Derik Holtmann*

survey was initiated. The cave appeared to "end" at very low air but obviously continued. Based upon the descriptions, it was suspected the cave, now called Scotia Furnace Cave, could be Mouse's Ballroom. One of the initial explorers of Mouse's Ballroom was brought to the cave to confirm if it was it, which was confirmed. With no one eager to go through the low air again, efforts were made to track down the original survey notes. An incomplete set was attained, though missing from it is the survey of the low section, so the notes may not be usable.

The survey of another, somewhat high profile cave bat cave along the Meramec River was also initiated in 2017.

Civil War era inscription in Saloon Cave. *Derik Holtmann*



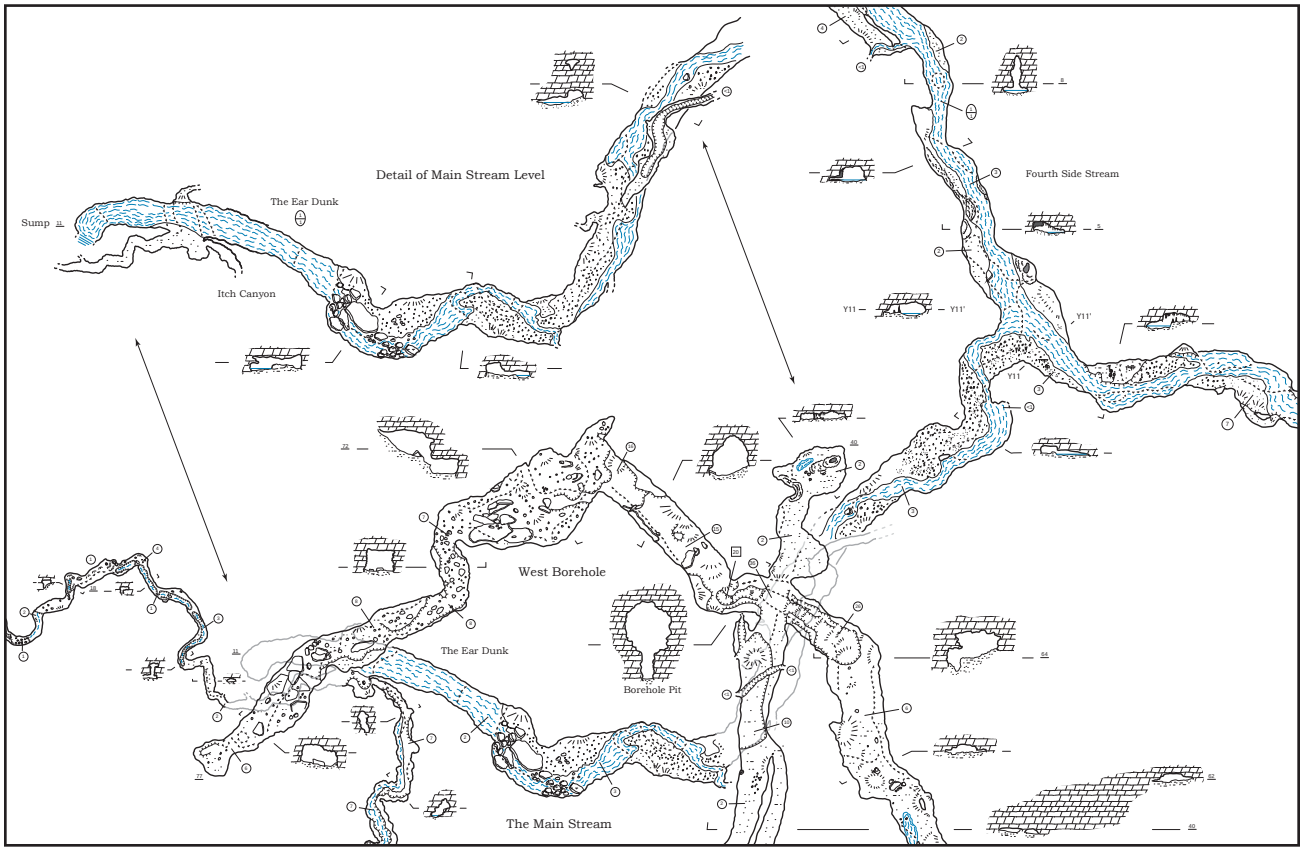
Joe Sikorski sketches in Saloon Cave. *Derik Holtmann*

Sarah Arpin reads compass and Dan Lamping sets station in Saloon Cave. *Derik Holtmann*

Thousands of people float past Saloon Cave each year as it's situated along a popular float route. The large entrance is gated due to gray and Indiana bat use. Surprisingly, no early map was ever made of this cave, despite the large, accessible entrance and mostly walking passage. Two trips went here in 2017. The first was done in conjunction with a Mossy Spring trip with a large group that created three teams and a cave biologist taking inventory. Unexpectedly, a large colony of bats were encountered, so we could not finish the cave. Later, a smaller group went back, along with the area MDC biologist and again, a smaller group of bats was encountered, so we shortened our work time there and again could not finish the cave, leaving one more short trip needed to finish mapping, large, walking passage. Interestingly, a Civil War era signature was discovered carved into the rock wall.

Lastly, a final push trip to Shop Hollow Cave was done by a group of young, skinny cavers who made it the back of low crawl, which moved considerable air. The team came to an absolute end and finished the cave. Shop Hollow is now one of the longest mapped caves in the Current River watershed with a bit less than 2 miles of passage surveyed. Likely, future trips will occur to improve profiles for the map.

Sarah Arpin sketches in Saloon Cave. *Derik Holtmann*



A detail from the Shop Hollow Cave map. Cartography by Scott House.

LAD Foundation

Dan Lamping

The LAD Foundation is the largest private landowner in the state of Missouri and operates the Pioneer Forest, a sustainable, selective harvest tree farm that covers large parts of the state. In total they own around 170 caves. CRF and the Meramec Valley Grotto have provided much assistance over the years in cave management for LAD.

2016

In 2016, six trips were conducted on LAD lands. A group visited Big Bear Cave, Little Bear Cave, and Two Flake Cave, most notably finding a sizable Indiana bat population in Big Bear Cave which was previously unknown.

A bio trip to Holmes Hollow Cave expanded the known list of cave fauna, primarily invertebrates with a diverse range of bat species also found.

Polecat Pit and Little Skunk Cave were both monitored. Neither cave had seen any visitation since they were both initially discovered and surveyed.

A new cave was found in the area of Bee Hollow and/or Island Branch Hollow, which still needs to be revisited and surveyed, along with great potential for additional caves. The cave, with a 20 foot by 8 foot tall entrance has a fair-sized entrance room and continuing walking passage.

Canyon Cave, Fern Rock Cave, and Cave of the Sentinel Tree, all three very small caves on the Big Creek, were surveyed, along with a short jaunt into nearby Plundered Canyon Cave.

Hibernating bats. *Mark Jones*

2017

In 2017 four trips were conducted on LAD lands.

Cookstove Cave and Martin Cave were both visited, in conjunction with MDC to inventory bats. As expected, bats were noted in each.

The survey of Plundered Canyon was completed. This is the longest cave on Big Creek, at 1,416 ft and has some really interesting compound cave formations growing on different axis, suggesting either seismic activity at some point or simply from formations collapsing under their own weight with additional deposits added later.

A trip to Medlock Cave along the Current River was conducted to check the gate and measure guano piles. Some bats were noted, but the cave is primarily known as a summer maternity roost.

A group with the Meramec Valley Grotto went out to the Big Creek. They monitored Plundered Canyon Cave, took photos of some charcoal remains and shared them with an area cave archaeology group. There was an attempt to visit Mossy Falls Cave, though there were concerns over safely accessing the cave due to an exposed climb on slick rock. Another group attempted to visit Bowen Cave but was turned back after noting the area outside of the cave torn up by feral hogs. They noted a strong odor coming from the cave entrance and decided to safely avoid entry. A third group visited a cluster of caves in Renfro Hollow, conducting bio inventory of four small caves which had not been visited in over a decade.

Lastly, a hand inked draft of Spout Spring Cave, a large cave on Blair Creek, was attained from the original project leader. A finished map was never completed. While the draft is also not completed, and the field notes are long gone, a somewhat usable map can be cobbled together from the draft along with a few additions from the memories of those who helped map it. The cave would a great candidate to resurvey given its large passages and profuse decorations, but right at the entrance is an ominous death rock which one much slither under. Most who've seen it have decided not to go further.

City of Perryville Project

2016–2017

Ken Grush

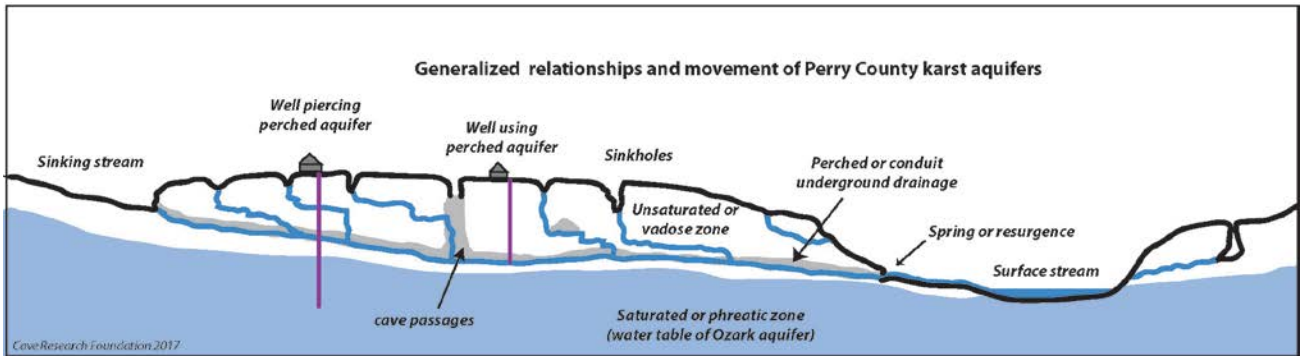
The town of Perryville in Perry County, Missouri is the county seat and has the highest concentration of caves in one county in Missouri; the current count stands at 700 caves. Only Shannon County with 685 caves in the heart of Ozark National Scenic Riverways is close to Perry County. It should come as no surprise that 83 caves or cave leads are considered part of the city project.

A little more than a third of these 83 caves have some vintage of map. Six of the mapped cave were completed in 2016 as part of this project. Crevice and Berome Moore Caves, the number 1 and 2 longest caves in the state, are part of the underground drainage through the city. Both of these caves are undergoing re-survey, see progress report of Berome Moore Cave by Chad McCain.

A Perryville cave. *Scott House*

Previous work with cavers got good cave locations during 1988, but almost no reports have been generated since. In 2015–2016 visits were made to verify the surface locations (which reaffirmed the locations) and all that have been checked have a wire basket of different dimensions to keep out trash and reduce visitation. Regrettably, no outlet can be seen at the bottom of the standpipe over the entrances of many of these caves, but many also have going passage.

Further work in the city will occur under the auspices of the city work crews who will open access and manage liability for the city while CRF crews map the caves. Working with the city previously has had positive results with the re-gating of both Crevice (2017) and Streiler City (2016) Caves. The city has been an excellent partner in this project. Their stewardship of the underground systems shines through when Mike Slay assessed the fauna diversity and found 23 species of cave life right in the heart of the city.



Perry County karst.

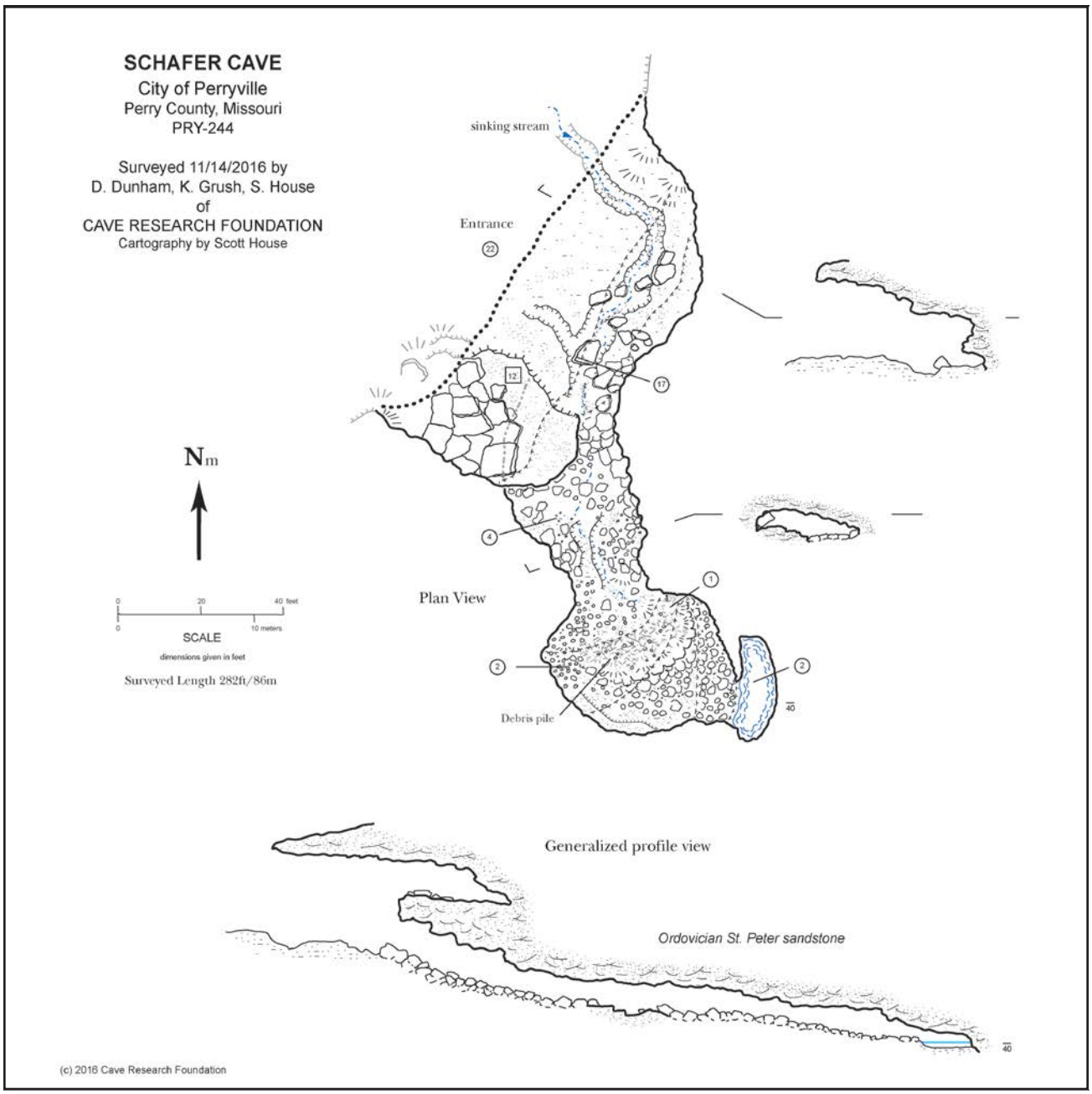
Crevice Cave work. *Scott House*

Streiler Cave work. *Scott House*

Crevice Cave gating. *Scott House*

Streiler Cave. *City of Perryville*

Crevice Cave gate. *Scott House*


SCHAFER CAVE
City of Perryville
Perry County, Missouri
PRY-244
Surveyed 11/14/2016 by
D. Dunham, K. Grush, S. House
of
CAVE RESEARCH FOUNDATION
Cartography by Scott House
sinking stream
Entrance
22
12
17
4
1
2
2
Debris pile
Plan View
Nm
0
20
40 feet
0
10 meters
SCALE
dimensions given in feet
Surveyed Length 282ft/86m
Generalized profile view
Ordovician St. Peter sandstone
40
(c) 2016 Cave Research Foundation

Berome Moore Cave Survey Project

Chad McCain

2017 didn't exactly start out with a bang in Berome, but the survey momentum did pick up after the winter meeting of the Missouri Speleological Society in Rolla. Scott House somehow talked Chad McCain into drawing this extremely loopy cave on Illustrator with help of roundtripping in Walls. Currently there are 111 loops surveyed in Berome, with 92 of those loops being actual new survey. The first survey trip of the year was on February 15, when Chad McCain and the sitting president of the Missouri Caves and Karst Conservancy, Alicia Wallace, recruited the help of local caver Mark Brewer to start surveying from the entrance passage, down into the water passage coming from the Tom Moore section of the system. Tom Moore is the upstream section of this cave, while Berome is the middle and downstream sections. Work continued in this area with the help of Lee Kraus, Brian Biggs, and Mark Jones. Many small mop-up leads were knocked out in this entrance area, as well as surveys into Breakdown Passage, the Agent Orange Crawlway (accessible only by ladder) as well as other small no-name cut-around leads.

During the May 27 weekend, which was the first actual CRF weekend at the cave, much progress was made as Jon Beard started pushing up Formation Passage with the help of Phil Goldman and Cindy Manley. Jim Sherrell, Jimmy Sherrell, and Alex Litsch knocked out a lead in Coon Passage, while Dan Lamping, Dane Driskill, Laura Belarbi, and Jeremy Weih began pushing into Upper Annex. Brett Meisel led Chad McCain, RaeAnn Drennen, and Brian Biggs into the Tom Moore section, to survey towards an elusive "handshake hole" that no one can fit through but can be connected through from both Tom and Berome. Survey in Tom continued through a breakdown passage that ended in an impossible squeeze except for maybe children under the age of 10. While survey continued to the Sherrell/Saberton entrance, that same team surveyed into Popcorn Passage, and Brett successfully found the connection point. As Dane Driskill was initially responsible for finding this connection by leaving a flashlight on the Tom side, this connection point was called the Driskill Connection.

At the June/July CRF expedition, Chad and Brian began their assault on the Mezzanine passage, which is an extensive crawling lead off of Coon Passage. Survey ended at an impossible chest compressor that Mark "Fish" Brooks had fit through so many years before. Stations were left and efforts resumed in other parts of the cave. During this time, Jeremy Weih, Chris Doerhoff, Shawn Williams, and Michael Leer continued into Upper Annex and then started surveying into the narrow Chert Vein Passage. On the next day, Alex Litsch helped Jeremy continue this survey while Jon Beard, Matt Bumgardner, Dane Driskill, and Diana Parra continued up Formation Passage.

In August, Brian and Chad returned to Breakdown Passage and successfully completed a survey loop into the Mezzanine with the help of the DistoX. In fact, most survey in Berome this year has been done with a slew of DistoX devices. Jeremy Weih took Matt O'Neal and Brandon VanDalsem back to Upper Annex and continued upstream from the Chert Vein junction. Chad McCain, Brian Biggs,

Spotted salamander. *Mark Jones*

Cave salamander. *Mark Jones*

Mark "Fish" Brooks, and Cody Brooks headed downstream to start the survey of the Maze. With leads abounding, they went back the next day with the help of Alicia Wallace, Jeremey, Shawn, and Brandon. While this was going on, Michael Freeman, Ann Eggemeyer, Pat Moriearty, and Audrey Freeman surveyed a low stream cut around near the mainstream/Annex Crossover Junction room. This was a highly successful survey weekend during which a considerable amount of survey data was obtained.

With the fall meeting of the Missouri Speleological Society being at Berome, a full onslaught was conducted on the Maze in attempts to get the multiple leads down to a few. Jeremey Weih, Brian Biggs, and Caleb Schlager were on one team. Gary Resch, Rita Warde, and Derik Holtmann were on a second team. Jon Beard, BJ Seidel, and Dave Seidel were on a third team. Mark Brooks, Cody Brooks, and Chad McCain were on a fourth team and all major loop portions of the maze were knocked out. This was essentially the last CRF scheduled expedition for the year at Berome, but it was not the last trip.

With the new length of the cave floating around 20.91 miles, Mark and Cody Brooks decided to come back up from Arkansas on October 21 to continue surveying in upper Annex. With the help of Kaitlyn Carr and Tim Morgan, they continued pushing the Annex passage closer to Popsicle Junction, which really begins setting the stage for a serious attempt at connecting the nearby mile long Dorothy Taylor Cave.

Brian Biggs organized the last trip of the year on December 9. With the help of Mark Brooks, Doug Kettler, Dane Driskill, Tim Morgan, and Aaron Graham, some hard-fought survey was obtained in Popcorn and Breakdown passages near the entrance.

16,950 feet of survey was obtained in 2017, which totals 3.21 miles of resurvey and new survey. 36 individual survey trips were conducted and the length of the cave has officially broken 21 miles. During the summer efforts, Chad McCain was able to obtain Paul Hauck's original Berome copies from the original survey efforts, as well as scrape up hanging survey data notes from Aaron Addison, Bryan McAllister, Don Dunham, and Jim Sherrell. Once all of this data was digitized, it was meticulously entered into Walls and merged into the new data set. We now know how much new survey is obtained on each trip as it replaces old data with highly accurate new data. 46,849.1 feet of survey, or 8.87 miles, has been obtained by the CRF since the Missouri Caves and Karst Conservancy purchased the cave in 2011.

Chad McCain also drafted most of new map into completion, which is currently broken up into 4 quad sheets. The only drafting that has not taken place is all of the new survey since the September expedition. As it stands about 8.1 miles of the map has been drafted to date.

Stats:

- 16,950.0 feet of survey, 3.21 miles new survey added in 2017 from 36 individual survey trips.
- 110,921.7 feet of survey total, 21.007 miles
- First survey FSB056 and the last FSB091
- 36 individual survey trips

CRF's Missouri State Park Initiative

Ken Grush

CRF in Missouri has a long working history with federal agencies like the Mark Twain National Forest and the Ozark National Scenic Riverways, but we've only begun to make inroads with the state. Previously, CRF was able to roll the state's Cave Life Database into the Missouri Speleological Society's Missouri Cave Database (MCD). This past year, a working agreement allowed CRF to capture state data on cave reporting and fauna records in caves.

Although the scope was big, the time was short. Negotiations began in 2016, but the agreement wasn't in place right away and the work didn't begin until May 1, 2017, and basically concluded with delivery of files on June 8, 2017.

The scope: CRF staff will travel to State Parks headquarters and other locales to investigate paper files containing information. Further, any electronic files containing faunal records will be examined and added to the database. Third, records from, specifically, Rockbridge Memorial State Park will be merged into the database. Activities and other priorities will be coordinated with the three State Parks natural resource specialists.

To kick off the project, I was able to scan lots of files in the central office in Jefferson City. After transcribing and entering lots of those reports, I also traveled to Meramec, Onondaga, Ha Ha Tonka, Lake of the Ozarks, and Rockbridge State Parks. High cave counts directed me to spend more time at these five parks. The different park naturalists at these parks were a big help and were able to focus my efforts again at scanning lots of material. An earlier, 2016, state park initiative was designed to map the known caves in the parks and this provided some personal insights into Lake of the Ozarks State Park.

At the end, the electronic archive consisted of 24 state parks with 228 caves, represented by over 11 thousand files and 40 gigabytes of data. Ultimately, time ran out and much work yet can be done. By far, most of the parks were not visited first hand, and perhaps more data could be collected in the field. Some files were not transcribed. The MCD gained about 300 reports and a like amount of new fauna records. Although survey was not part of the original project, the MCD recognizes about 250 state park caves and only about 170 have some vintage of map. Much more work can be done for state agencies, and the CRF agreement with the Missouri Department of Natural Resources (state parks only) shows what can be done even in a relatively short time frame.

Ozarks Cave Gating Initiatives

Jim Cooley

(with additions by Scott House)

CRF's work gating caves in Missouri for resource protection and bat habitat preservation, plus our work in gating mines and mined caves for public safety, continued to attract the attention of more land management agencies statewide. In June 2016, engineers from the Missouri Department of Natural Resources, Division of Land Reclamation came down to watch us build seven cave gates to secure mines and mined caves on the Mark Twain National Forest, all of them in or near Butler Hollow, in Barry County, Missouri.

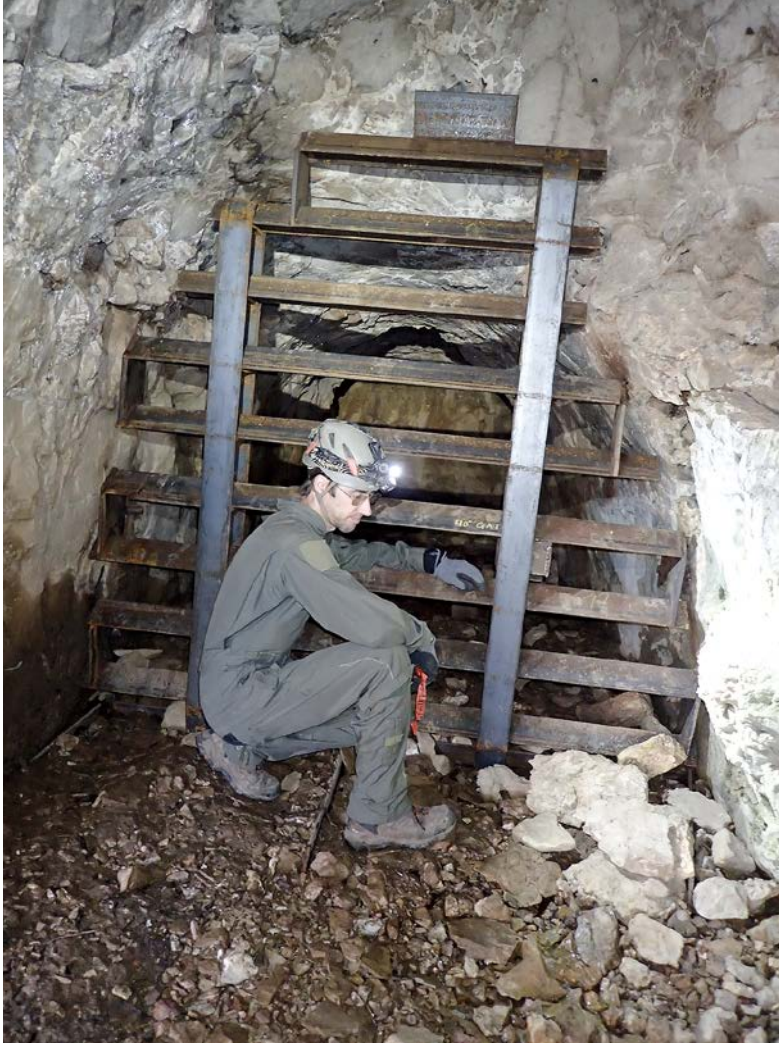
Dennis Novicky does a gate fix. *Mark Jones*

They subsequently asked us to construct four mine shaft enclosures at Valles Mines, a 4,500-acre privately owned property 40 miles southeast of St. Louis, to conserve bat habitat while protecting public safety. These four sizable mine shaft projects became our main focus in 2017. One of these cupolas covered an extensively mined sinkhole 35 feet long and 12 feet wide, requiring eight tons of steel and a week to construct. At this site, for the first time, we employed some seriously heavy equipment—specifically, a 22-ton track hoe—to do access road development and site preparation. Another project was a vertical "chute style" modified cupola enclosure, a novel design for CRF, which was required to provide large opening for an active maternity colony of gray bats. All four of these projects were constructed over pits with vertical drops ranging from 40 to 90 feet deep.

Another theme of our 2016 gating efforts was "fighting the elements." In July, CRF gating experts were called in to rescue a large gate removal and replacement project on the Ozark National Forest, in central Arkansas. Time was of the essence, as the project had to be completed by September 30, so as to not disrupt hibernation season. In this case, an accident during the demolition of the old, rusted-out gate severely injured the highly experienced private gating contractor normally used by the U.S. Forest Service on the Sylamore Ranger District. Although CRF had no previous experience with large gate deconstruction, we secured the expertise of a general contractor from Springfield, Missouri, Max White, who had extensive experience in large-scale demolition. Max, a long-time CRF Joint Venturer, knew exactly how to disassemble the tall, rusty, rickety steel gate quickly, efficiently, and most importantly, safely. After the old, dangerous structure had been disassembled with cutting torches and removed, CRF rebuilt the gate, which was over 50 feet wide and 15 feet tall. This project protected both endangered bat habitat and significant pre-Columbian cave art and petroglyphs. Then, in November, a standard, large-entrance chute-type gray bat maternity gate was constructed under the technical direction of CRF at River Cave, a large-entrance sinkhole cave at Ha Ha Tonka State Park near Camdenton, Missouri. This project rebuilt a large chute gate that had been (safely!) demolished by a catastrophic flood in July 2015. This gate secured an entrance measuring 41 feet wide by 21 feet high, offering a four-foot-high, ten-foot-wide slanted opening suitable for

gravid gray bats to navigate during their maternity cycle. During the 2016–2017 period, CRF teams also built a cave gate in Oklahoma to protect big-eared bat habitat; repaired a chain link sinkhole enclosure on the gray bat maternity colony on the Ozark National Scenic Riverways which had been smashed in multiple places by falling trees; and repaired a number of breached gates for the National Park Service, the Mark Twain National Forest, and private landowners. In addition to actual construction work, CRF gating personnel conducted on-site consultations, and when appropriate designed bat-friendly cave gates and prepared construction proposals and plans for a variety of Federal, state, and county land management agencies; the city of Kansas City, Missouri; a large Missouri show cave operator; and private cave owners. These gates have not yet been funded, and in fact, many may never be funded.

Lastly, CRF teams built gates on two caves within the city limits of Perryville, Missouri. Both were done to replace old, poorly designed gates with the idea of improving bat habitat and providing public safety. One of these was on Streiler City Cave, located within a city park. This cave is more than 3000 feet long and provides habitat for a variety of life. The other cave was the historic entrance to Crevice Cave, the state's longest. Here, a gate more than 40 years old was replaced with a new bat gate. Both of these gates were largely funded by the City of Perryville with technical labor and designs provided by CRF and MCKC (Missouri Caves and Karst Conservancy) personnel. Additional funding was provided by the TG Missouri corporation.



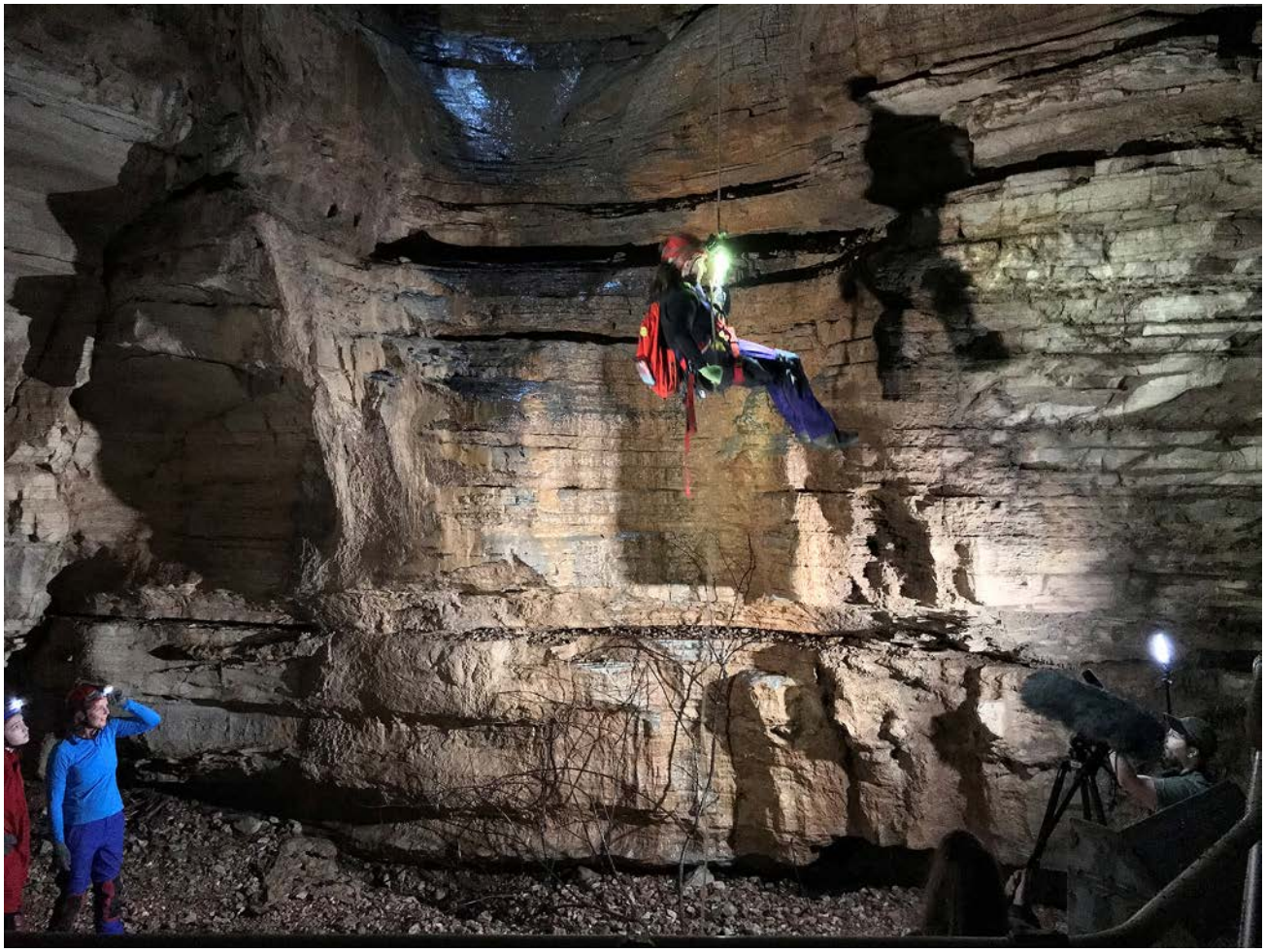
Dennis Novicky at Wallace Cave. *Mark Jones*

George Bilbrey maintaining generators. *Mark Jones*

CavesLIVE!

Patti House

For 60 years, the Cave Research Foundation has been dedicated to management, interpretation, conservation, protection, and study of caves and karst resources. In October of 2016, CRF (Ozark Operations) entered into a sponsorship with the US Forest Service, the Prince William Network and other partners to "bring learning to schools worldwide through a series of webcasts, webinars, social media and on-line resources under the *FSNatureLIVE* brand." CavesLIVE is a Distance Learning Adventure exploring the world of wonder that awaits just below the surface. In October of 2017, board member Kayla Sapkota and crew filmed a segment at Blanchard Springs Caverns in Arkansas. This video—"CavesLIVE: Bringing Caves and Karst to Light" will be available on the CavesLIVE website in February 2018. The video will help prepare students to ask scientists questions during the free, live program from Luray Caverns in Virginia at noon eastern time on March 14, 2018.



Kayla Sapkota on camera for CavesLIVE

Missouri Cave Database

Ken Grush

A demonstration of the Missouri Cave Database.

Ed Klausner

The Missouri Cave Database (MCD) records and tracks the caves of the state. The MCD is a living entity that has changed and morphed over my brief period with it. In the early 1950s, it was simply lists of caves held by the state geologist. Then in 1956, J. Harlen Bretz wrote his *Caves of Missouri* and his theory of speleogenesis. The Missouri Speleological Survey was also born in 1956 and only lost two of its three founding fathers this past year.

Early editions of the MCD were Cave Catalogs that shared a location, with minimal additional information, among the many grottos spread across the state. Computerized versions were coming around even in the late 1970s but were still just a listing, a location, and perhaps entrance dimensions. The hardcopy reports, documents, and maps were stored with a state agency, centrally located at Rolla. Perhaps two dozen, five-drawer file cabinets and additional flat files held the collective knowledge of caving throughout the state.

In the 1990s, computerization and software packages became available and many different paths were tried. I can't say when the first edition of the current MCD began. I retired in 2011 and first became aware of our electronic MCD. Then, cooperators throughout the state received a scaled back version of the master copy of the MCD, a run-time. A caver in southwestern Missouri might have the whole SWMO collection of counties and cave data. That caver would take responsibility for all the caves of the area and record all new entries. A less experienced but active caver might get a county to manage, or perhaps just a quadrangle to investigate and collect data on the local caves.

The first copies of the MCD that I saw were run-time also, but they covered the whole database. In early 2013, the MCD consisted of 6768 caves that were being tracked. The main table of the database includes separate tabs for directions, entrance dimensions, hydrology, geology, culture, descriptions, biologic notes, and connections with other tables that tracked maps and full-text written reports. We had over 3000 reports and 3500 map records that were entered and could be searched for key text or text strings. By early 2014, we had gained a few caves with the total at about 6870 caves, but reports in the database had more than doubled. A lot of historical reports were being added by many cooperators throughout the state. Then in 2015, we distributed full FileMaker software packages of the MCD to the many key people around the state for data collection. The full FileMaker software is more stable than the run times for the volume of date and makes it easier to export data for easy entry into the master copy. The MCD started that year with 7000 entities and 10,000 reports and 3500 plus map records. However, this year another metamorphosis came to the database. Fauna records, in light of WNS, became much more significant. How will this disease affect the cave biota? Can we track its impact? To start, there were previous faunal record collections and the MCD also always had a tab for biology notes. WNS demanded a new approach, tables of single observations by cavers of a single species on any given day. Scott House and others had always fostered the MCD, but adding 20,000 fauna records in a brief span was quite a remarkable addition. However, these were not the only addition to the MCD.

Monitoring forms had always been part of the CRF mandate on working with federal agencies. Now, in 2015, they became part of the database. Monitoring addresses many issues of public use and biologic change. A simple form provides an opportunity to "red flag" for management like significant changes to the cave: new graffiti, vandalism, camp fires, and unusual sightings. The year 2015, began with 30 or so reports with some 2014 forms but also many from the annual CRF-MLK event held on the Ozark National Scenic Riverways and now in the joint Mark Twain National Forest (ONSR-MTNF).

To borrow from the MSS Liaison (now available online to the public): "At close of the year, the Missouri Cave Database, MCD, has 2705 monitoring forms (for agency work like DNR, MDC, MTNF, ONSR and others), 5353 map records (not quite the same as caves with maps), 15375 reports, 31137 faunal records. By comparison, in January of 2017, the MCD had 2361 monitoring forms, 5111 maps records, 14078 reports and 26197 faunal records."

We are electronically archiving the database. The Rolla cave files, the many dozens of file drawers still hold the MSS archives, but we are also building an electronic database of scanned reports, photos, newsletters and other publications. Although we stand at over 300,000 files and 760 GB of data, there is still much more to do. Thank you and kudos to all of our volunteers and cooperators.

Meeting House Bolt Removal

April 9, 2016

Tony Schmitt

Cave Research Foundation, Ozark Operations

Personnel:

- Jim Ruedin
- Matt O'Neal
- Laura Ibáñez
- Andreu Gàzquez
- Edward Estrade
- Victoria Fernández
- Tony Schmitt

We arrived at the Flat Rock area around 10 a.m. Andreu and Tony went up the back side to rig ropes on the bluff from the top. Jim, Laura, Vicki, and Matt went around to the front side. We had radios to communicate.

Andreu and I arrived above the cave at the same time the crew arrived at the bottom. They directed us to the upstream side of the cave bluff where I had remembered a couple of routes from our trip last year. Soon we had two ropes rigged on two routes.

I went down to check positioning of ropes, and access to the bolts. I went down and assessed from the bottom, and then climbed up with a 9/16 ratchet. I was able to remove all of the bolts, hangers, and quick links except for one at the very top. The bolt was stripped in the hole, and would not remove despite my best attempts.

Andreu's route was a bit trickier, as it went on an angle up the rock face. He had to rig into the bolts and traverse the route at an angle to remove the bolts. He was able to remove all of them, except his top one, which was stripped as well.

We then turned our efforts to removing the two bolts and carabiners on the downstream side of the cave, up on the ledge, that were just out of reach.

Andreu rigged the rope over the face of the cave. Edward was able to reach one of the bolts and snapped the rope into it. Andreu was then able to pull himself over to the bolt. He clipped into one of the bolt. This allowed him to reach out to the other bolt, remove the carabiner, bolt, and hanger.

We then rigged a short tag line into a protrusion in the wall, which allowed us to stand on stacked rocks, reaching the other bolt. The carabiner was removed, but unfortunately the bolt itself would not budge. We did not have an impact driver; we were using hand ratchets. On the way back to the cars, I noticed another route. This one will have to wait for another day. I could see at least three bolts, and two at the top with carabiners hanging in them.

We were able to remove the lowest bolt by climbing onto a ledge. I also found a figure 8 rappelling device at the base of this drop.

The route in the ceiling is still there.

We did locate another route on the bluff, upstream of the cave about 500 feet, they will be difficult to remove due to cliff overhang. The rope will hang out from the bluff face about 10 feet.

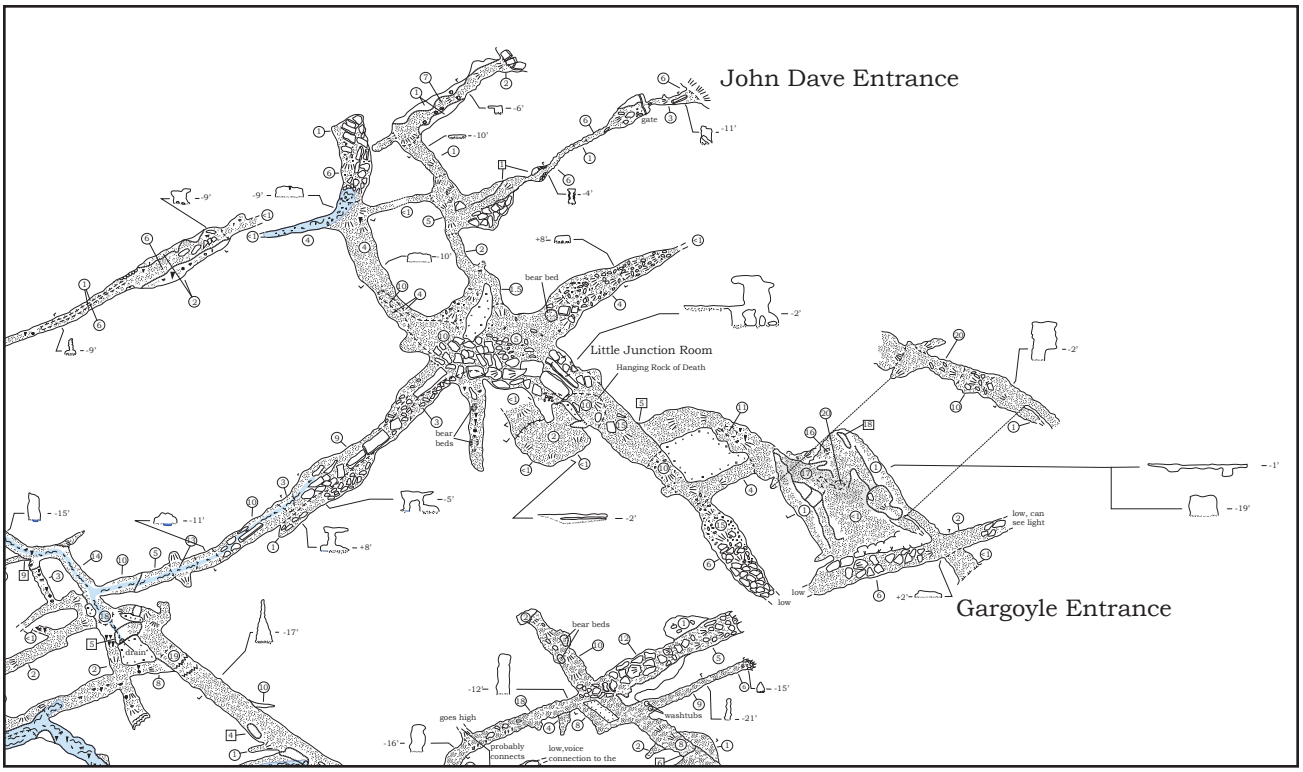
Oklahoma Ozarks Operations

Mark Jones

Clayton Russell in Three Forks Cave. *Mark Jones*

The seed for the CRF Oklahoma Ozark Operations was planted in the Fall of 2016 when Jim Cooley was called upon to design a bat gate to replace an obsolete barrier in Three Forks Cave in Adair County. After Dennis Novicky had the new gate in place a tour of the cave was offered by the landowners. Over a mile of passage had been surveyed down through the years, but a newer map was desperately needed to represent the higher standards of today. Beginning in the Fall of 2016, a group of cavers began systematically surveying and inventorying the cave. After each expedition, Ed Klausner would update the map for the project. In addition to the geological aspects, this cave has important biological activity.

As word spread about the significance of the caves in eastern Oklahoma, it was proposed to include this work under the umbrella of the Ozark Operations. An agreement with the landowner was developed to include the survey through the CRF. Currently Three Forks Cave has 1.5 miles of passage with another mile of cave estimated remaining to be surveyed. The goal is to complete this survey before addressing numerous small caves nearby as well as other caves in the area. There are many opportunities to assist in this work, and anyone interested should contact Mark Jones about participating in an upcoming expedition or answering any questions related to the project.



A detail from the Three Forks Cave map. Cartography by Ed Klausner.

Sequoia / Kings Canyon National Park: Redwood Creek, Lilburn Cave, and Mineral King

2016 Annual Report

Jennifer Hopper and Fofo Gonzalez

General Observations

- On our second year as project managers, we still faced situations that have prevented the full implementation of our plans for our project area.
- In April of 2015 the National Park Service issued the Wilderness Stewardship Plan and Final Environmental Impact Statement. The results were better than anticipated, but there is now a counter that resets every third year, and which could decide the fate of the fieldhouse for Lilburn Cave. This plan has not been enacted yet.
- The drought in California continues, and we are enduring the driest year in memory in Redwood Canyon, Kings Canyon National Park. The February expedition, normally a snowshoe trip, found a completely dry canyon, without any snow. There has been no running water at the fieldhouse, and we have had to resort to bring part of our own water and to hike a mile downhill to the one reliable spring to collect water, a hard and time-consuming task.
- A prescribed burn in the canyon forced us to cancel one expedition.
- The exploration project in Lilburn Cave is still moving at a very slow pace because of the type of leads left in the cave and the lack of major breakthroughs in the cave. We did, however, find a new passage that brought us to an upper level in an area where there were no mapped passages.
- The cave specialist for the park has recently left, and the position is currently vacant. As soon as a new cave specialist is named, we will establish a relationship with that person.

Wilderness Stewardship Plan

- In April of 2015, the Wilderness Stewardship Plan and Final Environmental Impact Statement was published by the National Park Service.
- The main concern regarding our project was the situation of the cabin in Redwood Canyon, since, being a man-made structure, there was a possibility for the removal of the cabin, due to its location in a wilderness area.
- Results were better than expected; the cabin will stay. However, the current plan calls for a revision every three years to assess the need for a cabin in the wilderness to support research in the cave.
- Some major changes will be required in the immediate area surrounding the cabin. The water reservoir will remain, but not the water system or reserve barrels. All exterior structures will be removed. The picnic tables will be missed but won't affect the operation in a substantial way. Losing the wood shed will be a burden, and we don't know if we will be able to stockpile wood, which would in that case be exposed to the elements. The major loss will be the outhouse, and we are discussing with the park the benefits of having a single enclosed place for human waste, instead of the proposal by the park to use cat holes that would disseminate human waste through the forest in a much wider manner. For larger group trips, the park could ask us to carry human waste out, which could also negatively affect participation in the future.
- The park expects to be sued on the plan, and in that case, the legal proceedings will delay its implementation, so we could be a couple of years away from the official starting date of the document. The infrastructure reduction would take place within a year of the official implementation date.

Cave Management

- We have managed to abide by the stricter qualification guidelines for cavers entering Lilburn. In the past, some people with no caving experience or who had not been vetted by other Lilburn regulars went on Lilburn trips. This qualification procedure has the ultimate goal of preventing any major incidents due to the possibility of an inexperienced caver being injured.
- The communication platform for the group has been met with enthusiasm by the park. Now the cave

specialist for the park can see in real time what the results from each expedition were. Furthermore, expedition leaders and joint venturers can access information and files pertinent to our project area from any computer connected to the internet.

Cave Data Management

- The Chief Cartographer, Dr. Jed Mosenfelder, has been updating the cave atlas with the latest survey information.
- Our goal is to create an up-to-date document that we can share with the park and can serve as a snapshot of the cave map as of 2016.
- The new laptop at the fieldhouse has been met with enthusiasm by trip leaders. Writing trip reports is much easier now, and we can now do searches for specific topics in the trip reports.
- We have been updating the information in Google Drive, which allows for faster sharing of information and controlled access to different parts of the file system. This also creates a more permanent storage solution, since no one person controls the information.

Cartography Project (Jed Mosenfelder, PhD)

- The total length of passages surveyed in 2014 was 342.6 feet, for a total length for the cave of 21.81 miles. For 2015 the total length surveyed is 390.19 feet. For the present year we have so far surveyed 210 feet, the vast majority of it in new passage.
- The main goal and also the main challenge in cartography is to expand the group of individuals working on the cave map. Having a single person responsible for all updates on the cave map has proven very ineffective due to the magnitude of the responsibility and the limited time that is normally available for any single person to work on it.
- We have enlisted the help of people with good knowledge of computer systems to aid in finding a method that will allow for multiple individuals to work on a map without causing the issue of having different copies of a cave map floating around, each with their own set of updates.

Other Projects

Isotope Geochemistry and Carbon Cycling in Epikarst of the Sierra Nevada (Jessica Oster, PhD; Corey Lawrence, PhD)

- Very unfortunately, Dr. Oster has decided to discontinue the research project in the canyon, due mostly to the cumbersome approval process and apparent constant questioning of her research by the park which made her feel unwelcome. We are in talks with her, and we hope to find a way to negotiate a solution that will be agreeable to Dr. Oster and the park.

Structural Geology and Lilburn Cave (Marek Cichanski, PhD)

- This project will evaluate the role of structural deformation on the karst and its surrounding non-carbonate rocks.
- Dr. Cichanski has conducted field trips and he has just extended an invitation to a consortium of geology researchers to attract their interest to the Redwood Canyon area.

Phreatic Passage Development at Lilburn Cave (Fofo Gonzalez)

- This project will evaluate the upper parts of the many canyons at Lilburn, mapping the location of phreatic tube development, which would constitute the primordial state of Lilburn. The results should be added as a layer to the Lilburn Cave Atlas, showing the location and extent of phreatic tubes.
- No major work has been done in 2016, but work on this project may resume in 2017.

Passage Restoration at Lilburn Cave (Bill Frantz)

- Not much has been done this year either because of the drought. Only a few sites were evaluated: The Glacier, Jefferson Memorial, Blue Passage, and Ice Formations. These areas are still doing well, without any extraneous mud cover on them. We hope to finally have more water in the canyon in 2017, which would be more conducive to restoration activities in the cave. Bill is always looking for areas to restore and would like to hear of any.

Mineral King Caves (Marcia Rasmussen)

- The higher elevation areas in the Mineral King section of Sequoia National Park are home to several small caves and karst features. They are accessible only for a few months every year, and this project requires strong hikers, doing ridge walking at elevation.
- A short term goal for the project is to finalize the maps of White Chief Cave and the Area of Thousand Entrances. Multiple marble pockets are yet to be explored, and this project will extend for many years into the future.

Hurricane Crawl Survey (Carol Vesely)

- For such a famous cave as Hurricane Crawl, it is surprising that the surveyed sections of the survey are not up to standard, and that there are still promising leads to be surveyed. Carol Vesely will work with Joel Despain in getting a research proposal ready to continue surveying at Hurricane Crawl.
- Unfortunately, 2016 was a very busy year for Carol Vesely, and so far, no trips have been conducted. We will work with Carol in organizing an expedition calendar for 2017 so that work can be started in this major California cave.

Slide Creek/Eleven Range Overlook (David Angel)

- Joel Despain proposed this area for a CRF project. The access is difficult, most likely requiring ropes, and the terrain is difficult to move through. Cavers are experienced in this kind of terrain, and some caves have already been located in the area. This project will do a thorough search of the area, locating caves to at a later date survey them.
- One trip was conducted in this area. Unfortunately the terrain proved to be extremely challenging, and the GPS data for the known caves and karst features was not accurate; nothing was found and the leader for this project wanted to have a second trip having someone who had been into the caves in the area before (Joel Despain), and once the base data of the known features has been established, then further trips will be planned.

Ursa Minor (Joel Despain)

- This project will focus on geomorphology research in the cave (sediments, bedrock features and water samples), as well as on continuing the cartographic study of the cave by pushing leads in the upper levels.
- A research proposal has been submitted, with a May 1, 2017 starting date, three proposed trips for 2017, and a total of three years for the project.

Other Possible Projects

- ***Monitoring of Stage at Big Spring (Jennifer Hopper).*** We are running field tests of the data loggers and Bluetooth data collection systems, since we are using equipment designed and created specifically for this project.
- ***Sedimentology of the Redwood Canyon Karst (John Tinsley).***
- ***Map Showing Karst Features of Redwood Canyon (John Tinsley).***
- ***Ebb-and-Flow Potentiated Air Flow Changes at Lilburn (Howard Hurtt).***

All these studies already have some history or need to be evaluated and re-shaped.

Educational and Cooperative Efforts

- Touch table. Multiple donations were made by CRF members and California grottos, of items related to caving and specifically, caving in Lilburn to be displayed for park visitors at the visitor center. This project is ongoing and will include historic and recent photographs of work done in Lilburn as well.
- We plan for possible work on educational posters regarding karst areas and the importance of caves and the surrounding flora and fauna.

Plans for the Future

- We want to have a higher degree of cooperation with the park. We will establish a relationship with the new cave specialist for the park once one is named.
- There are several areas in the park that have not been researched, and multiple existing caves other than Lilburn have a high potential for projects, even for continuing leads that were never explored. The CRF should be involved in more areas of the park, not just Lilburn Cave and Mineral King. These discussions are ongoing, and we are creating a plan for expanding our scope beyond Redwood Canyon and Mineral King.

A heavily impacted pool that we hope to restore in the coming year. *William Tucker*

Tammy Tucker picking lint from alongside the visitor trails. *William Tucker*

Carlsbad Caverns Restoration Work

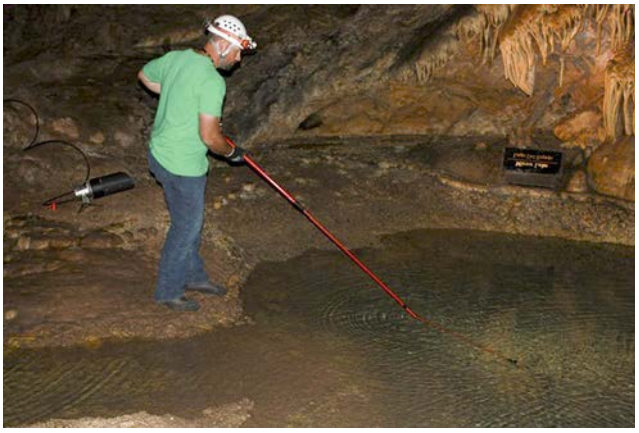
William Tucker

In February, on Presidents Day weekend, we started two new projects. These had been proposed months earlier and had been approved by the park. The two projects were Billing Doves Tunnel and two large pools near the Top of the Cross amphitheater.

Billing Doves is heavily impacted with tracked clay from the old dirt trail system. Obvious trails exist, and the pools are also heavily impacted with clay. We hope to restore it as closely to natural as possible, tackling the pool last. We worked on this project on Presidents Day weekend, Memorial Day weekend, and at Restoration Field Camp in June. More work still needs to be done, and we have not tackled the pools yet. This may be put on hold for a while, though.

At Top of the Cross, two large pools contained a large number of tossed stones which were clearly out of place as well as a thin, dark film which was believed to be decomposed lint. We started by using waders to retrieve as many of the tossed stones as we could. This one step was a great improvement, but we decided to persevere with a different method. Using a small, blow-up, vinyl swimming pool, we pumped all of the water from the smaller of the two pools, cleaned the bottom, and filtered the water as it was returned to the basin. The dark film came off easily and proved to be decomposed lint. Several pounds of lint were removed from the filters, basically, a single large zip-lock bag of the stuff. Rod was impressed and wanted to see us do the same thing to the larger pool. It will be much more difficult to use this same technique as it has over 2200 gallons of water in it, and there are few good options for holding all of the water at once. Using a pump through a filter is going to be the technique on the larger pool, but it too may have to wait.

During Restoration Field Camp in June, we completed several smaller projects as well as working on Billing Doves and Top of the Cross. We spent one whole day walking the trails to retrieve coins and trash. Over $5.00 worth of coins was retrieved mostly from the pools and mostly pennies. Several bags of trash and other detritus, some of which was nasty like a good amount of spit tobacco, was removed from the cave. We also worked on reflagging the trails in the lower cave and cleaning the bridges and removed several pounds of lint.



Jimmie Worrell removing coins from Mirror Lake. *William Tucker*

Labor Day weekend was a bust, but it turned out to be a good thing. Several people canceled at the last moment because of the hurricane in Texas and the inability to get gasoline. Tammy and I went anyway, and we walked the trails with Rod Horrocks. He wanted to try to convince us to work on a pool which he considers to be the top priority. The pool in question is loaded with algae. It is a large pool and is very visible from the trail. We are still working on the logistics of how to tackle it. We are calling it the Celery Stalk pool because of its proximity (just across the trail) to the Celery Stalk formation at the exit of Jim White Tunnel. We also identified 21 other projects, mostly pools, some of which can be accomplished in a day or a short weekend, and others which will involve a longer effort. We are anxious to get started on these projects. The biggest hold-up is housing availability.

We have reserved several three-day weekends in 2018 including: Veterans Day, Presidents Day, Memorial Day, and Labor Day. We had hoped to do a weekend or two at the end of 2017, but housing is just not available. We will try to do a few other weekends in 2018 as well as a weeklong expedition which has yet to be planned, but it will probably be June or July.

Lower Cave Section of Carlsbad Cavern 2016

Ed Klausner

Lower Cave can be entered a number of ways from the Big Room at Carlsbad Cavern. The easiest is a series of permanent ladders that are accessed from the tour trail in the Big Room. A number of leads remained that seemed easiest to reach by ladder. A long extension ladder would be very difficult to get into Lower Cave, but a folding/extension ladder that could be broken into three sections proved to be easy to bring into Lower Cave and carry to the leads.

Over the course of three days, Elizabeth Miller, Chris Beck, Karen Willmes, Mark Jones, Dwight Livingston, and I checked eighteen leads. The ladder was not long enough to reach one lead, eleven leads did not lead to passage long enough to survey (they were sketched in) and six were surveyed. We only got 275 feet of survey in these high leads, but that is often the case when only small or high leads remain in an area. Figure 1 shows one of these high leads near Kooree's Recess. Tour trail is depicted by the orange dashed lines, the red cross is a first aid cache, tt is "too tight" and tf is "too fragile". Figure 2 shows Mark Jones climbing to a high lead near the Col. Boles Formation. The map segment of this survey is shown in Figure 3. The portion surveyed by ladder is above the word "Formation."

With the ladder leads done (a successful expedition in itself), there were still plenty of leads left in Lower Cave. Most did not have enough passage to survey, but a few did, making the map more complex.

One lead was noted as small, and there could possibly be a connection to the King's Palace 300 feet above. The entrance to the passage was small (Figure 4), but the passage became bigger past this constriction. There was no connection that we could find, but the area is now surveyed with 127 feet of new passage.

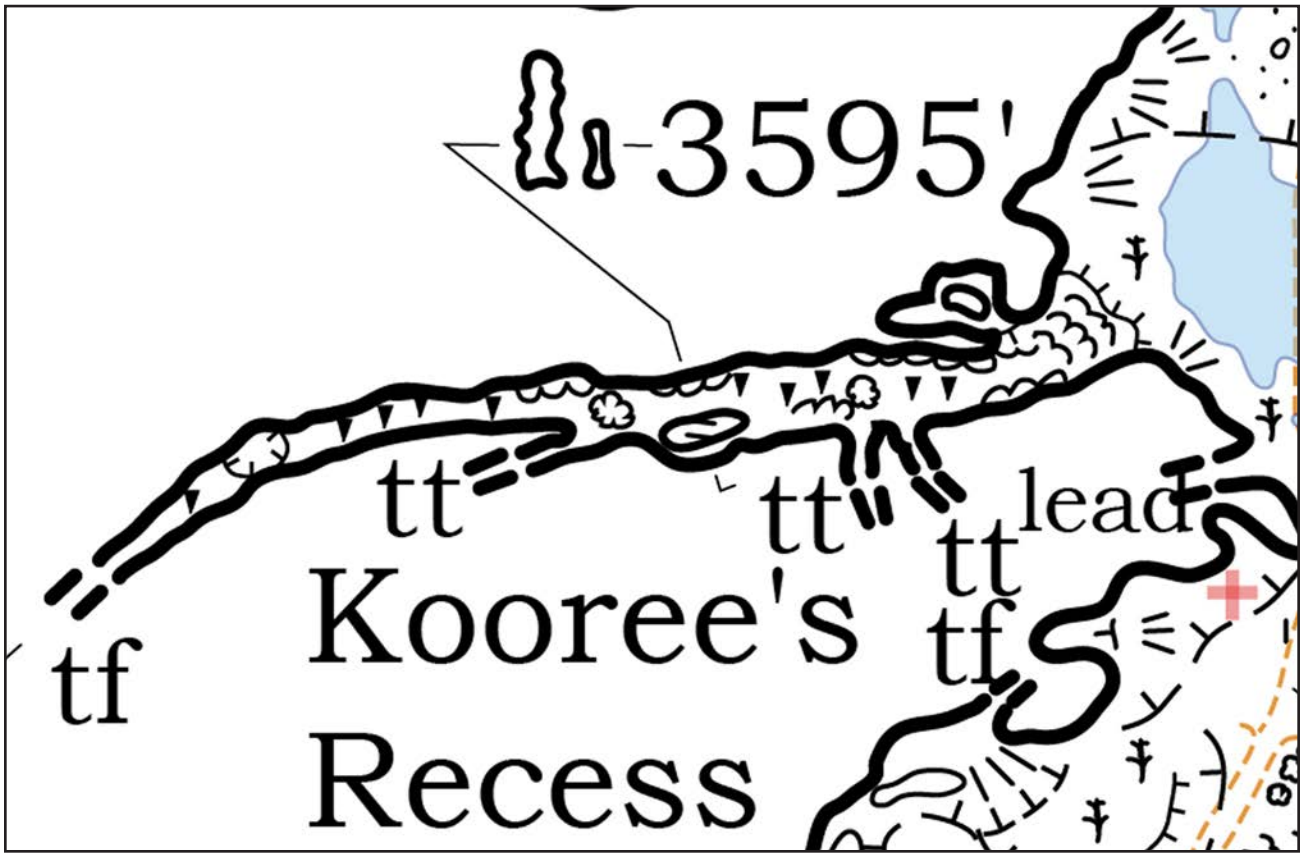


Figure 1.

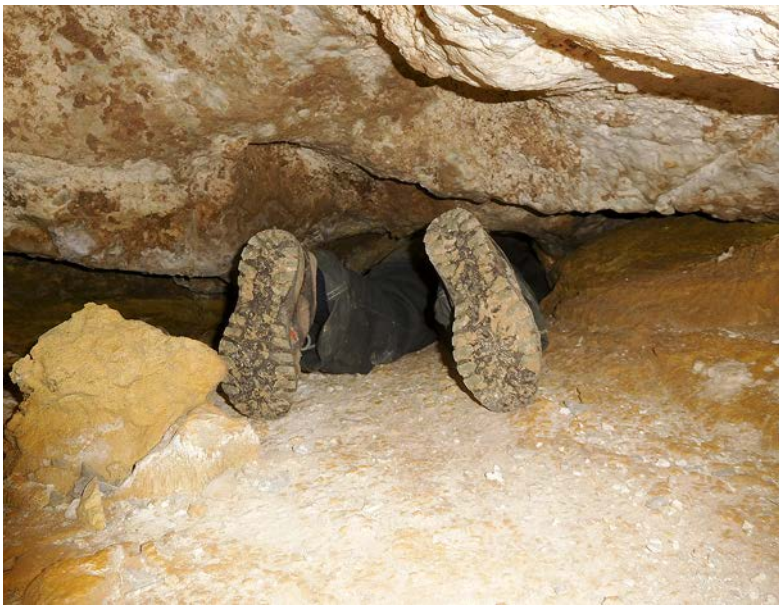


Figure 4. Karen Willmes' boots in a tight spot of Lower Cave. *Ed Klausner*

Figure 2. Mark Jones entering the lead near the Col. Boles Formation. *Ed Klausner*

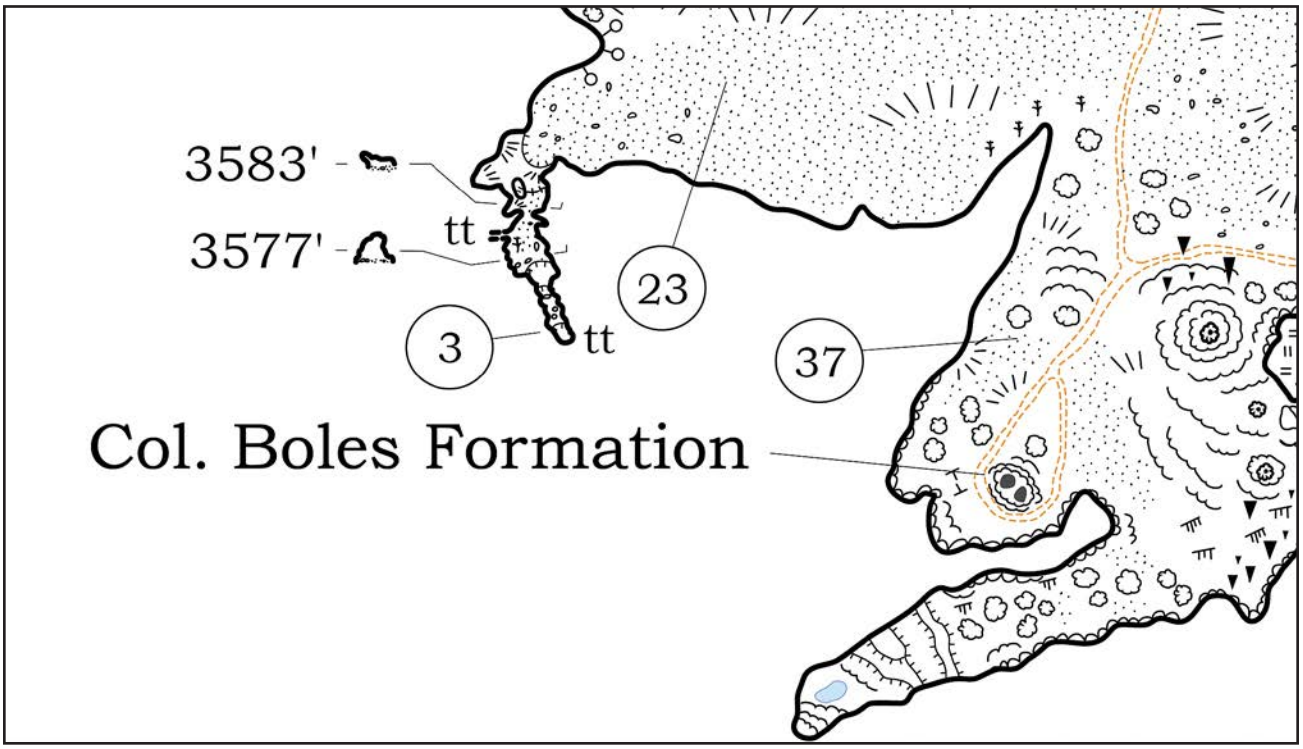


Figure 3.

Slaughter Canyon Cave Survey Completed (Almost)

October 21, 2016

Dave West

Elizabeth Miller ferries waders in the Pool Room. *Dwight Livingston*

The Cave Research Foundation began working anew in Slaughter Canyon Cave in 2008, producing a pencil draft of the main body of the cave. In late 2012 I was asked to complete the survey and produce a more finished map. Expeditions have been made at least annually since then, the most recent from September 28 through October 5, 2016.

Seven of us gathered at the housing facility provided by the Park on September 28 to begin work on both Slaughter Canyon Cave and Carlsbad Caverns' Lower Cave. In addition to Ed and I, participants were Elizabeth Miller, Karen Willmes, Mark Jones, Chris Beck, and Dwight Livingston. The goals in Slaughter Canyon were to finish the loop through the Pool Room, examine and survey remaining high leads, obtain two cross-sections at specific points in the cave to align with profile views, and gather additional detail for the various profiles in the cave.

On Thursday the 29th, Dwight and Mark would attempt a climb up to a ledge in the Subterranean Disaster Passage, while Karen and I would don chest waders and survey the Pool Room and beyond. While I was still sketching the Pool Room, Dwight and Mark appeared to advise us that the ledge seen high in Subterranean Disaster was only two feet wide with no passage leading off from it. I suggested they go to the end of the Monarch Passage and attempt to reach the remaining high lead there, which was partially rigged from our expedition last year. At the end of the day, Karen and I had finished the Pool Room, and the passage that continued in the same joint, but we had stopped at a climb

Black Forest. *Dave West*

to a crossover passage. Dwight and Mark did reach an upper chamber, which they surveyed, leaving a passage that continued back above the Monarch Passage for later.

Friday the 30th found Dwight, Elizabeth, and I back at the Pool Room to complete the work there. Dwight and I took turns with the large chest waders as Elizabeth acted as the wader ferry for us. Once beyond the pool, we surveyed to the top of the climb and over to the tight spot at the end of Mole's Run, through which none of us fit, although others obviously had. The area was well trafficked from past visitation. We then surveyed the Mole's Run extension to its terminus and called it a day.

On Saturday, October 1, Elizabeth and I focused on obtaining additional detail for the profile views of the Monarch Passage, Black Forest Passage, Subterranean Disaster, White Sands, and Fossil Avenue.

Sunday, October 2, found Dwight and Mark again teaming up as climbers. They used the ladder to gain access to a small chamber above Santa's Basement, which they surveyed to a hole that dropped back down into the passage below. They then went to the Tom Tucker Room southwest extension to investigate a climbing lead. Meanwhile, Dave and Karen obtained the necessary cross sections, and added detail to the profiles of Mole's Run, the Tom Tucker Room and both of its extensions. Dwight and Mark had determined that the lead they were investigating could not be free climbed due to numerous formations along the right wall, but that the left wall, which was bare rock, could be bolted. The day ended as Dwight and Mark carried down one of the ladder sections, now unnecessary, to the parking area, where it was hidden in the brush, as our vehicle could not transport it.

On Monday, October 3, I borrowed Ed's Rav4, which has a roof rack, and followed Dwight, Mark, and Chris to the parking area to retrieve the ladder brought down the previous day. The three of them went to the lead at the

Flowstone at the end of the Pool Room. *Elizabeth Miller*

A shallow pool in Mole's Run Extension. *Dwight Livingston*

Ceiling Pocket above Santa's Basement. *Mark Jones*

end of the southwest Tom Tucker extension, and Dwight bolted up to it. It was found to go only about four feet before ending. A couple of survey shots got it tidied up. They then carried all the remaining ropes, climbing gear, and the other ladder section down the hill. The ladder was stashed in the same place used the previous day, and they returned to camp, where I was entering data. Chris and I went back to the parking lot in Ed's Rav4 and retrieved the remaining ladder section.

Tuesday, October 4, was our last work day in the park, as several of us had flights to catch on Wednesday. Dwight and Mark returned to the high lead at the end of the Monarch Passage where they surveyed 120 feet of passage which they named the Tiger Passage, as many of the formations presented a banded appearance.

And we thought the survey was finished! But as I was drafting the week's work, I realized that the passage surveyed from Santa's Basement was not the lead I had expected to be surveyed. Mark and Dwight had identified a lead that we had overlooked. They had been able to look from it through a four-inch hole to open space but were unable to reach it. This coincides with where I thought they would have surveyed, so it appears there is more work to be done. In addition, our survey of the joint in the Pool Room does not seem to extend as far south as the previous map, so we may have missed something here as well.

The 32-foot ladder and the chest waders have been removed from the cave and donated to Resource Management for use by others in the park. During this expedition we invested 126.8 hours of field work plus 14 hours of administrative work. The total survey length of the cave stands at 20,920.9 feet (3.96 miles) with a depth of 242.8 feet. Over a thousand feet of unvisited passage has been discovered and documented during the project. The map to date will be forthcoming in the next month or so.

Flowstone in Tiger Passage. *Mark Jones*

Banded stalactites in Tiger Passage. *Mark Jones*

Lower Cave Section of Carlsbad Cavern 2017 Progress

Ed Klausner

The goal for the 2017 expedition was to work on the leads remaining in Lower Cave, most of which weren't expected to lead to much, if any, survey. In the end, a few did lead to a nice bit of survey (i.e., more than two stations.). This is typical for mopping up leads before a final map can be produced. I was joined by Elizabeth Miller, Karen Willmes, Chris Beck, Mark Jones, Kayla Sapkota, and Jenn Ellis in June. Also present were Dave West and Dwight Livingston, who worked on their individual projects. The survey team members were switched each day, so the surveyors could see different segments of the cave.

The LDD survey is in a confusing area known as the Central Boneyard as it is a three-dimensional maze. The first lead resulted in 41.9 feet of new survey before it tied back to the previous known survey. The second lead was more of what I expected. It was far too tight after 8 feet,

Mark Jones lead checking.

Jennifer Ellis checking a lead in the Central Boneyard (it went). *Mark Jones*

Ed Klausner near Mabels Room. *Chris Beck*

Ed Klausner sketching in new survey in Lower Cave.

Mark Jones

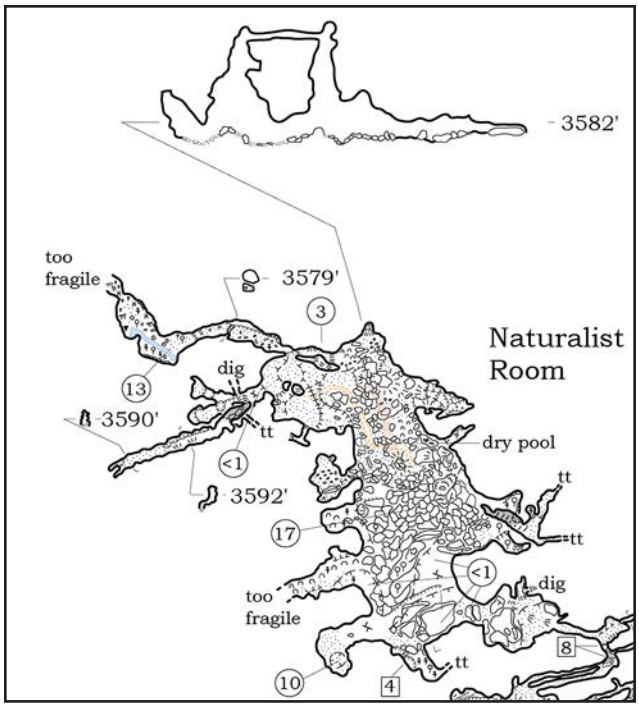


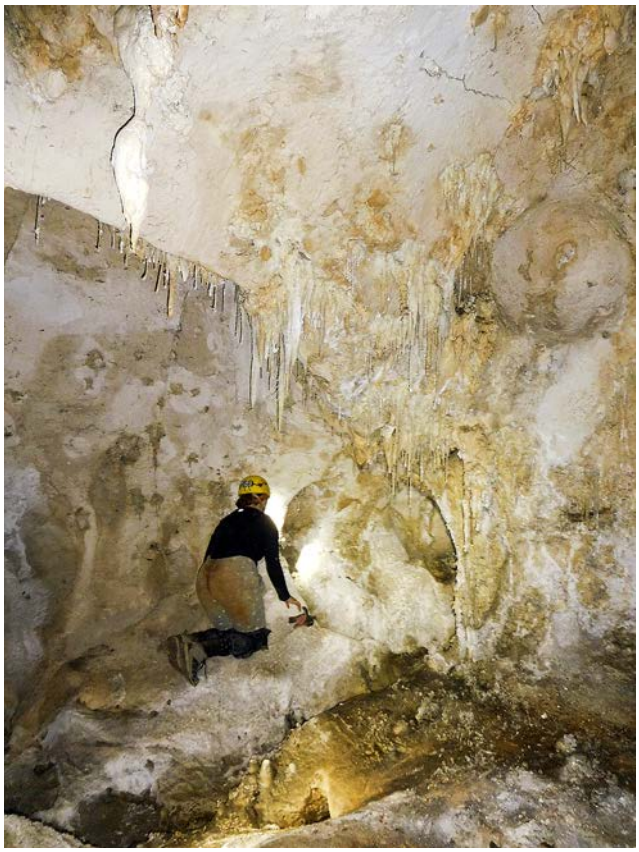
Figure 1.

but at least it can now be added to the map with an indication that the passage becomes too tight. The next lead was accessed from the Lower Cave Long Loop. There was one area that was too delicate to go through, but fortunately, the passage was also accessible from the next lead, and we were able to tie these two sections together with a disto shot from each end.

A decent sized passage was found towards the end of one day, and there was no trouble getting surveyors interested in continuing the survey the following day. Unfortunately, it only went a bit over 100 feet before getting too tight.

One of the objectives was to re-sketch the Naturalist's Room (Figure 1). From a past trip, I noticed that the original sketch did not do the room justice, and it needed to be re-sketched. We spent a day doing this.

Before the trip started, there were 92 leads, 18 areas that needed to be resketched, and one cross section that was needed. At the end of the trip, 37 leads were surveyed or crossed off the list with 8 of them being put into the "next generation" lead list, 7 of the needed resketches completed, and the one needed cross section completed. We added 597 feet of new survey to Lower Cave.



Kayla Sapkota checking a lead (it went about 20 feet).

Ed Klausner

Slaughter Canyon / Music Room Expedition

June 11–17, 2017

Dave West

Expedition Leader

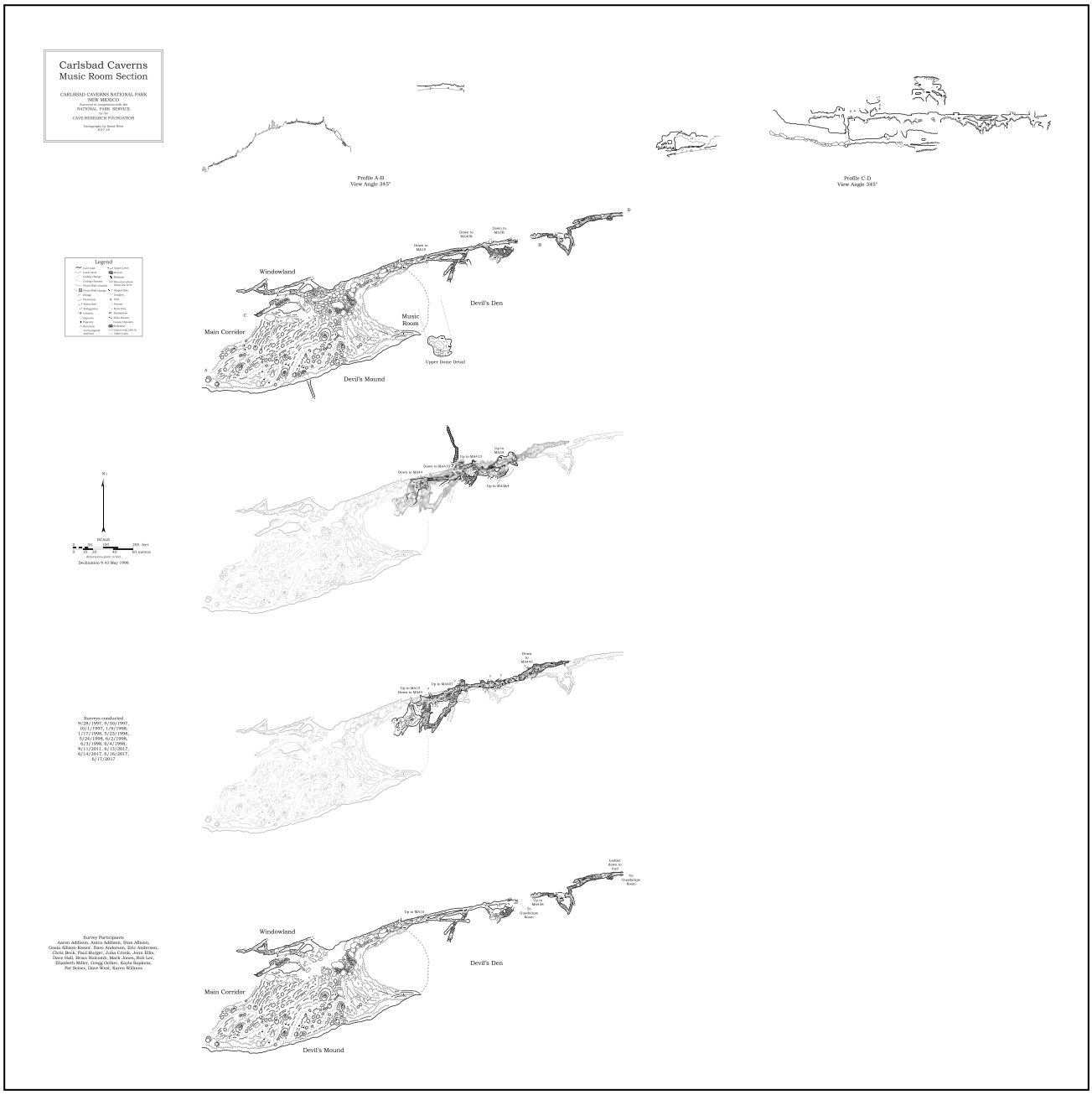
Karen Willmes and I arrived in Carlsbad a day early, as our flights on Saturday (my 69th birthday) were over $100 less expensive than they would have been on Sunday. Pat Seiser agreed to put us up for the night, giving us the opportunity to meet Erin Lynch, from whom we picked up the apartment key the following day. After signing out assorted survey gear, ropes, and webbing, we began settling in at the apartment. Ed Klausner, Elizabeth Miller, and Chris Beck arrived later that afternoon, and Mark Jones in the evening.

On Monday Mark Jones joined Karen and me on a trip to Slaughter Canyon Cave. Once inside the entrance, we were greeted by a buzzing sound, which originated from a small group of honeybees on the ceiling above us. We proceeded to Santa's Basement to clarify the lead situation there. We determined that the lead Ed and I thought might go didn't, and the one Ed and I had thought wouldn't go had been surveyed by Mark and Dwight Livingston last year. The map has already been drawn up and can be considered finished.

After the trip, we returned to the apartment and had lunch. Then Karen and Mark went to the Lunch Room in Carlsbad to meet up with Ed and the others on his Lower Cave project, which will be reported on separately. I met with Rod Horrocks to get started on the Music Room section in Carlsbad. After obtaining digital copies of the Compass data and survey notes for the MA survey, I returned to the apartment to see what I had gotten myself into. I quickly determined that although one individual's sketches were esthetically attractive, they had repeated inaccuracies that I felt made them unreliable. Shading was used for both breakdown and ledges, and it wasn't always clear which was which. The cross sections did not match the plan view, frequently being smaller or larger than they should have been. Cross-section ledges did not align with the plan and were sometimes shown in cross section but not at all in the plan. I decided to resurvey anything previously sketched, which unfortunately is a large portion of the section. The other surveys appeared usable and will be re-evaluated as the survey continues. Kayla Sapkota and Jenn Ellis arrived in late afternoon to help with the expedition.

On Tuesday Mark, Elizabeth, Karen, and I headed on into Carlsbad, but on arrival at the work area, my memory and Karen's memory were not in complete agreement on what we had done for Scott House's Main Corridor survey, of which I did not have a copy. We returned to the surface to consult with Ellen Trautner of Resource Management in an effort to obtain a copy of that work. This proved unsuccessful, and after a short lunch break, we returned and began a resurvey at station MA3. My plan is to survey

Dave West sketching in the Music Room. *Mark Jones*



the area in continuous levels to present as clear a picture as possible. The original survey was done in seemingly haphazard pieces that didn't connect well. I suppose that if the sketcher had also been the cartographer, he would have been able to produce a map, but I found the disconnected pieces hard to piece together. We resurveyed from MA3 to MA6, and included an un-surveyed portion off of MA3 and a tie to MA34 before calling it a day.

On Wednesday Mark, Kayla, Karen, and I continued surveying from MA4 through an un-surveyed route to MA36, tying to MA37 and MA414 before returning to MA34 to get the shot to MA35. Then from MA6, we continued to MA8, tied it to MA32 and ran a line from there out to MA24, utilizing an old NN4 station. Observing that the area in which MA9 is located has been "Closed for Resto," we elected to ignore it. We placed MA8A, MA9A, and MA9B to keep the survey on the "trail" in the highly decorated Upper Balcony area. We also tied to MA21 before sketcher burnout set in, and we headed out.

On Friday, Mark, Chris, Jenn, and I went to the cave hoping to finish the survey of the immediate upper level. We started by finishing the Upper Balcony, then tied in

MA10 and MA25, surveying up the small dome there. Then we started closing loops, many of which had been previously "sketched in." The tie from MA33 to MA8A is new, as is the tie from MA32 to MA6. MA32 was also tied to MA37 instead of MA31, which no longer is necessary. Returning to MA414, we replaced the string from MA28 to MA31, and took a side shot into an un-surveyed narrow canyon. We also made a new tie from this string to MA37. Having finished this portion of the upper level, we returned to MA3, shot back to MA2, and surveyed a chamber behind the drapery that forms a near wall there. The only upper level leads that remain are described from MA36, with three potential ways to go. The climb is exposed, and we need to evaluate whether a ladder might be useful.

Saturday Mark, Karen, and I returned to the area at MA3B and began a survey in this apparently un-surveyed area. We surveyed a canyon here with leads going down and northeast. We then surveyed back under a flowstone mound and into the canyon surveyed by Paul Burger and Stan Allison, tying into their station MA402, noting three additional leads along the way. There remains much to do in this area. We needed a short day in order to start packing and cleaning up the apartment, so we left a bit earlier than had been usual.

All members of the Cave Resource office were very helpful during this visit, and we appreciate their efforts in making the expedition possible. We look forward to our next visit, probably in April 2018.

Chris Beck getting inventory in Music Room Boneyard.
Mark Jones

Jenn Ellis checks a lead in the Music Room boneyard.
Mark Jones

Jenn, Chris, and Dave surveying Music Room boneyard. *Mark Jones*

2017 Mystery Room Survey in Carlsbad Cavern

Dwight Livingston

This 2017 expedition was part of an effort to survey and map the Mystery Room, an 800-foot-long chamber in Carlsbad Cavern, located adjacent to the Queens Chamber. We fielded two teams (Dwight Livingston, Nick Socky, Mark Minton, Yvonne Droms, Bob Alderson, Kristen Anderson, and Mark Jones) for 5 days, completed survey for all known areas except one 500-foot passage off the lower boneyard, flagged off trail boundaries, took a lot of pictures, and found no new passage. Roughly 3500 feet of total survey was added to the 4900 feet done from 2007 to 2010.

The Mystery Room contains no paved tourist trails, lights, or other improvements, and apparently never did. It has been heavily visited, with foot trails worn in most areas and station markers for at least 4 other surveys scattered throughout. Despite the traffic, most features are clean and apparently unchanged since the cave was discovered.

A tour starts with a ladder climb and a rigged traverse across a window that overlooks the Queens Chamber tourist trail about 30 feet below. Vertical gear and volunteer vests can be removed at the top of this traverse, just before one descends a worn aragonite free-climb. At the bottom, a flagged trail heads west and climbs a hill. As one climbs, the chamber bore grows larger, and the floor tilts upward on the left. A side trail on the right leads down to a small lake where, if you stand quietly, you hear the rumble of water somewhere beyond, a throb like the sound of distant

Nick on traverse. *Mark Minton and Yvonne Droms*

Dwight in the Dr. Seuss Area. *Kristen Anderson*

Yvonne on traverse. *Mark Minton*

Cable Pit. *Mark Jones*

Dwight in the aragonite bushes on the main slope.
Bob Alderson

Mark Jones at bottom of climb-down. *Kristen Anderson*

machinery. The source of this noise is a mystery, in fact the mystery for which the room is named. Back on the main trail, one climbs past white, cabin-size pieces of breakdown, each phreatically smooth and shapely, and somehow standing proud and unbroken after a 30- to 40-foot fall from the ceiling (perhaps the chamber was filled with water at the time, allowing a gentle descent). Past the breakdown, the hill crests as the trail hugs the left wall. Tall stalagmites, smooth and ghostly white, populate the hill top. These are maybe the most striking and appealing features in the Mystery Room. Some of our team likened them to something drawn by Dr. Seuss. Whatever the inspiration might be, I think they do need a name, something by which they can be noted on the final map. Too soon these stalagmites end, and the broad floor begins to descend. We see Cable Pit on the right, with a 2-inch-or-so-diameter pipe lying across the slot, a pipe with glass insulators that was perhaps borrowed from an old lighting system to rig a descent (we don't know its history). Past the pit, the slope gets steep, and the trail starts to switchback, here on phreatic bedrock, there on shockingly bright red and orange clays. It enters stands of aragonite bushes and finally, after dropping 150 feet in 250 horizontal feet, reaches its terminus. Here at the

HA7–HA8 handline climb. *Yvonne Droms*

Calibrating distos. *Bob Alderson*

Bob sketching. *Mark Minton and Yvonne Droms*

western end, the ceiling drops sharply, and the room is at its widest, about 250 feet across. There are three regions here. The south side is a low-ceiling forest filled with aragonite columns and pinched to a thin edge choked with straws and flowstone. The center region is breakdown, large blocks tens of feet across that have formed a 3D maze, most of them coated with clay, flowstone, and aragonite. The north side drops into a large canyon passage that runs east-west about 330 feet, with its western-most end in the Batacomb, a room containing more than 40 mummified bats.

Survey began about halfway down the big western slope. One team continued the H survey down along the south side of the slope and worked the southern forest and central breakdown. The other team started a new HA survey and did the northern side of the slope, the canyon passage and the lower boneyard. Both teams surveyed with DistoX2s, usually with a pair of them. We calibrated three of the Distos using a calibration frame and the program Topodroid. We'd seen Brian Pease show us how to shim a DistoX2 body with electrical tape in order to align the body with the laser. Such work allows one to do accurate body-aligned calibrations, which should be quicker, more consistent, and doable in daylight. Our method was effective, and we all had fabulously calibrated Distos for front and back shots. It was a pleasure getting excellent numbers all week. Our frontsight and backsight mismatch was almost always under 1 degree without even trying. Each evening, after entering data, we found the loop closures were looking great, much better than the earlier 2007–2010 numbers.

Our first encounter with the Mystery Room impressed everyone. I was surprised, even elated. It is an elegant room and a lot of fun. We soon found the last stations of the 2010 H survey and split up into our teams: me, Nick, and Kristen in H team on the left; the two Marks, Vonny, and Bob on the right. I found it tough to start sketching in that big space, without a wall in sight, but after a couple of hours, I had enough down on paper to feel better. Both teams reached the bottom of the main slope. We only worked on plan-view sketches and left the profiles and cross sections for later when we had a better idea of where they should go.

Monday, we met with Rod Horrocks, Physical Scientist, and Erin Lynch, Cave Resource Technician. After picking up where we'd left off the day before, the H survey soon found the south wall. We surveyed back uphill, almost to the top of the big slope, and connected to an old H survey station. We then surveyed down along the south wall. At the end of the day, we made a couple shots northward to close up with the HA survey. The HA team surveyed down into the canyon passage and headed east, up into a low

Formation gallary above H26 with Kristen Anderson.
Nick Socky

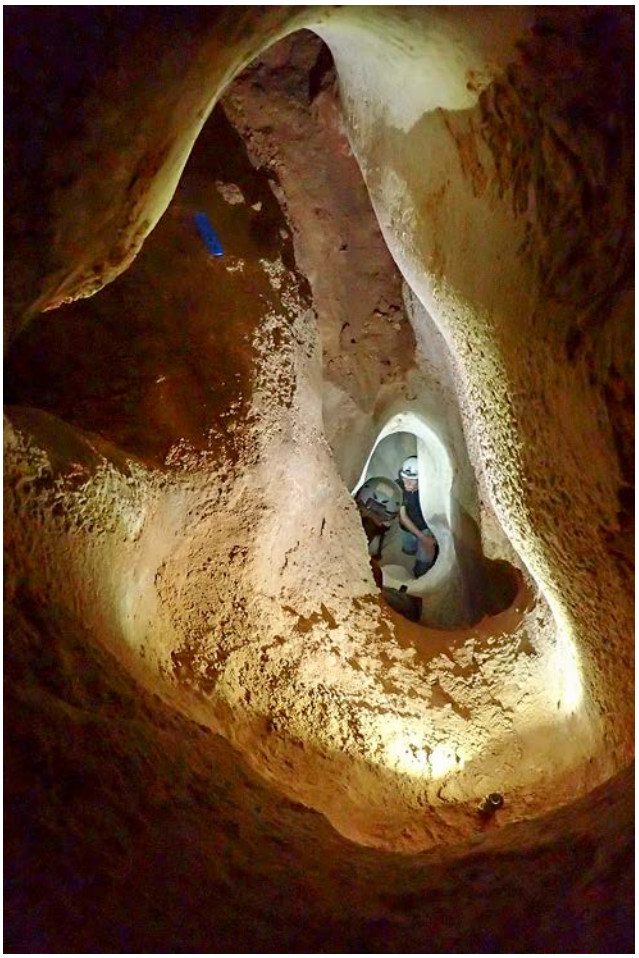
room full of formations. Mark Jones found a small dried out pool with pool fingers. The canyon passage then went down a very steep slope to a pool of water, its walls covered with mammillary formations. Past the lake, the passage went up slope steeply and ended in a flowstone choke. Returning back to the climb-down, the HA team surveyed into the lower boneyard, where they pushed many holes. Mark Minton found a "J. Matlock 4—66" scratched in the floor.

Tuesday, the H team, now fortified with Mark Jones, continued to survey along the south wall, pushing into holes among the low thickets of straws. Only one lead remains there, not especially viable. It goes through two squeezes and ends twisting downhill with two 3-inch tight spots in sight, and no air. The survey rounded along the west wall and, for the last couple of shots, entered the central breakdown region. On the north side, the HA team first surveyed on the main slope, among the aragonite bushes, to fill in against an area already covered by the H team and finish the main room. They then picked up where they left off in the lower boneyard.

Wednesday, the H team continued in the breakdown region. We cleaned up a few small holes, surveyed back through breakdown to the main room, then completed the survey along the west wall through a back route to the canyon passage, where we connected to the HA survey again and completed the Mystery Room perimeter. In the last hour, we surveyed another route through the breakdown. The HA team finished cleaning up in the lower boneyard. They worked particularly hard to find a passage near HA37 that is shown on the 1988 working map but is not included in the old survey data. Either it is reversed on the map or doesn't exist. They also pushed to find passage shown at HA49 both in the old map and the data. A lead there does continue but goes very low, and no one could fit. The HA team left the lower boneyard and surveyed

Yvonne at Mammilary Lake. *Mark Jones*

more of the canyon passage, heading west this time. Here again, the 1988 map shows some passage that neither team could find, again not in the data (we suspect this one is the same western canyon passage rendered twice). After the 5:15 rendezvous, we laid more trail flagging on the way out and studied what looked like ropes hanging in a high shelf, what we later determined is Mabel's Room.



HA28 boneyard. *Mark Minton*

Ellen surveying at H98. *Yvonne Droms*

Thursday, the H team, now without Mark Jones (who left Thursday morning), began to survey a large space on top of the breakdown, a shelf with a lot of flowstone and aragonite bushes. We connected through the breakdown in a few places and finished with a dive into the breakdown at the north end. The HA team completed their survey of the canyon passage west, back into what we named the Batacomb, where they found at least 42 mummified bats. They turned around to fill in parts of a main profile sketch and completed a canyon passage profile up into the main room. They also completed a cross section at the base of slope.

Friday, Bob Alderson left us, and Ellen Trautner, Physical Science Technician at the park, joined the expedition. We all descended into the lower boneyard to have a short tour and to look for the passage at HA49. After a bit of poking about, Ellen found the way through, in a different hole than that which is shown on the 1988 map. Kristen and Nick followed, but it was too tight for us regular folk. We had planned a short day, not enough time to survey the whole passage they found, so we left the whole thing as a good day trip for little people when we return. Back up in the canyon passage, we split into two teams, Nick leading an HA team with Vonny and Kristen to survey a lead he'd found two days earlier in the breakdown, and the H team of me, Mark Minton, and Ellen back up into the north end of the breakdown. The H team reconnected in a couple of shots. This was Ellen's first time using a DistoX2 in the field, and now they are on her shopping list for the park. On our way to a remaining lead, we heard the other team through a hole that a couple of days before Nick had made accidentally when the floor collapsed under his foot. Both teams made a few shots to connect through this hole, then the H team found their last lead. This connected in a few shots back near the rendezvous column. Meanwhile the HA team had completed their lead and arrived as well, so we headed out.

Mummified bats. *Yvonne Droms*

Nick on shelf. *Bob Alderson*

The resurvey is largely complete, but a number of tasks remain for the next expedition. Though we found no new viable leads, there remains the passage in the lower boneyard to resurvey, and that may contain leads. A couple of profiles through the breakdown will be useful. I would like to drop Cable Pit and visit Mabel's Room to check on details. Drafting a map will likely produce clean-up tasks, perhaps in places near the eastern end that I have not yet seen. In particular, there is a station in an alcove on the northern wall that would be good to visit to check the climb. There are various shelves near the Queens Chamber that might be climbed as well.

Science

Mike Slay from the Nature Conservancy pointing out cave life to Elizabeth Miller and others at the CRF Annual Expedition in Buffalo National River, Arkansas.

Ed Klausner

The Sand Beetle Feces Community in Great Onyx Cave, Mammoth Cave National Park, with Particular Reference to the Cave Pseudoscorpion *Kleptochthonius cerberus*

David Griffith

Department of Biological Sciences, Ferris State University

In 2015 I decided to return to the study site where I originally studied the interactions between the sand beetle *Neaphaenops tellkampfi* and the cave cricket *Hadenoecus subterraneus.* The main purpose of my research was to investigate the biology of the cave pseudoscorpion *Kleptochthonius cerberus* (Figure 1), as well as the community to which it belongs. Poulson (1975, 1977) published two reports on the sand beetle community that depends on the feces produced after the consumption of the beetle's primary food, which is the egg of cave cricket *Hadenoecus subterraneus* (see Poulson, 2017 for a recent summary of terrestrial cave communities in Mammoth Cave National Park). Some representative members of this community include Lyniphyiid spiders (Figure 2), diplurans (Figure 3), and mites (Figure 4). In this report, I am going to present preliminary results of my research on this small and graceful arachnid, and other members of its community.

Figure 1. **Kleptochthonius cerberus**

Figure 2. **Anthrobia monmouthia**

Figure 3. **Litocampa cookei**

Figure 4. **Rhagidia cavernarum**

Figure 5. **Kleptochthonius *eating a 1st instar* Hadenoecus.**

Kleptochthonius cerberus is a small pseudoscorpion (1.94 mm in length, Malcolm and Chamberlin, 1961) typically found under rocks in sandy deep cave terrestrial sites. Occasionally, they may be seen on flowstone that is covered with cave cricket guano. The original description of the species came from three specimens collected on flowstone in Whites Cave in Mammoth Cave National Park. After several trips to Whites Cave and Great Onyx Cave, I concluded that *Kleptochthonius* can be found with more consistency in the sandy environment of Great Onyx Cave. My main study site is located near the end of Edward's Avenue in Great Onyx Cave (see Griffith 1991 for a detailed description and a map of the site).

Anecdotal Observations of Predation

Two instances of predation by pseudoscorpions in the wild were observed. In the first case, a pseudoscorpion was eating a first instar cave cricket nymph (Figure 5), and in the second case, one pseudoscorpion was cannibalizing another. Both pseudoscorpions were found under rocks. The feeding experiment below suggests that pseudoscorpions do not normally eat cricket nymphs, but I hypothesize that the pseudoscorpion may have captured the larva as it emerged from the sand. The cannibalism observed was surprising, since pseudoscorpions in general are not known to be cannibalistic (Weygoldt 1969). Poulson's 1975 report (Figure 14, page 35) has a figure showing a pseudoscorpion (presumably *Kleptochthonius*?) with a collembolan (springtail) as its potential prey. Although springtails are a common food of pseudoscorpions (Weygoldt 1969), I found only a single collembolan in the past two years at the main study site. Future observations and experiments should help settle this issue (see below).

Community Census

A series of censuses of the invertebrates found in Great Onyx was begun in 2015. Rocks were overturned by hand and examined, and the presence of any organisms was recorded. Searching was initially systematic, with virtually every rock examined in some areas, but the size of the research site (~340 meters in length) made it impossible to search all areas with equal effort. So far, many *Kleptochthonius* appear to be located in the vicinity of an area called Bubbly Pit, although areas at the end of the passage have not been examined thoroughly yet. Results of the census within Bubbly Pit are presented in Figure 6. Bubbly Pit is a vertical shaft complex that is believed to be an exit route for the cave crickets when they leave the deep cave site to roost near the entrances, from which they emerge under the right conditions to forage for food (Lavoie et al. 2007).

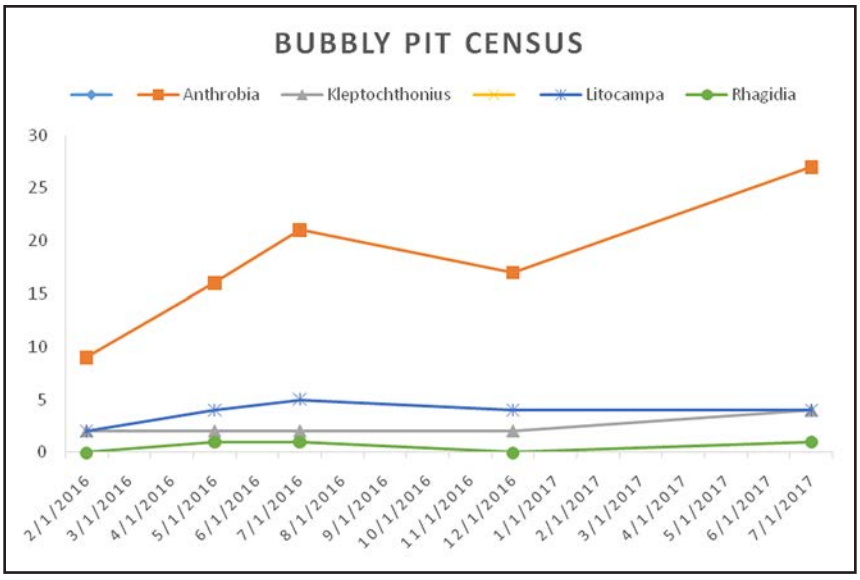


Figure 6. Results of the Bubbly Pit census beginning from February 1, 2016.

Results of the census may be found in Figure 6. Although it appears that the number of spiders (*Anthrobia*) are increasing over time, more counts need to be performed to establish a pattern. In the future, a detailed map is going to be prepared of Bubbly Pit and the surrounding area, and the distribution within the passage will be measured. Additionally, size categories will be estimated of all invertebrates encountered during a census.

Predation Experiments

To determine trophic relationships within the sand beetle feces community, a pilot experiment was conducted in July of 2016. Different potential prey were placed in closed containers (15.2 cm × 12.7 cm) with two or three *Kleptochthonius* and checked periodically over the course of the next four days. Table 1 shows the basic design.

The selection of prey was based on availability in the field at the time of the experiment. All organisms involved were collected in the vicinity of Bubbly Pit, placed in containers (Figure 7), and left in the cave for 3 days. Sand from the cave passage was placed in each container (arena). A rock was placed inside each container to provide cover for the pseudoscorpions (observations of wild pseudoscorpions showed that they always went underneath rocks as soon as they were exposed). All survivors were returned to the site where they were collected at the conclusion of the experiment.

Only two of the seven potential prey items were missing at the end of the experiment. One *Litocampa* was missing from arena 1, and one *Anthrobia* was missing from arena 2. It is possible that they may have escaped, but a careful inspection did not reveal any possible escape routes. Direct observations of individuals within arenas showed that the cricket nymphs changed their direction of movement and ran away from the pseudoscorpions when encountered. Interactions of other species with the pseudoscorpions were not observed during the course of the experiment. The results, combined with the single field observation of cannibalism, suggest that the pseudoscorpions may consume each other. Poulson (personal communication, December 30, 2017) recently told me that springtails (*Pseudosinella argentea*) may be found underneath the rocks outside of Bubbly Pit. Preliminary searches have revealed many more pseudoscorpions (a total of 38 *Kleptochthonius* were found on one day) among the rocks that are across the path from

ARENA	Predator (*Kleptochthonius*)	Potential prey
1	2	2 *Litocampa*
2	3	2 *Anthrobia*
3	2	1 *Phalangodes*
4	2	1 1st instar Hs; 1 2nd instar Hs

***Table 1. Design of arena experiment. Hs* = Hadenoecus subterraneus.**

Figure 7. Arena used for the predation experiments.

Bubbly Pit, but so far I have seen only a single springtail in the entire area in two years. There are many more rocks in this area outside Bubbly Pit that may provide shelter for pseudoscorpions, and future trips will examine this area in more detail. Further experiments will be necessary to determine the trophic relationships within this community.

Conclusions

Right now I have more questions than answers about the sand beetle feces community. The areas outside Bubbly Pit need to be examined in more detail. Possible exclusion experiments may be possible to try to determine the effect of pseudoscorpions and spiders on the community. Ultimately, laboratory experiments on the feeding and reproductive biology of pseudoscorpions, combined with field experiments should reveal the secrets of this community.

Acknowledgments

The Cave Research Foundation provided many valuable resources during this research. The following persons assisted in the field: Melody Avery, Gordon Birkhimer, Michael Ciczerski, Katie Gorman, Neeka Grimm, Austin Hermann, Brandon Herrmann, Hillary Sadoff, Bill Steele, Mark Schweizer, Mary Schubert, David Simmons, Derrek Von Nieda, Jake Tholen, Rick Toomey, Kurt Waldron, Matthew Weir, and Dean Wiseman. Ferris State University generously provided funding. Rick Toomey of the National Park Service was particularly helpful in supporting my research. Special thanks to my wife, Jeannette, for taking notes in the cave and for taking the time out of her busy schedule to drive with me on all of my trips.

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Philip M. Smith Graduate Research Grant Recipients

2016 Grant Recipients

Oana-Alexandra Dumitru ($2800)

Ph.D. Candidate
School of Geosciences
University of South Florida

Five-Million Years of Sea-Level Variability in the Western Mediterranean using Cave Deposits from Mallorca

Abstract—How quickly sea level rises ranks as a top priority in the Earth sciences. Because over one-third of the world's population live along coastlines, even a slight rise of sea-level would have a substantial economic and societal impact. For this reason, there is a critical need to precisely predict how quick the sea-level will rise in the next decades and centuries. Past sea-level changes provide considerable insight into Earth's tectonic and climatic history, and is of great importance to predict possible scenarios of rising seas. Of particular interest are the intervals of warmer-than-today climate, like the Last Interglacial and mid-Pliocene Warm Period (3.3 to 2.9 Ma). Over the past 5 million years repeated flooding events caused by sea-level rise in caves along Mallorca Island's coasts left distinct carbonate encrustations called phreatic overgrowths on speleothems (POS). Preliminary data show that POS are suitable for absolute dating by using U-Th-Pb methods and they proved to be a valid and precise sea-level marker. All POS located 15 m or more above present sea-level returned preliminary U/Pb ages between 1 and 5 Myr, suggesting warmer-than-today climate, when sea-level rose due to significantly shrinking of northern and southern hemisphere ice sheets. Our aim is to precisely establish the timing, position, and duration of sea level high stands in western Mediterranean over the past 5 million years, using (POSs) from caves of Mallorca.

Jorge Luis Pérez-Moreno ($2600)

Ph.D. Candidate
Department of Biological Sciences
Florida International University

Evolution in the Underworld: Molecular Insights from Subterranean Waters

Abstract—The unique characteristics of aquatic caves and of their predominantly crustacean biodiversity nominate them as particularly interesting study subjects for evolutionary biology. Cave animals usually undergo various distinct physiological, morphological, and behavioral changes, which together are commonly referred to as "troglomorphy." Troglomorphic modifications can be classified in either progressive (enlarged sensory and ambulatory appendages, increased numbers of chemoreceptor setae, or enhancement of spatial orientation) or regressive (reduced pigmentation, reduction or loss of visual functions, or decreased metabolism) phenotypes, with cave fauna typically presenting a combination of both. The use of current and emerging molecular techniques, e.g. next-generation DNA sequencing, bestows an exceptional opportunity to answer a variety of long-standing questions pertaining to the realms of biogeography, population genetics, speciation, and evolution. I propose to use modern molecular methodologies to examine colonization patterns of caves, phylogeography, evolution, and functional adaptations within a variety of species within the sub-phylum Crustacea. For these purposes, phylogeographic and transcriptomic studies will be undertaken to investigate adaptations of troglomorphic cave life. With these, the present study will result in the discovery of evolutionarily significant patterns among cave fauna, and the underlying mechanisms that permit the survival and evolution of life in extreme environments such as caves.

2017 Grant Recipients

Samantha Feist ($2,000)

M.S. Candidate
School of Geography and Earth Science
McMaster University

Understanding Sediment Pathways in Hidden River Cave, Kentucky

Abstract—Examining sediment transport in cave systems is difficult due to the complex nature of karst systems, and it is not as well understood as surficial systems. Cave sedimentology studies explore sediment transport and deposition within cave systems. The objectives of this study are to better understand sediment transport in karst cave systems by examining the sedimentological record in Hidden River Cave in Horse Cave, Kentucky. Hidden River Cave is an active cave system recovering from contamination, providing a unique opportunity in the sediment record to understand past sedimentation in the system. Additionally, current research has uncovered microplastics, "plastic particles less than 5mm in diameter" in surficial sediment samples from Hidden River Cave. Further exploring the extent of microplastic contamination combined with exploring the sediment record in the cave will allow for better understanding of sediment transport in Kentucky cave systems and others in similar karst landscapes.

Robert J. Scharping ($3,000)

Ph.D. Student
Department of Cell Biology, Microbiology, and Molecular Biology
University of South Florida

Impacts of Groundwater Extraction on a Karst Aquifer Ecosystem and the Use of Ecological Surrogacy for the Management of Underwater Caves

Abstract—Karst springs in Florida support important surface ecosystems and provide valuable services to humans. Spring water is sourced from underlying aquifers, which support their own taxonomically rich microbial communities. Microbial communities are particularly sensitive to environmental disturbance and may therefore be useful indicators of aquifer ecosystem condition. One type of disturbance occurring naturally in karst aquifers is spring flow reversal, which brings surface water directly into dissolution conduits. This natural phenomenon has yet to be recorded as a result of human activity, but it may be happening at Sulphur Springs, Tampa, FL, due to groundwater extraction and drawdown of the local water table. We will deploy acoustic Doppler velocimeters and water quality multiprobes in the Sulphur Springs karst conduit to characterize the hydrological and physical profiles of this site. We will also analyze water nutrient profiles spectrophotometrically and characterize the groundwater biological community through molecular methods. We will simultaneously study the same ecological parameters at a pristine site, Crab Creek Spring, as a reference. Resource managers of the City of Tampa will work with us to experimentally manipulate the activity of municipal pumps at Sulphur Springs, which will alter the flow within the conduit and potentially induce spring reversals. This research will identify if spring reversals at Sulphur Springs are caused by groundwater extraction, and what impacts hydrological condition has on aquifer ecology. We will also identify the ecological factors that should be managed for the conservation of karst spring ecosystems in Florida and around the world.

Natasha Sekhon ($2,000)

Ph.D. Student
Department of Geological Sciences
University of Texas at Austin

Validating Near-Entrance Cave Deposits as a High-Resolution Sub-Annual Paleotemperature Proxy in New Mexico

Abstract—The geochemistry of speleothems (cave deposits) are used to reconstruct past terrestrial climate (i.e., rainfall amount, moisture source, vegetation) on annual (high-resolution) or centennial (low-resolution) timescales, have been commonly studied from deep parts of caves. Recent studies of speleothems from the traditionally overlooked near-entrance cave zones (Webster et al., 2007) and shallow caves (Flohr et al., 2017) have displayed the potential to study climate variability on a seasonal timescale from these locations. Speleothem scientists have long avoided the near-entrance cave zones and shallow caves because of concerns regarding evaporation, kinetic isotope effects, and biological activity. A recent cave monitoring and speleothem calcite study (Feng et al., 2014) from a small, well-ventilated, near-entrance cave zone (Westcave) in central Texas shows temperature of surface air as the primary control of calcite growth on a seasonal time scale. I propose to couple modern cave monitoring, stable isotope ($\delta^{18}O$) and trace element (Mg/Ca and Sr/Ca) analysis in a shallow cave to test the potential of recording seasonality of temperature in speleothems. The focus of the study is a shallow cave from New Mexico in the southwestern United States similar to the Westcave setting of being well ventilated with near-atmospheric CO_2 concentrations and temperatures. The added motivation to study southwestern United States is that it is a moisture limited and drought-prone region, which is poorly studied for severity of pre-instrumental droughts. The results from the study will have implications for reconstructing high-resolution terrestrial paleoclimate records to study seasonality in temperature in drought-prone regions using speleothems.

Hali Steinmann ($1,600)

M.S. Student
Department of Geography and Geology
Western Kentucky University

A Geomorphic Approach to Understanding Karstification in the Late-Mississippian Pennington Formation, Savage Gulf State Natural Area, Tennessee

Abstract—Karst processes drive landscape evolution on the Cumberland Plateau, a physiographic province spanning from northern Alabama and Georgia through Tennessee into southeastern Kentucky. Situated near the crown of the plateau's stratigraphic sequence is the Pennington Formation, a heterogeneous geologic unit that contains intermittent soluble rock layers such as limestone and dolostone, along with varying amounts of shale, siltstone, and sandstone. This research will take a geomorphological approach with the goal of understanding solutional processes and structural and lithologic controls on drainage in the Pennington Formation in Tennessee's Savage Gulf State Natural Area. The research questions are: 1) what are the major controls on speleogenesis in the Pennington Formation?, 2) how might the presence of soluble rocks in this unit influence the overall karstification and denudation of the Cumberland Plateau?, and 3) how can morphometric indices be applied to cave survey data in order to distinguish between cave types and interpret the effects of speleogenetic processes? The proposed research will consist of geologic mapping and a karst feature inventory of the Pennington Formation, a detailed survey of Pennington caves, fluorescent dye tracer tests and chemical analysis of the hydrologic system, morphometric analysis of cave survey data, and spatial analysis using a GIS. Karstification of the Pennington Formation has implications not only for geomorphology, but also for local ecology and biodiversity, water quality, and land management.

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Reconstructing Paleo-linkages between Central California's Hydroclimate and Global Climate Change

Abstract—Prolonged drought over several years severely impacted California's water resources, indicating the need for a better understanding of how global climate can affect California's precipitation patterns. I propose to monitor the evolution of surface precipitation geochemistry in response to cave-related processes by measuring environmental surface conditions above and within two Sierran foothill caves. The monitoring project will allow for a greater understanding of how individual storms and seasons impact the isotopic and physical parameters of the cave system and will lead to a framework to be used in interpreting speleothem based paleoclimate proxies. Cave monitoring is intrinsically linked to the longer research goal, which is to develop and investigate the feasibility of using speleothem fluid inclusion stable isotope and noble gas compositions to assess quantitative changes in California temperature and precipitation. Results from this work will include seasonal variability in the stable isotopes in precipitation and drip water in these locations, how individual storms impact those values, how sensitive noble gas concentrations in dripwater are to changes in cave air temperature, and how in cave systematics relate to precipitated calcite. The proposed project is of great societal significance as it will lead to a better understanding of California hydroclimate and the link to global climate change.

Evolution in the Underworld

Molecular Insights from Subterranean Waters

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Background

The mechanisms and processes that underlie the colonization of extreme environments constitute major research themes of evolutionary biology and biospeleology.[1–4] Subterranean habitats, with truncated food webs, anoxic environments, and permanent darkness, often require specific adaptations from their inhabitants for them to survive in such hostile environments.[3] These special adaptations and the geographical isolation of caves nominate cave-dwellers as logical study subjects to answer long-standing questions concerning the interplay among adaptation, biogeography, and evolution.[4,5] The ability of a species to successfully colonize such extreme environments requires specific exaptations to life in darkness.[3,6,7] Exaptations to cave life include morphological (reduced dependence on vision, elongation of body and appendages) and physiological (tolerance to oligoxic conditions) characteristics that are already present in many species inhabiting benthic and interstitial ecosystems. Molecular phylogenetics of cave organisms offers the possibility of elucidating cave colonization events, especially when genetic data of surface and cave-dwelling organisms are coupled with their geographic distributions to infer past events. However, to fully understand these events through present-day phylogeographic patterns it is essential to incorporate approaches that consider the environment and ecology of the organisms under study, and therefore the factors that ultimately drive their evolution.

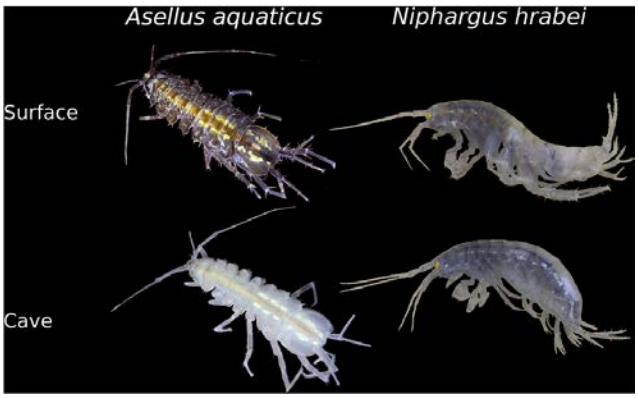

Figure 1.* Asellus aquaticus *displays contrasting phenotypes in and out of the cave, while* Niphargus hrabei *exhibits the same phenotype in both environments.

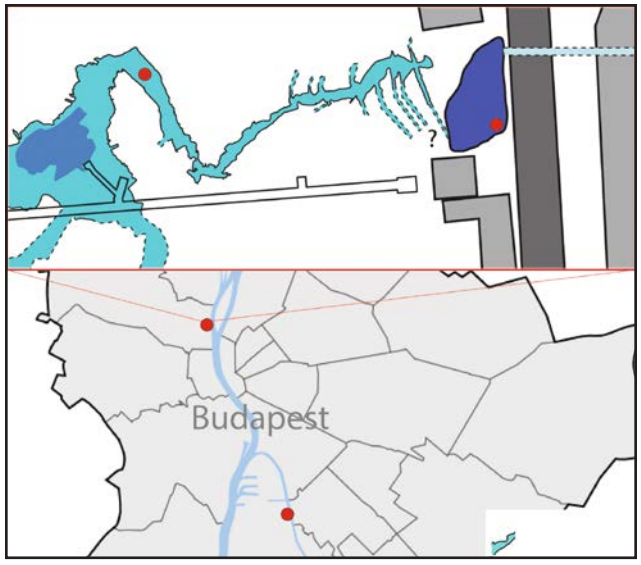

Figure 2. Sampling locations within Budapest, Hungary. Red circles indicate sites within Molnár János Cave (Rakos Rock) and surface environments (Malom Lake and Soroksár).

The isopod *Asellus aquaticus* and the amphipod *Niphargus hrabei* are two crustacean species that serve as ideal models to explore questions regarding the colonization of caves and evolution of cave fauna. *A. aquaticus* is a widespread species of freshwater isopod found in European surface waters.[8] They occasionally colonize caves where populations exhibit high degrees of troglomorphy (Fig. 1), the physiological and morphological adaptations to life in caves.[8,9] *Niphargus hrabei* (Fig. 1) is a surface representative of an almost exclusively cave-dwelling genus.[10] Its distribution spans a wide-area of central and eastern Europe, where it lives in sympatry with *A. aquaticus*. In contrast with *A. aquaticus*, observations suggest that *N. hrabei* populations are troglomorphic in both caves and surface waters, which may be due to the ancient cave-origin of the genus. The present study's aims are twofold: I) to elucidate the role of isolation in cave colonization by

examining the phylogeographic patterns of *A. aquaticus* and *N. hrabei*; and II) to investigate the transcriptional basis behind the loss of vision in cave-adapted populations.

Part I: The Role of Isolation on Contrasting Phylogeographic Patterns in Two Cave Crustaceans

(Published as: Pérez-Moreno et al. 2017. The role of isolation on contrasting phylogeographic patterns in two cave crustaceans.* BMC Evolutionary Biology, *17:247.)

Specimens were sampled from three sites in Budapest, Hungary: The Molnár János cave system, the adjacent Malom Lake, and the Soroksár branch of the Danube River (Fig. 2). These sites are connected hydrologically and both study species (*Asellus aquaticus* and *Niphargus hrabei*) inhabit all the sites. DNA was extracted from each specimen's pereiopods, and mitochondrial and nuclear loci were sequenced. These have proved to be useful in inferring intra- and interspecific relationships across Crustacea (12S, 16S, COI, ITS, NaK) or were targeted to increase population-level resolution (PseudoND2).

Haplotype network reconstruction (TCS) and phylogenetic inference (using both Bayesian and Maximum Likelihood methods) were used in conjunction with population trees (inferred by multi-locus coalescent models) to elucidate the genetic structure, phylogeographic patterns, and divergence times of *A. aquaticus* and *N. hrabei*

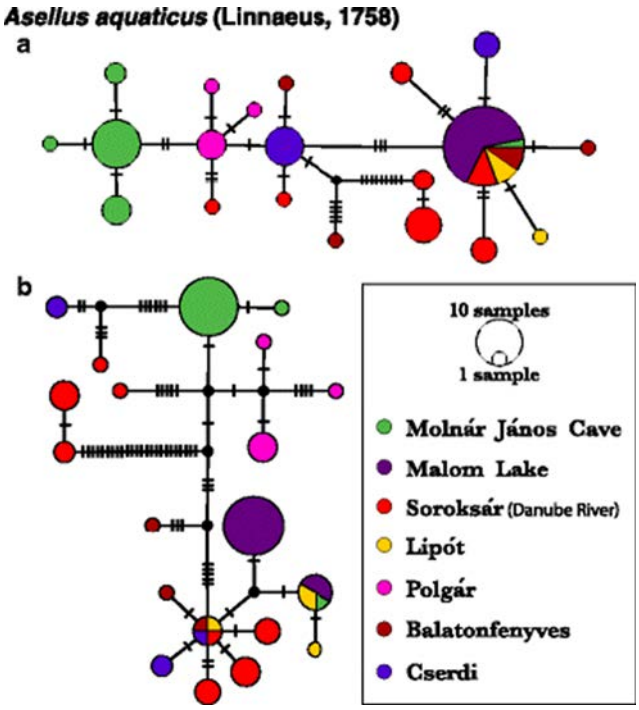

Figure 3. Haplotype networks of* Asellus aquaticus: *nuclear (a: PseudoND2) and mitochondrial (b: 16S, 12S, and COI) loci. Node diameter denotes sample sizes, while hatch marks represent mutational steps between haplotypes.

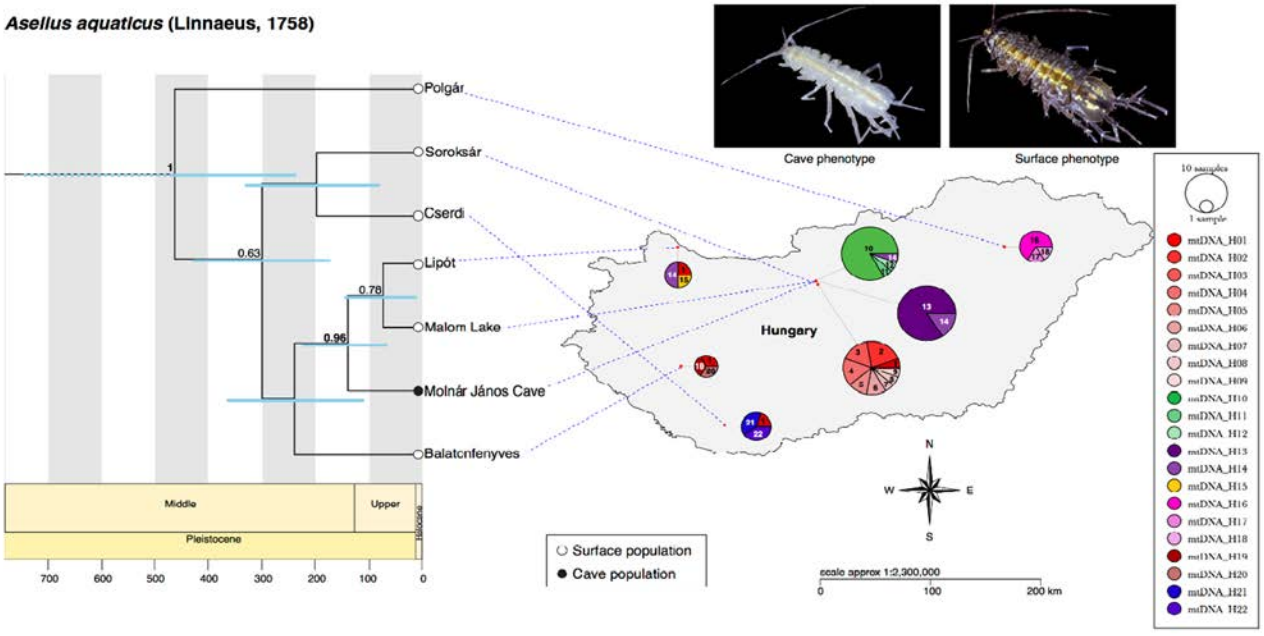

Figure 4. Divergence time estimates (x axis in thousands of years) of* Asellus aquaticus *populations (outgroups not shown) and the distribution of relative mtDNA haplotype frequencies.

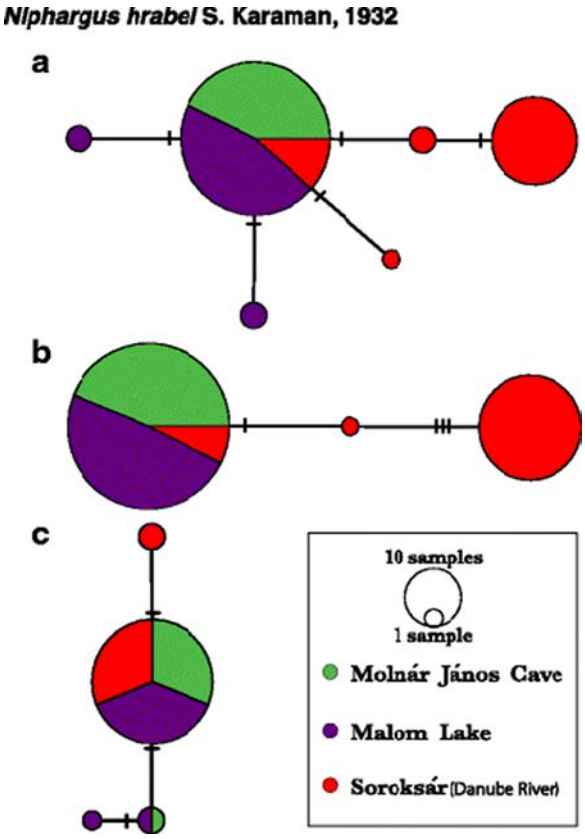

Figure 5. Haplotype networks of **Niphargus hrabei:** *nuclear (***a:** *ITS;* **b:** *NaK) and mitochondrial (***c:** *16S and COI) loci. Node diameter denotes sample sizes, while hatch marks represent mutational steps between haplotypes.*

populations. Contrasting patterns were found between species, with *A. aquaticus* showing strong genetic differentiation and *N. hrabei* lacking evidence of genetic structure mediated by the cave environment.

Niphargus hrabei populations show low levels of genetic differentiation, which suggests recent expansion events. Isolation by cave environment, rather than distance, is likely to drive the genetic structure observed between immediately adjacent populations of *A. aquaticus*, a predominantly surface species. For *N. hrabei*, whose populations exhibit a fully "troglomorphic" phenotype, the lack of genetic structure suggests that subterranean environments do not pose a barrier for surface-cave species.

Under the scenario suggested by the divergence time estimates (Fig. 4), Molnár János Cave would have served as a thermal refuge for *A. aquaticus* during climatic changes throughout the Pleistocene. *Asellus aquaticus*, colonized Molnár János Cave and was isolated from surface populations of adjacent Malom Lake (Fig. 4) resulting in the emergence of troglomorphic phenotypes. Upon cessation of physical isolation, the possibility arises that competitive exclusion prevented new surface populations from successfully surviving/reproducing in the cave. This would be in accordance with the observed patterns of genetic differentiation. *Niphargus hrabei* is a surface representative of a cave-dwelling genus and as such it displays troglomorphic characteristics. *N. hrabei* cave and surface populations appear to be panmictic and show no evidence of isolation by the cave environment nor of competitive exclusion in the cave. Further modern molecular analyses will be required to

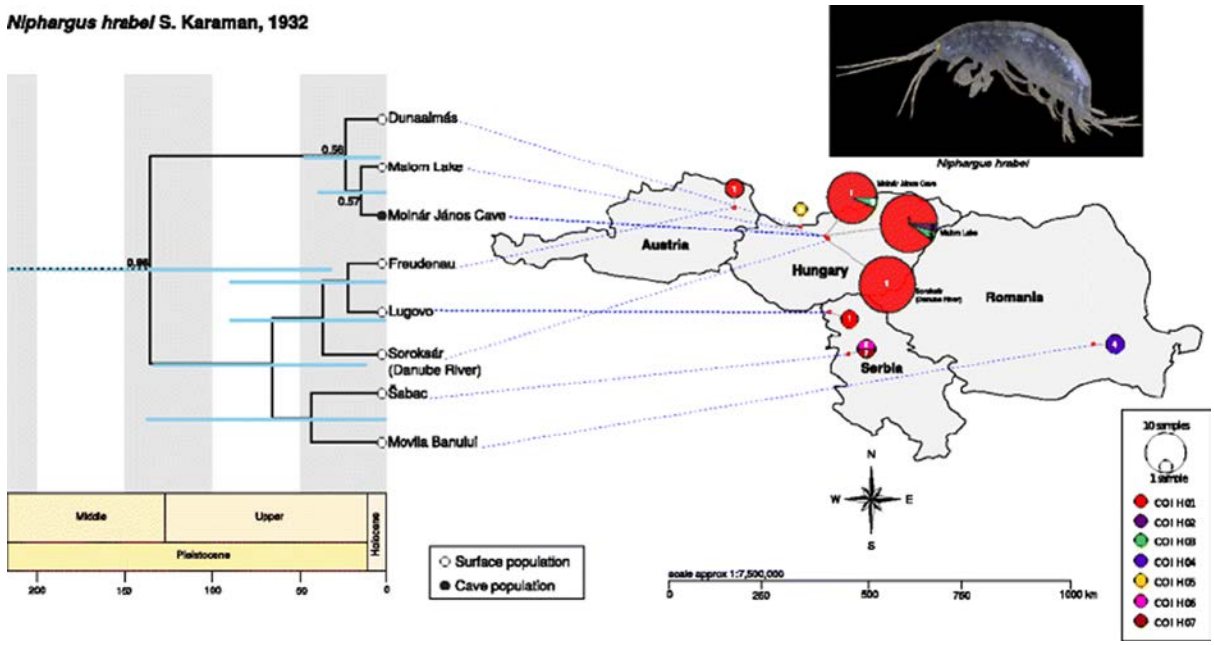

Figure 6. Divergence time estimates (x axis in thousands of years) of **Niphargus hrabei** *populations (outgroups not shown) and the distribution of relative COI haplotype frequencies*

elucidate the exact causes of the observed patterns, and to investigate the influence of exaptations and troglomorphy in shaping the observed phylogeographic patterns.

Part II: Transcriptional Basis of Vision Loss in Troglomorphic Cave Crustaceans

(Current work. To be submitted to* Integrative and Comparative Biology.*)

Total RNA was extracted from 2 whole organisms of each species per population (Molnár János Cave and Malom Lake) in order to evaluate the transcriptional basis underlying vision loss in cave organisms. RNA was prepared for sequencing by mRNA isolation, cDNA synthesis, adapter ligation, and size selection. Prepared libraries were then sequenced on a lane of Illumina HiSeq 4000. Sequencing reads were then quality filtered and trimmed, and assembled via the Trinity pipeline resulting in high-quality and complete transcriptomes (Table 1).

Identification and classification of putative opsins, photosensitive pigment proteins that initiate the phototransduction visual pathway, was achieved through the use of the Phylogenetically-Informed Annotation (PIA) tool.[11] The multiple sequence aligner PROMALS3D was then invoked to align putative opsins to a large opsin dataset (n= 910; Fig. 7) from the Porter Lab (University of Hawaii at Manoa). A final phylogenetic reconstruction was undertaken with IQ-tree.[12] Branch support was assessed in tripartite by Ultra-fast bootstrap approximation (UFBoot; 10,000 replicates), a Shimodaira–Hasegawa–like approximate likelihood ratio test (SH-aLRT; 10,000 replicates), and an approximate Bayes test.[13–15] Differential gene expression was evaluated with EdgeR to further elucidate transcriptional differences between populations.

Asellus aquaticus transcriptome analyses show that major key components of the phototransduction pathway are expressed within the cave population. Both populations express the same opsin genes, albeit different isoforms with minor

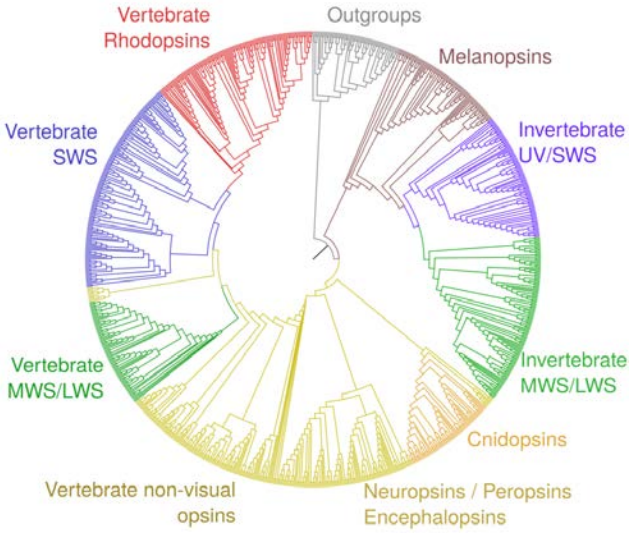

Figure 7. Maximum-Likelihood phylogeny of opsins. Clades are annotated with opsin types contained.

substitutions (Figs. 8 and 9; UV/SWS: Gly110Ala; LWS: Glu-12Asp, Val200Ile) that could be attributed to allelic variation. The expression of opsins and other genes involved in optic lobe formation in *A. aquaticus* was significantly down-regulated in the cave suggesting their vision loss is mediated via transcriptional regulation rather than pseudogenization. *Niphargus hrabei* does not express most components of the phototransduction pathway, except for identical opsins in both cave and surface. Due to the lack of functional visual pathways and visual structures, it is hypothesized that the presence of opsin proteins in this species is related to non-visual light detection through alternate pathways.

Future Directions

The results of this ongoing project offer valuable initial insights into the mechanisms by which organisms are able to adapt to cave environments. Further work will include additional transcriptomic with improved sampling.

Species	Population	Mean contig length	N50	BUSCO Complete	BUSCO Fragmented
Asellus aquaticus	Molnár János Cave	845	1682	95.7%	2.7%
	Malom Lake	976	1909	95.7%	1.9%
	Combined	819	1517	94.3%	3.3%
Niphargus hrabei	Molnár János Cave	687	994	79.6%	9.1%
	Malom Lake	677	966	80.6%	8.9%
	Combined	716	1055	85%	8%

Table 1.

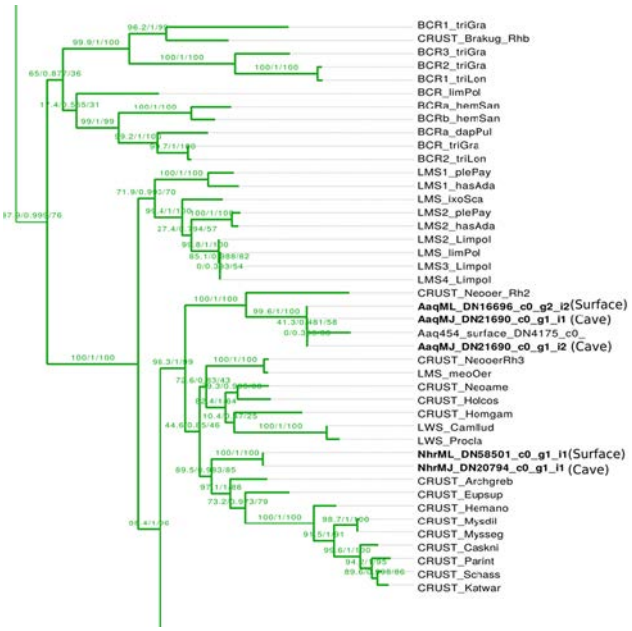

Figure 8. Phylogenetic placement of* Asellus aquaticus *and* Niphargus hrabei *opsins within the Long Wavelength Sensitive clade.

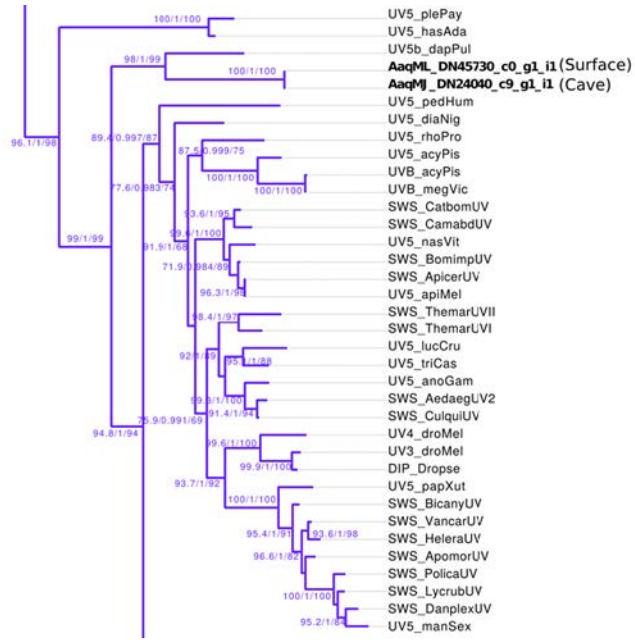

Figure 9. Phylogenetic placement of* Asellus aquaticus *opsins within the UV / Short Wavelength Sensitive clade.

Additionally, an investigation of the epigenetic basis of troglomorphy is being undertaken. These analyses will help bridge the gap between molecules and phenotype, and improve our understanding of evolution in caves and other extreme environments.

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Understanding Sediment Pathways in Hidden River Cave, Kentucky

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The purpose of this research is to further the general understanding of sediment transport and potential contamination pathways in karstic systems through the sedimentological analysis of three cave systems in central Kentucky: Hidden River Cave, Diamond Caverns, and Mammoth Cave. This study reports on the preliminary analysis of sediment cores collected from Hidden River Cave and the ongoing data collection process for both Diamond Caverns and Mammoth Cave. This is an ongoing project and should be viewed as a status update and not a final report. There are currently over 20 cores left to analyze in what hopes to be a long-term research project.

Hidden River Cave

Hidden River Cave is situated in the town of Horse Cave, Kentucky and has a long history of negative impacts due to contamination from numerous sources. A series of sediment cores obtained throughout the cave system were logged, with grain size interpreted using a grain size card in conjunction with visual assessment of the sediment. Cores were cut in half and faces were cleaned and smoothed in preparation for a Cox ITRAX core scanner to obtain elemental concentrations (through x-ray fluorescence), magnetic susceptibility, radiography, and high-resolution photography. Relative metal concentrations were recorded in total counts at 200-micrometer intervals using a Mo X-ray source. Metal values are reported in relative concentrations (total counts) as standard metal concentration data for Hidden River Cave are not available (Gregory et al. 2015). Additionally, certain cores were selected for Lead-210 analysis where they have high clay content and were located on a cave bank or another similar area, where there is a relatively high potential for a continuous sedimentary record to be preserved (Ford & Williams 2007).

Within Hidden River Cave, relative concentrations of metals in the core record were obtained and were observed to decrease moving downstream from the industrial area, a suspected contamination source. Sediment core analysis allows depositional patterns in the cave system to be observed and related to historic surficial processes. The chronology of sedimentation events was determined using Pb-210 analysis of core sediment and indicates a strong connection between historical contaminating events in the town of Horse Cave and cave sediment deposition. Sediment core analysis has thus allowed depositional patterns in the cave system to be determined and related to historic surficial

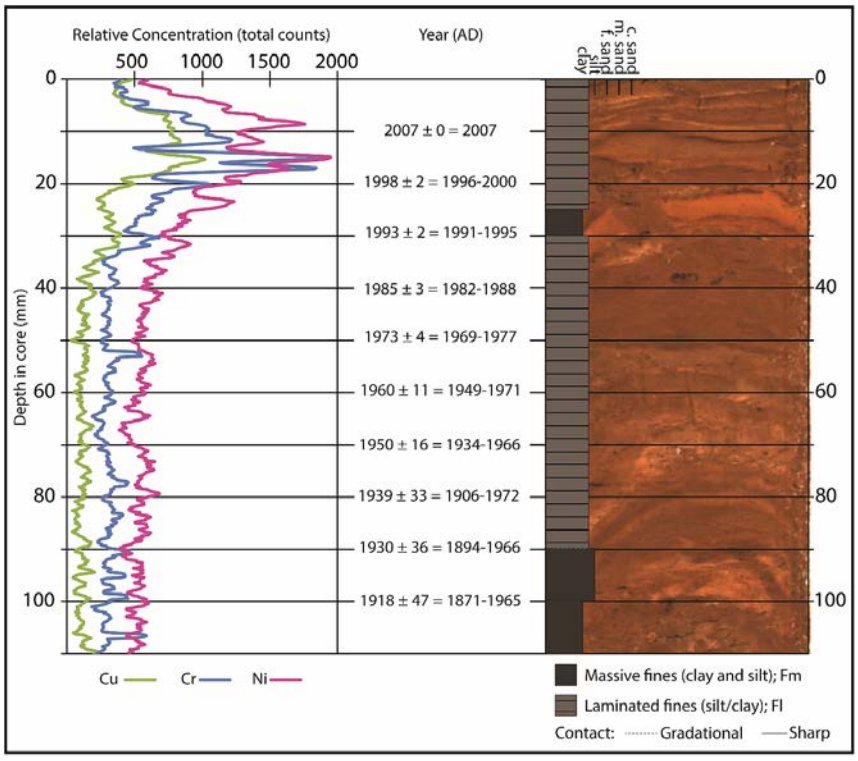

Figure 1. The upper section of core sample CS 302 showing ITRAX elemental data on the left (see Fig. 4), lead-210 dates in the middle as years (AD), (with standard deviation values and the resulting year range) and the core image on the right overlain with a sedimentological log. Horizontal lines are drawn through the graph and core image corresponding with where lead-210 dates were analyzed.

Figure 2. A core obtained from the flood plain of the "Dead Sea" of Mammoth Cave. The intention is for this core to undergo similar analysis as that completed for the Hidden River cores to allow for comparison of results.

Figure 3. An example of the sedimentary structures found in the "Sandy Crawl" portion of Diamond Caverns. These cross laminations are asymmetrical and were likely formed by an underground stream. These ripple marks (emphasized by a white outline in the figure with accompanying arrow) illustrate direction the stream was flowing.

processes. These findings can be applied to enhance understanding of the combined effects of landscape evolution and anthropogenic impacts which may be used to inform decision making processes for communities overlying both Hidden River Cave and other karstic cave systems. Figure 1 illustrates the breadth of data available through the analysis of a single core. Interestingly, peaks in concentrations of nickel and chromium in the period of time between 1998 and 2007 are common throughout the data analyzed, leading to the conclusion that connections to surficial processes are apparent in the sediment record of the Hidden River Cave system. Historical chrome plating plant contamination events can be correlated to increases in relative metal concentrations in cored sediment using an ITRAX core scanner for determining elemental concentrations and Pb-210 dating techniques. Relative concentrations of metals accumulating in sediment tend to decrease downstream from the contamination source, indicating dilution of contaminants as deposition occurs moving downstream from the chrome plating plant. Lag time between contaminant input at the surface and deposition in the sediment record occurred when contaminants entered the cave system indirectly (i.e. after moving through the sewage treatment plant rather than direct input). Using the relative metal concentrations identified in a number of cores the effects of anthropogenic landscape development on sediment composition and chemistry can be determined, and known contamination events are used as stratigraphic markers to correlate between cores in the same passage. This information is useful in understanding not only the paleo-record of anthropogenic activity on the surface, but also how that activity impacts the subsurface sediment and water. This helps to understand how best to protect the subsurface, especially when groundwater is used to support the local community.

Diamond Cavern and Mammoth Cave

In the Spring of 2019 cores were obtained from both Diamond Caverns and Mammoth Cave National Park. To date, the cores have been prepared for analysis with more work needed to complete and analyze the data (Figure 2). The cores obtained will undergo similar analysis to those obtained from Hidden River Cave in an effort to compare the results.

While sediment cores are a great way to reconstruct the history of an area, it is also important to use other methods. Traveling through the "Sandy Crawl" area of Diamond Caverns, there are numerous clues to helping reconstruct the history of the cave. Unlike other areas of the Diamond Cavern, caves that are used as tourist caves, the "Sandy Crawl" is a passage that is reserved for staff and researchers. The walls in parts of the Sandy Crawl were riddled with sedimentary structures, such as cross laminations and cross bedding, providing valuable information about how that sediment was deposited (Figure 3).

There is a wide-ranging amount of interesting data that needs to be explored within these two cave systems over the coming years. The data collected will support numerous research projects and tie in to the overall research goal of further understanding of sediment transport, and potential contamination pathways, in karstic systems.

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Impacts of Groundwater Extraction on Submerged Coastal Cave Ecosystems

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Florida's iconic springs and submerged caves produce rivers and estuaries along the Gulf of Mexico coast, supporting wildlife habitat and municipal water supply. These coastal spring-cave systems are fed by a combination of fresh and saline groundwater, which generates dynamic cave ecosystems. We studied one of these systems, Sulphur Springs Cave, to better understand the impact of human activity on coastal caves. Sulphur Springs Cave was a perfect site for this project because it is hosted by the limestone beneath metropolitan Tampa and produces a large perennial spring from which local municipal resource managers extract water.

When compiling historical information about Sulphur Springs, which stretches back about 70 years, the first thing we noticed was that Sulphur Springs Cave water is currently 10 times more saline than it was in the 1940s. Inside Sulphur Springs Cave, we found many saltwater vents (Figure 1), but we wanted to find out how the relative influence of these vents and their source of saltwater could have changed over the past half-century. To do this, we studied the hydrogeology of Sulphur Springs Cave and the long-term, high-resolution salinity patterns that have been recorded at the spring by the US Geological Survey and the Southwest Florida Water Management District.

Our research showed that the increasing salinity of Sulphur Springs was due primarily to groundwater extraction activity occurring at the site, as well as to sea level changes in Tampa Bay, which has risen ~20 cm since records began in 1947. We found that saltwater vents in Sulphur Springs Cave are connected to bedrock fractures which draw up deep-sourced, landward-intruding seawater. Though the influence of these vents has increased the salinity of Sulphur Springs Cave, shallower parts of the aquifer surrounding the cave have remained fresh. Our study demonstrated the effect of direct groundwater extraction from coastal karst features and showed that although these systems are easy targets for groundwater extraction, their complexity makes them vulnerable to mismanagement. The increasing urbanization of coasts will surely impact submerged cave ecosystems throughout the world, but their deterioration can be prevented by the development and implementation of science-based aquifer management plans.

Figure 1. An example of a Sulphur Springs Cave saltwater vent which issues warm, saline, sulfidic water. In the foreground, white sulfur-oxidizing biofilms take advantage of the saltwater vent habitat. Vent diameter is ~20 cm.

With this part of the project complete, we began wondering how human-caused seawater intrusion could impact the lifeforms of the Sulphur Springs Cave ecosystem. The most obvious impact was that the Sulphur Springs Cave saltwater vents hosted visually distinct microbial biofilm communities (Figure 1). The saltwater vent biofilms were white and filamentous and were using the toxic hydrogen sulfide issuing from the vents to generate energy in a process called *chemosynthesis.* Chemosynthesis is like the evil twin of photosynthesis—while plants use sunlight energy to turn carbon dioxide into organic biomass, chemosynthetic bacteria use the energy stored in chemical compounds for essentially the same purpose without depending on light. It is likely that the white biofilms were not able to

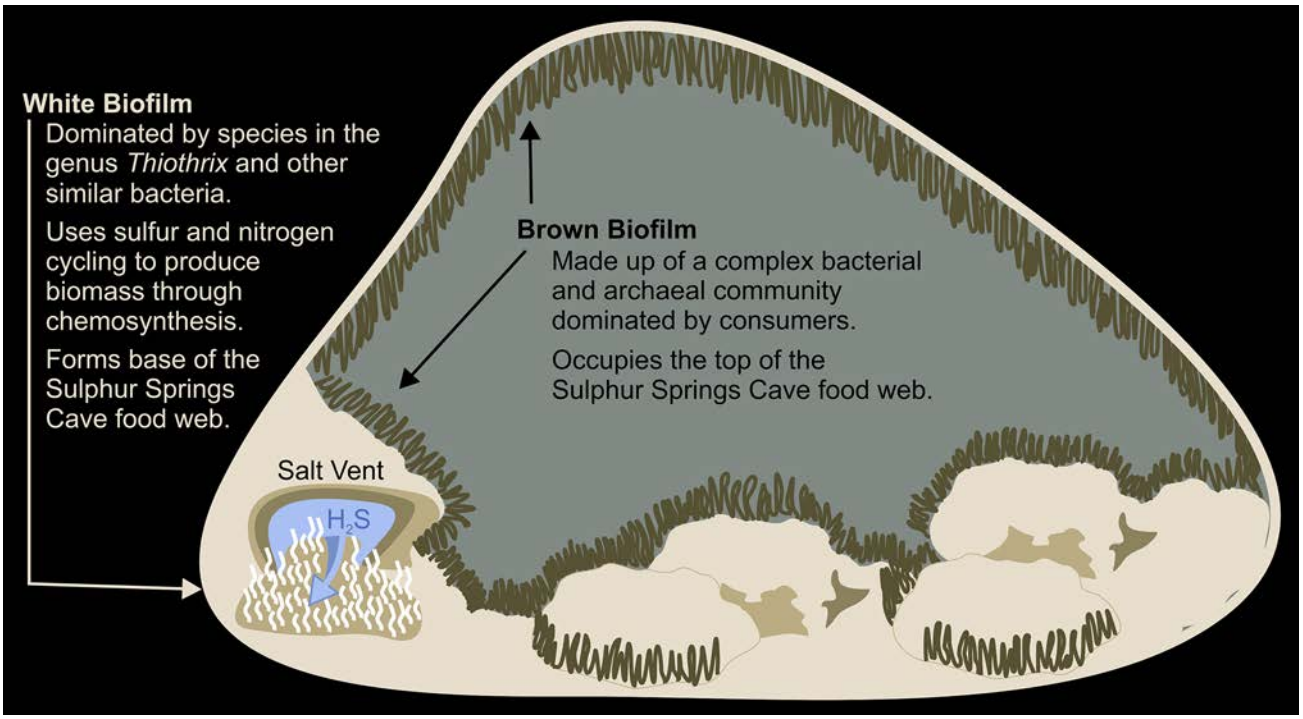

Figure 2. A cross-sectional representation of Sulphur Springs Cave showing the cave's different microbial biofilm communities and their major ecological functions.

colonize Sulphur Springs Cave before the saltwater vents began issuing sulfidic, saline water (this cave contained only freshwater as late as the mid-20th century). The success of the white biofilms is thus a result of seawater intrusion at the site.

The delicate white biofilms stood in bold contrast to the thick, brown biofilms which colonized the rest of the cave walls and ceiling (Figure 2). We discovered that while the white biofilms were primary producers that made up most of the cave food web base, the brown biofilms were consumers. By analyzing the stable isotope geochemistry of the brown biofilms, we determined that their diet consisted partly of chemosynthetic white biofilm material, and partly of surface-derived organics that washed into the cave through sinkholes.

On long dives in Sulphur Springs Cave, we would lose count of how many suspended tufts of white biofilm we would see as they floated by us. The tufts had become dislodged somewhere upstream and were making their way toward the spring mouth. Apparently, the brown biofilms were accessing their food source as if it were on a conveyor belt. These observations led us to ask whether cave-sourced chemosynthetic material could significantly contribute to downstream coastal ecosystems—places where photosynthesis should dominate base of the food web. We are currently investigating the suspended material flowing out of Sulphur Springs Cave to determine the extent to which subterranean chemosynthesis can support surface environments.

The results of our research in Sulphur Springs Cave imply that subterranean seawater intrusion driven by groundwater extraction and sea level rise can produce brackish conditions in once-freshwater caves, which can enhance cave chemosynthetic activity. Caves supporting chemosynthesis are important ecosystems and deserve special attention from coastal resource managers and researchers.

We would like to thank the Cave Research Foundation for its support for this project. Our work at Sulphur Springs Cave is still on-going, but please see our recent articles in the *Journal of Hydrology*[1] and *Science Trends*[2] for more detailed information about our findings and photographs of the site. So far, we have been able to demonstrate how human activity can impact the hydrogeology and ecology of coastal underwater caves. We will continue to study Sulphur Springs Cave and other sites in west-central Florida to see what caves can teach us.

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Controls on Speleogenesis in the Upper-Mississippian Pennington Formation (Cumberland Plateau Province: Tennessee and Alabama)

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Introduction

Cave survey and exploration are often biased towards large cave systems that have "going leads" (areas yet to be explored or surveyed) or the potential to connect to other cave systems; however, much of the plumbing in karst systems consists of thin cracks and flooded conduits that remain inaccessible to even the smallest and bravest of cavers. The Pennington Formation's thin (1–10 meters) limestone members contain hundreds of caves (defined in Tennessee and Alabama as a natural cavity traversable for at least 50 ft/15 m) and host karst conduit networks at scales below this threshold but significant to local hydrology and ecology. Despite this, the Pennington Formation is poorly represented in the literature on Cumberland Plateau karst hydrogeology and has been misrepresented as a confining layer in many circumstances. The purpose of this research was to identify controls on speleogenesis in the Pennington Formation with the goal of better understanding its place within the greater context of Cumberland Plateau landscape evolution.

This work consisted of a regional study of Pennington caves on the western Cumberland Plateau escarpment in Alabama and Tennessee, and a case study of Pennington caves in Savage Gulf State Natural Area (SGSNA, Grundy County, Tennessee). Cave geomorphology, dye tracing, and Geographic Information Systems (GIS) were used to explore lithologic, hydrologic, and structural influences

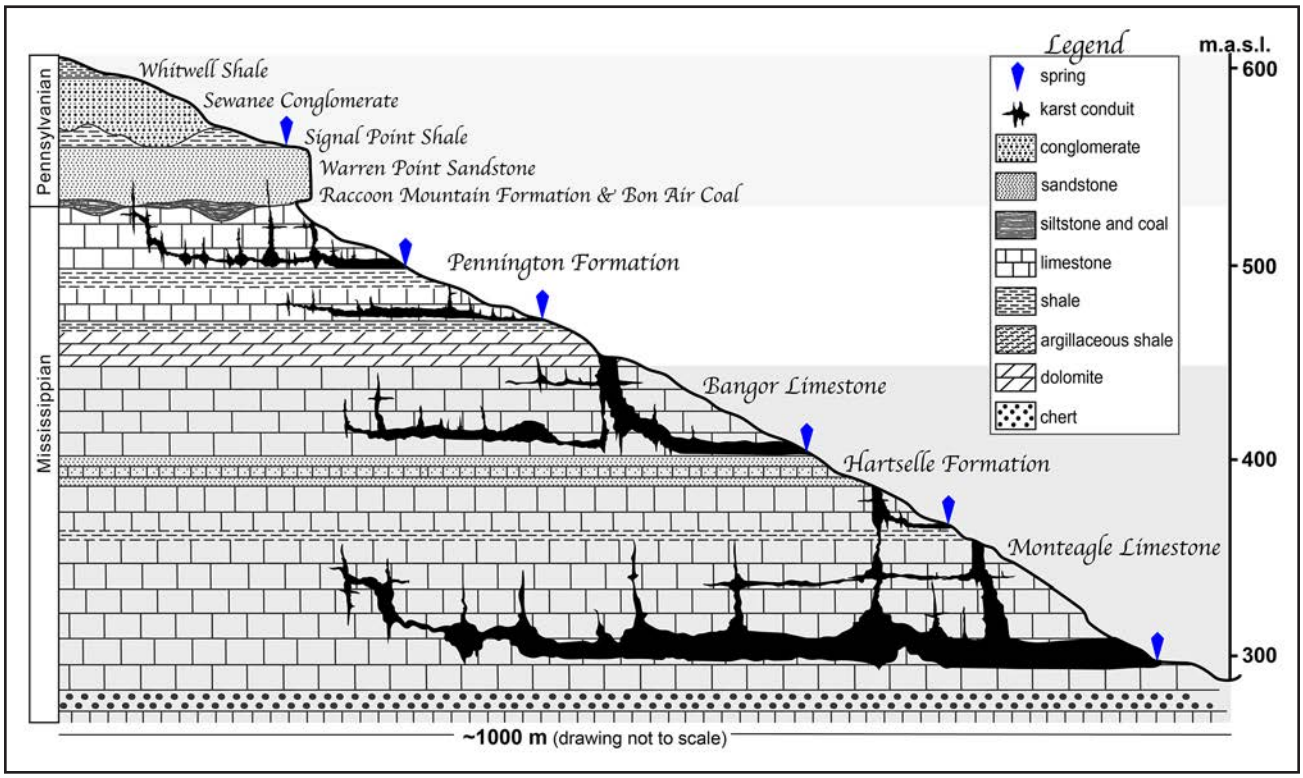

Figure 1. A revised karst geologic model of the Cumberland Plateau escarpment (vertically exaggerated) recognizing the potential for karst conduit development in limestone members of the Upper Mississippian Pennington Formation.

on karst processes. This resulted in a conceptual model for speleogenesis in the Pennington Formation, with the major controls being: 1) direct and/or diffuse recharge from the caprock, undersaturated with respect to calcite; 2) thin, horizontally bedded limestones sandwiched by shales and other insoluble rocks; and 3) networks of stress release fractures oriented parallel to major stream valleys. A revised karst geologic model for the Cumberland Plateau is presented, which includes the possibility for caves and karst in the Pennington Formation (Figure 1).

Stratigraphic Trends

The distribution and nature of Pennington caves on the Cumberland Plateau is dependent on the lithologic characteristics of the formation that vary spatially as a result of sedimentary conditions in the basin during the time of deposition. Generally speaking, continental clastic deposits dominate the Pennington Formation in the north of the study area, grading into estuarine and shallow marine coastal-tidal deposits to the south (a basinward shift in facies). Therefore, Pennington caves are relatively rare in the impermeable shales and mudrock of the northern plateau but are common in the central and southern portions of the plateau where soluble limestone and dolomite are interspersed throughout the formation.

Cave entrances in the Pennington Formation tend to be found at higher elevations on the western side of the Cumberland Plateau and lower elevations to the south and east. The entire Cumberland Plateau province dips slightly to the southeast, which partially explains this phenomenon; however, carbonate members are not continuous throughout the unit and occur at different points in the section depending on location. Limestones in the upper part of the formation tend to be thicker and more well-represented to the west, grading into shale and sandstone to the east. Basal limestone and dolomite are present throughout most of the extent of the formation, but are generally thicker to the south, which accounts for the many low-elevation Pennington caves in the south of the study area. Caves high in elevation on the western escarpment tend to be formed in limestones sandwiched by shales at the top of the formation, or in carbonate rocks in direct contact with the Pennsylvanian caprock at the disconformity. The occurrence of true pit caves (vertical shafts formed by dissolution) in the Pennington Formation is strongly dependent on the available thickness of carbonate rocks; most "true" pits are located in the southern portion of the study area.

Structural Trends

Structural discontinuities are the framework for speleogenesis on the plateau. The Cumberland Plateau has experienced superficial structural deformation in the form of folds and low-angle thrust faults in the Pennsylvanian strata; these features along with stress release fractures (recent openings resulting from valley unloading) throughout the section provide the primary point of entry of water into karst conduit systems. In the Pennington Formation, this is evidenced by passages that trend along-valley, or parallel to major streams, and sets of near-vertical joints and fractures that guide surface runoff through the caprock and/or epikarst into the groundwater. This pattern is consistent with the trend observed in caves of the Mississippian Bangor and Monteagle limestones (Sasowsky and White 1994) and in Newsome Sinks, Alabama (Varnedoe 1963; Moravec and Moore 1974).

Rose diagrams from 60 Pennington cave models show general agreement between the directionality of cave survey ties and the orientation of major stream valleys. Cave passages tend to develop parallel to the axis of the major stream valley in which they are formed. The mean angle of cave passages was 84.5 degrees (the null hypothesis that there was no mean direction was rejected with Rayleigh z 17.253, $p<0.001$). The mean angle of stream valleys was 98.3 degrees (the null hypothesis that there was no mean direction was rejected with Rayleigh z 20.051, $p<0.001$). Watson's U2 test (U2 0.0818, $p>0.50$) was used to accept the null hypothesis that the two groups of azimuths are not significantly different. Therefore, cave passage directionality in the Pennington Formation is related to valley directionality in a statistically significant way.

The dip of strata on the western escarpment of the plateau is so slight as to be locally undetectable, and any effect of the regional southeastward dip on the morphology of individual Pennington caves was imperceptible. Observation of cave passages in GIS resulted in no further conclusions because passages develop both updip and downdip from major surface streams. However, on a larger scale, dip direction affects landscape morphology and the placement of Pennington Caves. Studies of blind valleys on the Cumberland Plateau (Crawford 1992; Davis and Brook 1993) attribute their formation to structural circumstances where strata dip away from the plateau, rather than toward it. In Sinking Cove and Lost Cove (blind valleys in Franklin County, Tennessee), strata are dipping away from the plateau, and the Pennington Formation's limestone members are the first soluble rocks encountered by incising streams. This results in piracy of the surface stream by karst conduits, and eventually the formation of traversable caves.

Hydrologic Trends

Depending on localized lithology, the Pennington Formation can either confine the movement of water (as in shales that dominate the formation to the north) or conduct water rapidly through conduits (as in limestone members of increasing thickness and regularity to the south). Pennington caves are best categorized as plateau-margin caves, which interact with the modern surface and subsurface drainage as water makes a stair step journey down and through the plateau escarpment. Recharge is both diffuse, through fractures networks and openings in the epikarst, and point source, through sinking streams.

Because recharge is primarily allogenic, and drainage from the caprock is highly undersaturated with respect to calcite, the geochemical gradient in Pennington karst aquifers usually favors dissolution over precipitation of calcite. In some cases, the highly aggressive nature of runoff from the caprock causes streams to incise directly through thin limestones in the Pennington Formation with little to no conduit development. Speleothems were not common in Pennington caves observed in this study, except in a few cases where slow drips through fractures created small stalactites. Much more common are dissolutional features like rills, scallops, and anastomoses. Where undersaturated water enters a confined limestone bed at the entrance of Greeter Falls Cave, turbulent floods have created beautiful scalloping on the walls and ceiling of the cave.

Seasonal variations in stage, and the general flashiness of the Cumberland Plateau hydrologic system, cause the behavior of Pennington karst aquifers to differ according to the amount of flow present. Many Pennington caves fed by diffuse allogenic recharge (e.g. Coon's Labyrinth Cave and Buckets of Blood Cave in Franklin County, Tennessee) have streams that converge to a single discharge point or spring. However, distributary flow paths are also common, especially in caves where a flood-prone point source of recharge is channeled laterally into soluble layers sandwiched between impermeable rocks. "Flood mazes" such as Greeter Falls Cave and Short Creek Maze Cave (White County, Tennessee) have many points of outlet, which may change depending on the amount of water passing through the system. The series of intermittent springs draining the Greeter Falls Cave system are a good example of this; under dry conditions they are mostly inactive, and in the rainy season maintain steady flow (Figure 2).

Dye tracing results from SGSNA shed light on the complex behavior of anastomotic and distributary flow routes through karst conduits in the Pennington and allow for interpretations of similar systems observed elsewhere in the study area. Based on surveyed cave passages and hydrologic tracer tests of springs in the Greeter Falls system, there exists a maze-like conduit network within the western bank of Firescald Creek. The sink at Greeter Falls Cave entrance is the primary source of recharge to this system, which behaves differently depending on stage. At high stage, Firescald Creek resurges at a multitude of ephemeral springs and seeps that are inactive at low stage. Site 8, a spring that continued to be active during low stage, was confirmed to be the resurgence of an underground flow path from Firescald Creek to Big Creek. This system provided clear evidence of karst stream piracy through the Pennington Formation, which is likely to occur elsewhere and occurs in the form of meander cutoffs in many places. Based on cave narratives and visualization of data in GIS, a maze-like system of conduits in Short Creek Maze Cave cuts off a major meander in the surface valley and distributes the flow of Short Creek from a single sink to multiple outlets. Lockwood Cave (White County, Tennessee) is another example of a meander-cutoff cave formed in preferred-gradient karst conduits in the Pennington Formation.

Concluding Remarks

When lithology, stratigraphy, structure, and hydrology are favorable, there is the potential for karstification and speleogenesis to occur in the Upper-Mississippian Pennington Formation. The stratigraphy of the western Cumberland Plateau is favorable for Pennington cave development due to the presence of multiple unnamed carbonate members. Pennington caves are generally limited in vertical extent by confining shales and clastic rocks. Commonly, they are fragmented pieces of horizontal branching stream passages, with tube or canyon-like tributaries. Some small pit caves occur, especially to the south and west of the study area where limestone and dolomite beds tend to be thicker. Geochemical conditions are especially favorable for speleogenesis in the upper Pennington Formation since drainage from the sandstone and shale caprock is highly solutionally aggressive. Structural discontinuities caused by valley stress release create the framework for conduit development, meaning passages generally trend in the direction of major streams. Solutional enlargement of conjugate joints is apparent in many Pennington caves, and in confined limestones can create a maze effect by diffuse drainage and even enlargement of the joint network, enhanced by floodwater injection into the confined karst unit. Future studies should acknowledge that karst processes in the Pennington Formation, especially on the western escarpment of the plateau, are capable of producing conduit systems and caves that are significant in terms of local and regional hydrology, ecology, and geomorphology.

Figure 2. **(Left)** ***dry-season view of Pennington Formation springs in the Greeter Falls Cave system;*** **(right)** ***the same springs after a period of wet weather.***

Cave Monitoring in Western Sierra Nevada

A Key to California's Past Climate

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Prolonged drought over several years severely impacted California's water resources (Sewall, 2005), indicating the need for a better understanding of how global climate can affect California's precipitation patterns. For the CRF research grant, I proposed to monitor the evolution of surface precipitation geochemistry in response to cave-related processes by measuring environmental surface conditions above and within two Sierran foothill caves. We have found that California Caverns is impacted by tourism in terms of pCO_2 and temperature, that Lilburn Cave is sourcing water from two distinct end-members, and that it is likely that California Caverns and Lilburn Cave are impacted by the same precipitation sources separated by elevation.

As part of this project, I began monitoring Lilburn Cave in May 2018 at three drip-sites and California Caverns in August 2018 at two drip-sites. At Lilburn, drip-site #1, Glacier Pool, is near the entrance of the cave. Glacier Pool is always near atmospheric pCO_2 and is the coolest location that we monitor, with an average temperature of 6.5°C. Drip-site #2, Big Yellow Hungus Thing (BYHT), is at the mid-level of the three-tiered Lilburn Cave. It also has a consistent near atmospheric pCO_2 and is on average 7.4°C, ~1°C warmer than the near surface site, Glacier Pool. BYHT site is also continuously monitored by a "live-in" CO_2, relative humidity, and temperature monitoring devices that are changed when necessary. Drip-site #3, Canopy, is in the bottom level of the cave and is separated from BYHT by the underground portion of Redwood Creek. The average temperature at Canopy drip-site is 7.5°C. The degree to which air is circulated through Lilburn Cave to support near-atmospheric pCO_2 with temperature stratification is a question that needs further data and research to understand.

At California Caverns, drip-site #1 and #2 (Vanity and Chamber Pot, respectively) are near each other (~1.5 m away) in the "Bridal Chamber" portion of the cave. California Caverns is a tourist cave with 4–5 tour groups walking past the monitoring sites every day, and the cave floods from December–March of every year. The temperature (avg. 12.9°C) and CO_2 (760–2500) in California Caverns is diurnally variable, likely impacted by active tourism. The relative humidity in the cave, however, stays constant at between 90–100% humidity. California Caverns began flooding in November of 2018, ending the sampling season.

Our team collects four chemical parameters of the cave drip-water: the stable isotope values ($\delta^{18}O$ and d2H), the trace element concentrations (e.g. Mg, Sr, Ba), the pH, and the alkalinity (Fig. 1A). These chemical parameters allow us to be able to determine the residence time of the water flowing through each cave system and the source of that water. Lilburn Cave drip-sites have an average $\delta^{18}O$ value of −11.27 ± 0.4 ‰ but exhibit seasonal variability (Fig. 1A). California Caverns has an average $\delta^{18}O$ value of −8.7 ± 0.2 ‰; however, lack of access during the winter season limits are ability to assess seasonal variability. The stable isotopic values, high alkalinity values, low drip rates, and constant trace element values at Lilburn during the summer indicates that Lilburn Cave drip-water is sourced from a groundwater supply that is isolated from the surface and provides a constant water source (Fig. 1 B–E). As Redwood Creek (near surface creek in the same canyon as Lilburn Cave) has a similar $\delta^{18}O$ value of −11.9 ‰, we hypothesize that water infiltrates into the system during the spring melt of large snow-pack and then flows into Redwood Creek and to our cave drip-sites as base-level in the creek decreases. In wet seasons, though, precipitation and snow meltwater are abundant enough to flow into the system and feeds the creek and the drip-sites. In October 2018, when precipitation increased in the canyon, stable isotope values became more variable (Fig. 1E) and are associated with lower alkalinities (Fig. 1B), supporting the hypothesis that during wet-seasons Lilburn cave drip-water received a greater contribution of winter precipitation, recharging water sources. These chemical findings suggest that the stalagmite from Lilburn Cave (Lilburn 1) can be interpreted as recording seasonal variability. Additionally, the difference between the average stable isotope values at Lilburn and California Caverns is ~−2.5 ‰ consistent with caves that receive similar precipitation and are separated by 1.09 km (Lachniet, 2009). Thus, future stalagmites harvested from California Caverns and Lilburn can be considered analogous records of precipitation variability, as long as the elevation separation between the 2 caves is accounted for.

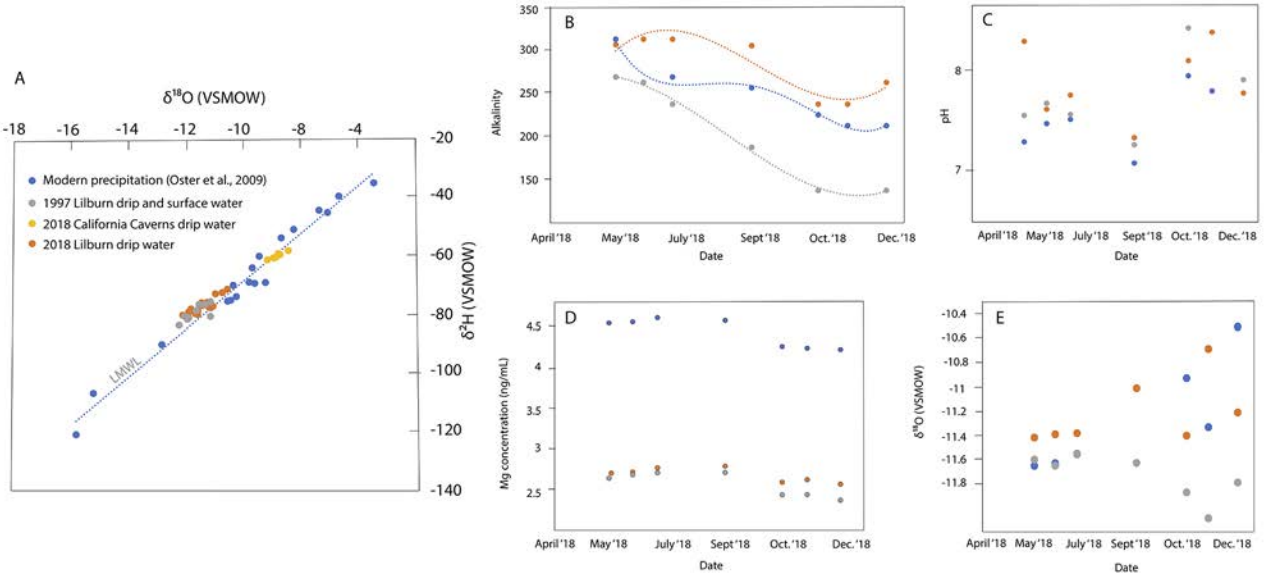

Figure 1: The local meteoric water line determined by 5 years of precipitation monitoring data is close to the global line at $\delta^{18}O = 7.8 * \delta^{2}H + 9.8$ (A). Lilburn surface water and drip water from 1997 agrees closely with dripwater and surface water from our last monitoring year (A; orange and gray dots). California Caverns data clusters at higher values (yellow; A). Monitoring data from Lilburn Cave (B-E) show decreased alkalinity (B), variable pH (C), decrease Mg concentrations (D), and more variable d18O (E) through time as precipitation increases in the winter (October).

Future work for the Lilburn Cave monitoring project includes continued monthly monitoring of drip-water and cave parameters via in-person visits to the cave with a CRF team. It will also include the installment of wind vanes at both entrances to Lilburn Cave. Wind vane installment will be tied to a stage meter at the spring on the south end of Lilburn Cave. These meters will help us document the ventilation of Lilburn Cave to accurately describe when and how Lilburn Cave responds physically to changes in water level in the spring. Additionally, next winter we will install acoustic drip rate sensors and drip-water collectors over the winter. We delayed installing these features through the past winter as it was unclear if equipment would be lost due to cave flooding. Now that we have a better understanding of cave flood stages, equipment placement will be optimized to reduce likelihood of losing equipment. We will fully develop the stable isotope, trace element, and Sr isotope records in Lilburn stalagmite over the next year and compare the records to the cave monitoring project for interpretation.

This work has been presented at the Sequoia and Kings Canyon Research Symposium in November 2018 and has involved 5 undergraduate research assistants (4 UC Davis undergraduates and 1 undergraduate from the University of Chile). Over the next year, the cave monitoring work will be presented at the Undergraduate Research Symposium at UC Davis and at the national meeting of the Geologic Society of America in Phoenix, Arizona.

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