Cave Research Foundation Annual Report 2018–2019

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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 2018–2019 Annual Report

Editor: Ed Klausner
Copy Editor: Elizabeth Winkler
Layout: Karen Willmes
Publisher: Bob Hoke, CAVE BOOKS

The text of this publication is composed in Adobe InDesign CS6

Front cover photo: Miranda Allen discovers virgin passage in Lava Beds National Monument, California. Photo by Mark Jones.
Back cover photos: *top*, Jenn Ellis pushes a lead in the NSS Donald Russell Cave Preserve, Oklahoma. Photo by Mark Jones. *Bottom*, Ed Klausner sketching in Carlsbad Cavern, New Mexico. Photo by Jeannette Muller.

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ISBN-13: 978-0-939748-42-6
ISBN-10: 0-939748-42-8

CAVE BOOKS
4700 Amberwood Drive
Dayton, OH 45424-4602, U.S.A.
www.cavebooks.com

CAVE BOOKS is the publications affiliate of the Cave Research Foundation

Contents

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2018

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2019

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National Personnel Officer
Phil DiBlasi

Newsletter Editor
Laura Lexander

Finance Committee
Elizabeth Winkler
Charles Fox
Scott House

Operations Areas and Managers

Eastern Operations Area
Charles Fox (2018)
Karen Willmes (2019)
Mammoth Cave National Park
Cumberland Gap National Historical Park
Cave Hollow–Arbogast Cave

Ozarks Operations Area
R. Scott House
Mark Twain National Forest
Ozark National Scenic Riverways
Missouri Dept. of Conservation
Missouri State Parks
Buffalo National Scenic River
Russell Preserve, Oklahoma

Sequoia / Kings Canyon Operations Area
Fofo Gonzalez and Jen Hopper
Sequoia / Kings Canyon National Park

Northwest Operations Area
John Tinsley
Lava Beds National Monument
Craters of the Moon National Monument

Southwest Operations Area
Janice Tucker
Carlsbad Caverns National Park

Hamilton Valley Operation
Patricia Kambesis
Hamilton Valley Field Station

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 2018 and 2019:

2018 Fellows

Brenda Goodnight

Brenda has participated in over 110 trips and has been trip leader for upwards of ten trips. In addition, she frequently helps in administrative tasks involving field facilities—helping maintain and clean and supply whatever facilities we have used. She is a qualified bio-observer and works closely with the NPS and other agencies. She has also been a great help in cave gating projects.

Dennis Novicky

Dennis has led more than 25 trips for CRF Ozarks and has participated in an additional 145+ trips and work days. He has been a mainstay of gating efforts, particularly gate repair efforts. He is a very good sketcher and prepares everything necessary for a final draft on cave maps. He shares cartography credits on several cave maps in our operations. In addition, he has been a huge help with facility issues.

Dillon Freiburger

Recruited just a couple of years ago, Dillon has graduated from prospect to trip leader, cartographer, and biologist. In just two years, Dillon has led over 30 trips for Ozarks and participated in another 40+. He has drafted at least 13 maps in Missouri alone and probably an equal number in our Buffalo River project.

Jim Ruedin

Jim is an experienced caver who has worked with CRF for some years now. He has led 12 trips including five in this calendar year alone. Jim is not a cave surveyor, per se, although has helped on several maps. His forte is leading monitoring trips, particularly on Missouri Department of Conservation lands. He has also helped with tracking down obscure caves in answer to agency questions.

2019 Fellows

Matt Beeson

Matt has come out of long retirement to become an active trip leader, project director, and cartographer on various Ozarks Operations projects.

He has drawn a number of maps (his recent Butler Hollow Mine Cave map won an award at the NSS convention.) He has led numerous trips and submitted trip reports for all; he has also submitted faunal reports and public use monitoring reports. Matt led the project to inventory and survey several caves in an interstate right of way in SW Missouri, completing the project within one month. This was a funded project. All maps were completed. Matt has also taken on leadership for a survey of a large gray bat cave in SW Missouri, with permit from the Department of Conservation. In addition, Matt has also worked extensively on Fitton Cave and small caves in Buffalo River.

Shawn Williams

Shawn has been around for quite some time but fell through the cracks and this should have been awarded years ago. Shawn has worked on several projects in both Missouri and in Arkansas and has been a good team player on even the most unpleasant of tasks.

Dave Socky

Dave began his CRF participation at Cumberland Gap, seeking out the longest and hardest survey trips. He is currently co-leader and cartographer of the Cave Hollow–Arbogast Cave project in Monongahela National Forest.

2018 Certificates of Merit

Charles Fox

Charles has held many positions in CRF leadership, most recently Eastern Operations Manager. Charles has also been the web master for the CRF website and has also provided legal insight into many CRF issues.

2019 Certificates of Merit

Aaron Thompson

Aaron has made contributions in both Southwest Missouri and in the Buffalo National River. He's been a very dependable asset to projects related to mapping, biological monitoring, and even cave gate welding.

Katrina J. Smith

Katrina was hired at Lava Beds National Monument (LABE) to help with resource management in general and also cave-related issues. Being especially bright and motivated, she quickly advanced to become the cave management specialist succeeding Shane Fryer. She has been a physical science technician, cave management specialist, and lastly rose to Acting Chief of Resources Management. She brokered a deal to allow her to complete a MS in wildlife management (bats) at California State University at Humboldt. Katrina was an unflinching supporter of CRF's efforts to conduct science at Lava Beds, working with John Tinsley (Lava Beds CRF Operations Manager) and the Principal Investigators to make our operation as efficient as possible. With the rise of WNS elsewhere, Katrina invested in multiple sets of cave gear, vertical gear, and survey gear to enable volunteers to work at LABE without fear of dragging in P. destructans from elsewhere. We could not have had a more benevolent and supportive contact with LABE management than Katarina J. Smith.

Annie Esperanza

Annie Esperanza came to SEKI as a newly hired science technician in 1977; her acumen secured her advancement when women in government service faced any number of sexist challenges and obstacles to career advancement. Since discharging progressively more administrative roles since the middle to late 1980s, Annie's care and expertise has largely driven productive karst management policies at Sequoia / Kings Canyon (SEKI). Annie has been a stalwart advocate for, and when necessary, articulate defender of science in general, and the karst-related sciences in particular at SEKI. She has been a principal bulwark against ill-advised administrative policies when these have arisen from time to time. Her advice and counsel certainly have served the Foundation well at all times, but especially during the successful efforts to defend the research field station in Redwood Canyon (2010–2014) when the Wilderness Management Plan proposed eliminating that facility. A short list of the karst folks she has mentored/supervised follows, as a partial gauge of her impact as a supporter/broker for karst science.

- Joel Despain, Cave Management Specialist—Annie allowed Joel to undertake MS thesis research on karst geochemistry of Tufa Spring, at Western Kentucky University;
- Greg M. Stock, now Park Geologist at Yosemite NP—Greg did his Ph.D. dissertation applying Darryl Granger's cosmogenic burial dating to caves of the western Sierra Nevada;
- Ben Tobin, now with NPS at Grand Canyon—PhD dissertation at SEKI, characterizing and modeling aquifers feeding the Kaweah River using stable isotope geochemistry.

Annie's entire administrative existence at SEKI has embodied the goals and purposes of the Cave Research Foundation.

Eastern Operations: Mammoth Cave National Park

Karen Willmes

Eastern Operations Area Manager

2017–18

Overview and Highlights

Ten expeditions took place at Mammoth Cave between October 2017 and September 2018. Volunteers traveled a total of 229,930 miles to work at the park. They spent 10,909 hours on work directly applicable to Mammoth Cave National Park and another 1,261 hours on work indirectly applicable, for a total of 12,170 hours.

The year kicked off with CRF's 60th anniversary. The celebration was held in conjunction with the October expedition. 62 people attended. The weekend began with a reception at Diamond Caverns on Friday evening. During the day on Saturday, cave trip options included trips to accommodate all ages and fitness levels in addition to the usual expedition objectives. Roger Brucker was the banquet speaker on Saturday.

George Crothers explains archaeology to the kids in Salts Cave. *Ed Klausner*

For the Fourth of July expedition, we hosted a group of four Eagle Scouts. This is a continuation of a program begun by Bill Steele in 2016. The scouts participated in all expedition activities as well as learning about cave science and going on field trips to visit archaeologist George Crothers, geoscientist Jason Polk, and the HydroAnalytical Lab at Western Kentucky University.

A highlight of the year was the Kids Caving Expedition in August. CRF members and park personnel brought their kids (or grandkids) for a weekend of learning activities organized by Rachel Bosch and Aaron Bird. The 51 participants were led by kid expedition leaders Sam Bosch-Bird and Hal DeLong. Rick Toomey, Val Hildreth-Werker, and Roger Brucker were guest speakers. The teams of kids, parents, and adult mentors went to four caves:

- In Mammoth via the Historic Entrance, the team measured scallop sizes and water flow and observed cave sediments in Main Cave, Gothic Avenue, and Gratz Avenue.
- In Great Onyx, the team observed and recorded the presence of salamanders, crickets, snakes, and other animals and conducted bacterial sampling in order to compare microbiological activity in various cave and non-cave locations.
- In Salts Cave, the team found and described a variety of artifacts of prehistoric people, including an aboriginal dig site, flint pieces associated with digging tools, and petroglyphs, all of which were previously unknown to researchers.
- In New Discovery, the team learned about geology, hydrology, history, and speleothem growth. They made visual observations of scallops, sediments, CCC trail building relics, and gypsum crystals.

During 2017–18, there were 111 trips both inside and outside the park, which supported a variety of projects (some trips supported multiple projects):

- MCNP cartography—60
- Archaeology—2
- Biology—10
- Caves outside park (Biosphere Reserve)—27
- Geology—6

- Hamilton Valley—4
- Hidden River survey—3
- Photography—2
- Roppel cartography—16
- Small cave inventory—10
- Park requested support—5
- Hydrology—2
- Biomonitoring—2
- Conservation and restoration—1
- Signatures—1
- Technology—1
- Education—9

Cartography

Cartography has long been a major focus of Eastern Operations, and this year was no different. 60 trips supported cartography inside the park, in caves both large and small.

Seven teams surveyed in New Discovery over the course of the year. This was primarily resurvey of Big Avenue, but three parties found some previously unsurveyed passages near Noah's Way and along the route to Roaring River. Continuing survey on the Historic mapsheet took four parties to Albert's Domes to work on vertical leads. Seven parties worked to mop up leads in the Historic section in such places as Ina's Hall, Williams Dome, Ruins of Karnak, Bottomless Pit, Sidesaddle Pit, Ariadne's Grotto, Lee's Cistern, Calypso Avenue, Lively's Way, and Briggs Avenue. Although very near tourist trail, much of the survey footage was new, but it came in small chunks. In addition, one team worked to establish the elevation difference from the Walker benchmark in River Hall to River Styx. Two parties went to Gratz Avenue to refine the survey of Napoleon's Dome and nearby features. There were additional trips to Cleaveland Avenue, Silliman Avenue, Miller Avenue, Gothic Avenue, and East Bransford.

Six parties went to Salts Cave. Most of the survey accomplished was new survey. Two parties worked in Frosted Flake, at the bottom of the Corkscrew. Three did the tough trip to East Salts. One went to Finch Avenue to work on unsurveyed side leads.

Two teams headed to Crystal Cave, one of which went to the very end of Left of the Trap to investigate a possible connection to Side's Cave. They were able to hear the party in Side's Cave hammering, but the passage to go forward was only 4 inches high, 2 feet wide, and floored with flowstone. A nearby side lead was filled with sediment. They put dye into a small trickle of a stream to determine where it goes; at the writing of this report, the results of this test are not yet available. The trip in took 7 hours and the trip out 8. Pushing these connections requires determination and stamina.

Colossal Cave was the destination of 14 parties. Four parties worked on Sandy Crawl, Sandstone Tumbledown, and associated leads in this complex area. Three parties accomplished new survey and resurvey along Austin Avenue. Four parties continued the resurvey of the Bedquilt Route (the old trail between the Bedquilt entrance and the Colossal entrance) by entering from the Colossal side. Three parties worked in the Belfry Helictite area. One team worked on a profile of Grand Avenue, as requested by the National Park Service, to help them develop a potential new public tour of this passage.

Four parties entered the Doyle Valley Entrance. One party surveyed a significant amount of virgin passage in the X Loop. Three parties worked on the big breakout dome downstream and found some new passage to survey.

The other ten parties worked on small caves within the park. Two parties tried to push a crawlway to reach the known second room in Ice Cave. In South Cave, one party sketched a profile of the lower level, and one party continued the resurvey of the upper level. Photos were taken of Davis Waterfall Cave. Amphitheater Slot and Denham Cave were located and mapped. The survey of Blowing Springs Cave was begun. Two parties of thin and determined cavers went to Wilson Cave to survey in the Not Kansas Domes, Netherdomes, and Northwest Territory.

Cartography Outside of Mammoth Cave National Park

Eastern Operations supported mapping efforts outside the park in Hidden River Cave and Roppel Cave. There were three trips to Hidden River Cave, in Wheet River and Whiskey Way.

During CRF expeditions, 16 parties went to Roppel Cave. Three parties worked on the resurvey of Fleeceway. Two teams completed the resurvey of Black River. Three parties went to Lexington Avenue and came back with new survey. One party learned the through-trip route from the Kahn Entrance to the Weller Entrance. There were also trips to Currens Corridor, Roppel Junction, Yahoo Avenue, Lower Elysian Way, Western Kentucky Parkway, Klondike Crawl, and Evansville Dome.

There were also trips to nearby small caves. One group acquainted the new owners of Dogwood Cave with their property. Three ridgewalking parties located several unknown caves outside of the park boundaries. A new cave was surveyed in Hamilton Valley, called Paddy's Pot.

For the other half of the connection attempt with Crystal Cave, a team went to Sides Cave to attempt to communicate with the team going all the way Left of the Trap. Despite hammering and yelling and hearing hammering and yelling in return, they were unable to connect. While in the area, they placed and retrieved several dye bugs. They also surveyed in in Canis Major West.

Science Support

Eastern Operations was able to provide assistance to a number of scientists this year. Tom Polson took people on a biology field trip. Hazel Barton collected samples for a study of saltpeter and also tested people's feet to see how many fungal spores they picked while walking on tourist trails in the cave. Dave Griffith continued his visits to Great Onyx Cave to survey sand beetle feces with particular focus on pseudoscorpions. As part of her graduate research in geology, Rachel Bosch collected high definition video for Structure from Motion 3D reconstructions of a number of features in Historic Mammoth and New Discovery. Stan Sides used radiolocation to find the surface location of a 5-inch bore hole into Long Cave.

Park Support

If park personnel request specific assistance, Eastern Operations does its best to provide. One team went in the Doyel Valley Entrance to replace the pump at the Hawkins River confluence. Another party went to Unknown Cave to look for evidence of possible visitation or vandalism. CRF members accompanied a group of geology students from the University of Chicago who were learning about water sampling. A party assisted with water sampling to test coliform levels to see if a sewage leak was affecting Mammoth Cave.

Training and Education

The Kids Caving Expedition is just one example of educational activities that took place this year. Another was a sketching class taught by Pat Kambesis for two days during the July expedition. The trainees were able to go on cave trips and put what they had learned to use right away.

Lynn Brucker and Bob Osburn talk in the map room, little Bosch-Bird on computer. *Mark Jones*

2018–19

Overview and Highlights

Eleven expeditions took place between October 2018 and September 2019. Besides the usual expedition schedule, an expedition took place in mid-November 2018 in conjunction with the CRF Board of Directors meeting held at Hamilton Valley.

Volunteers logged a total of 292,302 miles traveling to expeditions. They spent 12,185 volunteer hours on work directly applicable to Mammoth Cave National Park and another 1,580 hours on work indirectly applicable, for a total of 13,765 hours.

The August 2019 expedition was another highly successful Kids Caving Expedition organized by Rachel Bosch and Aaron Bird. The goals were to foster a sense of connection between the kids and the cave and to encourage a stewardship ethic. Sam Bosch-Bird was this year's Expedition Leader. Kid party leaders accompanied by adult mentors led teams of other kids and their parents on four trips:

- In Crystal Cave the trip participants went to locations of historic and geologic interest such as Scotchmans Trap, gypsum crystal repair sites, and the A level in Collins Avenue. They learned about the 1954 C3 expedition and its importance to CRF, the A level, and gypsum restoration.
- Another team entered the Historic Entrance of Mammoth Cave and exited at Violet City. They learned about map symbol interpretation, prehistoric and historic cave visitation, and sketching techniques for cave survey.
- In Salts Cave the team observed and studied artifacts of prehistoric people. Their objectives included safe and careful caving techniques in a culturally sensitive location and learning about prehistoric and historic cave visitation.
- A team went in the New Entrance and exited from Carmichael to observe and consider human impacts on the cave, discussing how they affect the cave and how they affect human experience of the cave. They looked at concrete, stairs, doors, evidence of digging, benches, trash cans, telephones, lights, first aid kits, railings, trails, evidence of rock blasting, writing on walls, survey markers, bathrooms, Aero Bridge Canyon "zipline," transformers, "be mindful of bats" signs, tour groups, the elevator, and the old kitchen

equipment. They also looked at the impact people a long time ago had on the cave.

After some concern last year about declining attendance at a few of the expeditions, I am pleased to report that we saw an uptick in participation:

- October—21
- November (CRF board meeting)—32
- Thanksgiving—40
- New Year's—26
- February—56
- March—22
- April—12
- Memorial Day—26
- Fourth of July—48
- August Kids Caving—28
- Labor Day—37

The attendance for New Year's was affected by the fact that the federal government was shut down. We knew a few days in advance that we would not be able to run trips in caves inside the park. The expedition still took place, but all trips went to caves outside the park including ridge walking on the surface.

144 trips took place between October 2018 and September 2019. A variety of projects were supported, both inside and outside the park (some trips supported multiple projects):

- MCNP cartography—89
- Archaeology—4
- Biology—5
- Biomonitoring—1
- Caves outside park (Biosphere Reserve)—29
- Education—11
- Gazetteer—1
- Geology—7
- GIS—2
- Hidden River survey—2
- History—1
- Hydrology—5
- Paleontology—1
- Park requested support—25
- Roppel cartography—21
- Small cave inventory—22
- Technology—1
- Visiting scientists—3

Park Requested Support

The park asked for our assistance with several different projects, some new and some ongoing. This cooperation is a vital part of our relationship.

The park requested a map of the tourist trail between the New Entrance and Frozen Niagara with all of the light fixtures indicated so they could map algae growth associated with the lights. Nine parties devoted their attention to this task.

Cave crayfish in West Lexington Avenue in Roppel Cave.
Mark Jones

The park is considering reopening Colossal Cave to tours and would like to have a map. Nine teams worked on various aspects of this, such as surveying the Pearly Pools route; drawing profiles of Grand Avenue, Twin Domes, and Colossal Dome; and adding some additional details and cross-sections.

Another project for which the park requested our assistance is a study of the hydrology of the Great Onyx basin. Several CRF members with knowledge of the area helped identify some possible water inputs. Two teams helped place dye receptors and pour the dye in Lucykovah River and Halloween Crawl in Great Onyx Cave. Another team went in the Austin Entrance to look at water inputs in Ruth's Room and to place dye bugs and pour dye in Blindfish River.

Additional parties helped with carrying out inflatable kayaks that had been used in Roaring River, mapping some benches at Snowball Dining Room and Mt. McKinley that are scheduled to be removed during trail upgrades, retrieving pumps in Hawkins River, and checking for damage after the Sand Cave gate failed.

Cartography

Cartography continues to represent a significant part of our efforts. 89 trips supported cartography inside the park. Many of the trips listed above under park assistance also contributed to cartography objectives.

44 parties went to various locations in Mammoth Cave.

Seven parties went to New Discovery West, launching a complete resurvey of the area. As far as I can tell, no one had surveyed in that part of the cave since the early 1980s. Besides resurveying Discovery 70 and nearby passages, they found several hundred feet of virgin walking passage and another several hundred feet of cave that been scooped by an earlier explorer but never surveyed.

Four parties continued the resurvey of Big Avenue, the large trunk passage in New Discovery, some of it with profuse gypsum deposits. They also resurveyed Onyx Avenue replacing survey from 1970. A side passage of Big Avenue was surveyed for the first time, turning out to drop into Little Paradise.

New Discovery's Fossil Avenue occupied five teams. One dropped the pit located in the upper levels of Crevice Dome. Four spent time in the tangle of braided levels of North Gypsum Avenue.

One party photographed a shark fin spine and checked leads in Roaring River, and another party carried out the inflatable kayaks afterwards.

Four teams went to Alberts Domes. One team did some rigging. The other three teams surveyed leads in this complex and difficult area, finally finishing it.

Three parties worked on Cathedral Domes objectives. One resurveyed in Emilys Avenue, one tied an old survey to new survey near Bottle Hall, and one familiarized a cartographer with the area.

Four parties went to an intriguing dome complex with waterfalls on the East Cocklebur map sheet to survey and check leads.

Two parties cleared up some questions in a confusing area of cut-arounds in Bransford Avenue.

One trip went to Historic to survey small leads in Harvey Avenue.

One party checked leads off Franklyn Avenue.

Two parties surveyed the Holy Sepulcher near the Snowball Dining Room, using an extension ladder to reach the passage known to early tourists.

Sixteen parties went to Colossal Cave. In addition to trips supporting the creation of the tourist trail map for the park described above, there were three trips to survey in the Helictite Route area. There were also four trips to the Bedquilt section. One party cleared deadfall on the trail to the entrance. One party mopped up leads in the Pirates Maze of twisty passages all different and another looked at Toms Hole. A party surveyed an exciting but obnoxious lead in Silver Lining until it got too tight to follow.

Five parties headed to Salts Cave. One party mopped up leads in East Salts. Three parties tied up some loose ends off Salts trunk and drew cross-sections. Another party mapped some newly documented glyph locations and found some more.

In Unknown Cave, two parties worked on rigging and surveying in Grund Trail. One party pushed leads at the end of North Mather and White Way. The party that went to Blindfish River for the dye trace also did some survey.

Four parties went in the Doyel Valley entrance. One team mapped some odds and ends while retrieving the pumps for the park. The other three went to Fritsch Avenue, about six hours into the cave.

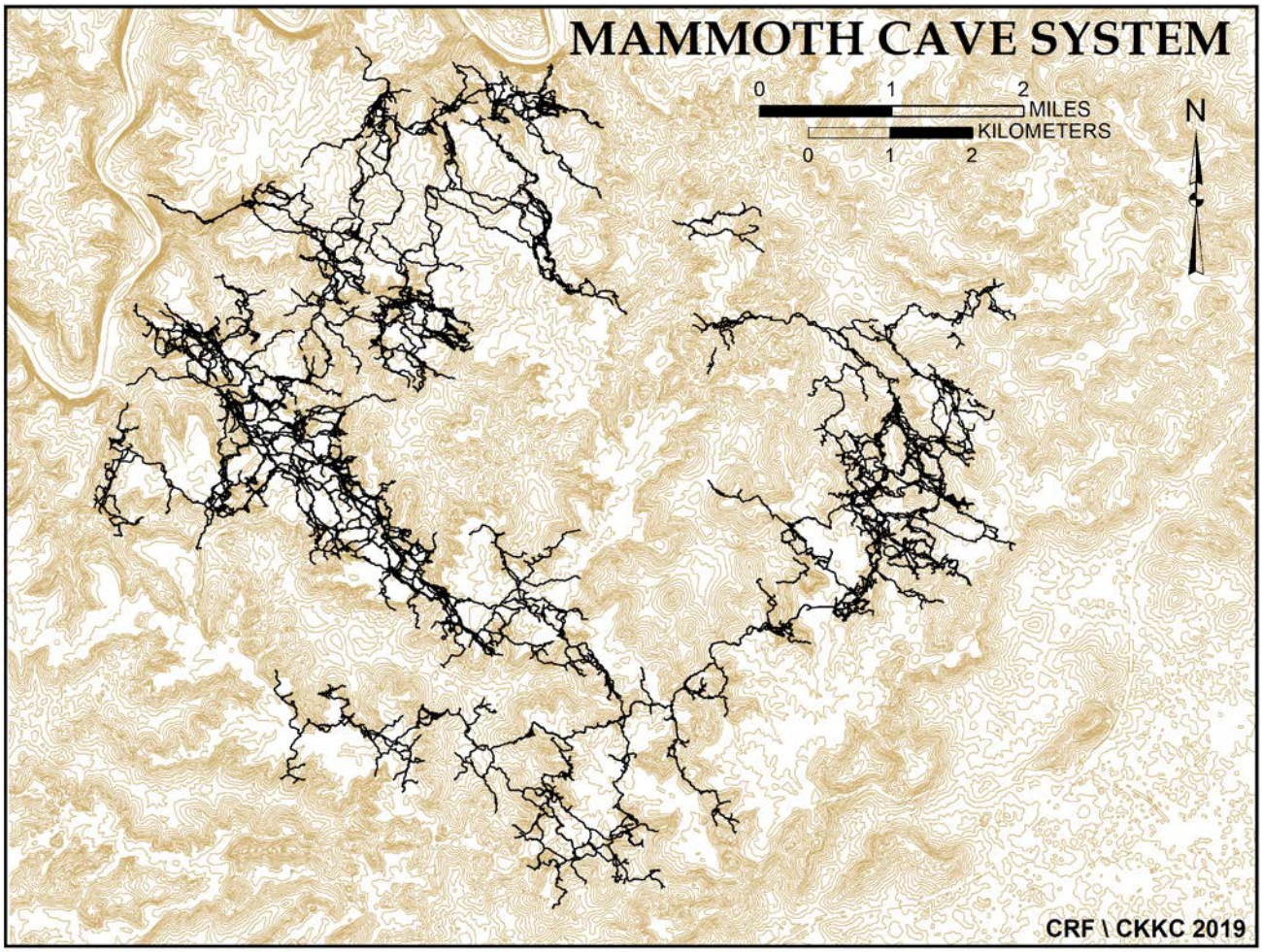
Hazel Barton does science. *Mark Jones*

Another 20 parties worked on small caves within the park. The survey of Blowing Springs Cave was continued. Brill Cave was located by one party and the survey was begun by another. Cathole Cave, Saucer Cave, Cooke Cave, Cold Creek Cave, July Cave, and Dwarf Cave were located. Root Cellar Cave, Bone Cave, Poe Wine Cellar Cave, Box Turtle Trap, Frying Pan Cave, Jims Attic, Furlong Pit #2, Moonshine Cave, Mile 197 Cave, Mt. McKinley Cave, Jessie Cave, Slippery Cave, Black Salamander Cave, Mossy Well, and Easter Cave were surveyed. Wire Cave was looked for but not found. The entrance of Oero Cave was photographed. The upper level of South Cave was continued. Two parties went to Wilson Cave to extend the cave to the northwest.

Cartography Outside of Mammoth Cave National Park

Teams surveyed in Hidden River Cave and Roppel Cave. There were two trips to Hidden River, one to continue the survey of Jingle Bell Lane and another that stumbled on some virgin passage on the way to Whiskey Way.

22 parties went to Roppel. Teams resurveyed Elephant Trunk, Goblin Trail, Johnson Way, Hobbit Trail, from Pirates Pot to Black Canyon, and to the start of Psycho Bypass canyon. One party finished redoing the loop between South Arlie Way and Western Kentucky Parkway. Other teams checked and surveyed leads in Lower Level Arlie Way, Petes Puzzle, Roppel Junction, Walter Way, North Crouchway, Lower Elysian Way, and the western end of Lexington Avenue. One party looked at Boston Domes. Teams carried equipment to Katie Jane Way, and Lower



Elysian Way for other teams to use and carry out.

Other caves outside the park that got attention included Diamond Caverns, where a party surveyed a tight lead in the Rotunda, and Stans Well, where four parties worked to regain access after the entrance collapsed. A party looked for a lost pit on a nearby property. Another party returned to a lead near Little Waterfall Cave, but not all of the party members fit.

Science Support

There were several trips to support Great Onyx basin hydrology research described above. Dave Griffith continued his observations of the sand beetle community in Great Onyx Cave. Mitchell Barklage brought a group of students from Northwestern University to the Thanksgiving expedition to perform geophysical survey experiments. Maggie Osburn and some graduate students performed water sampling from the sulfur seep pool of Mariannes Pass. Hazel Barton collected saltpeter samples in Gothic and Miller avenues. Rachel Bosch took measurements and installed an erosion monitoring station for her dissertation research. We also had a demonstration of a portable Lidar unit in Historic.

Training and Education

We once again had a group of four Eagle Scouts attend the Fourth of July expedition. They take part in a national competition to be included. This year in addition to participating in expedition activities, they were given an archaeological tour in Historic led by George Crothers, an orientation to the history of Mammoth Cave given by Stan Sides, and a briefing about geology, biology, and hydrology given by Rick Toomey while following the route from the Carmichael Entrance to Echo River.

Mammoth Cave National Park Small Caves Report

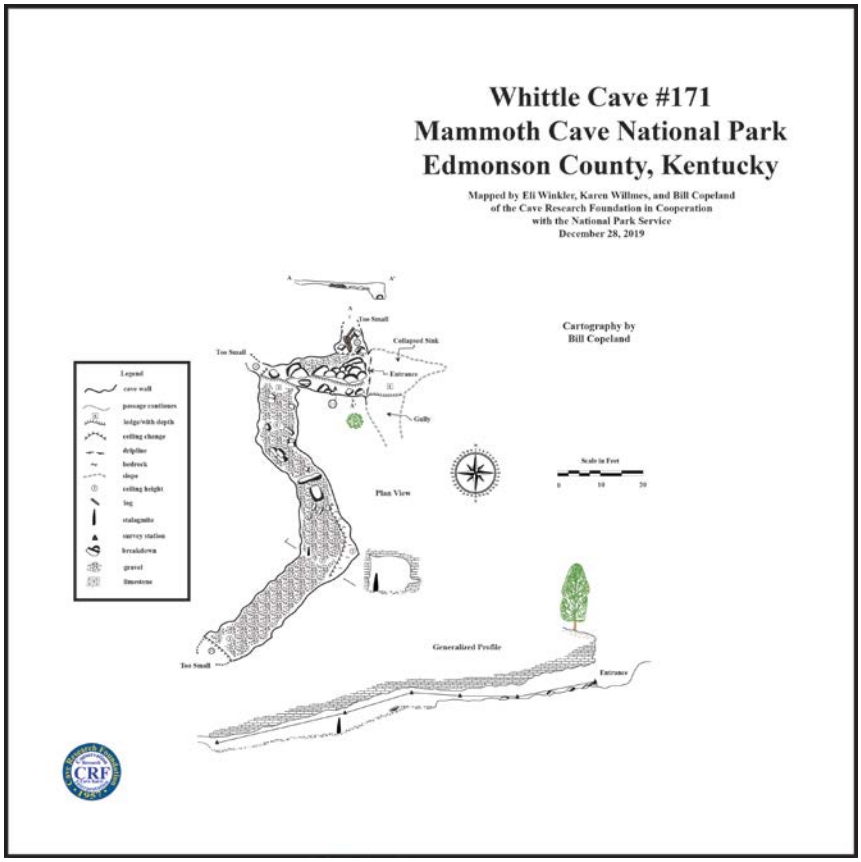
Bill Copeland

2018

Field work pertaining to small caves slowed somewhat in 2018 due to many factors. Weather patterns in and around some expedition weekends made it unfeasible to be out in the woods, but the main contributing factor was it was getting harder to field a survey crew to bust through the brush to survey a cave that took only a few shots to complete, and then have to completely decontaminate for White Nose before another cave could be entered. That being said, 12 small cave trips did occur during the year with half of those were led by David Griffith to Great Onyx pertaining to his study on cave beetles. There were two survey trips to Wilson Cave, and one to South Cave. Bob Lodge began the survey on Blowing Springs Cave.

Dave West led two surface trips to clean up the paths to Bedquilt and Wilson Cave.

I used the bulk of my time working to finish final maps of small caves that had been surveyed years and even decades earlier.



2019

This was a much better year for small caves. During the Memorial Day expedition, Rick Toomey gave us the good news that we no longer had to decontaminate between small caves. Mammoth Cave National Park contains many clusters of small caves that are a few minutes' walk from each other. These are mostly found south of the Green River and are found near the sandstone/limestone contact. It makes much more sense to send a survey crew to map three or four caves at a time than just one. We made good use of the new rules the rest of the year.

Thirty total small cave trips occurred during 2019 with 15 being survey trips. Seventeen total small caves were finished with a final map drafted. Eight trips were ridge walking trips with two new small caves found. One of these new caves was on the north side in the Wilson Cave drainage. Dave West is hopeful that once the entrance is

Whittle Cave.

Ed Klausner in Furlong Pit #2. *Bill Copeland*

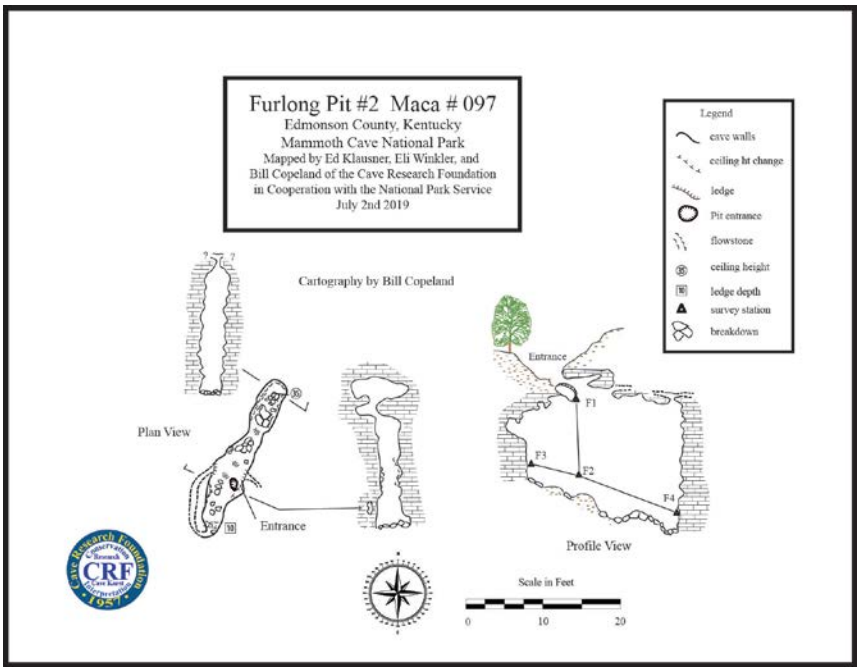
stabilized, it will be a back door into Wilson Cave. Two trips to Great Onyx were done to place dye bugs for a hydrology study. A data logger was replaced in Wilson Cave for a humidity study.

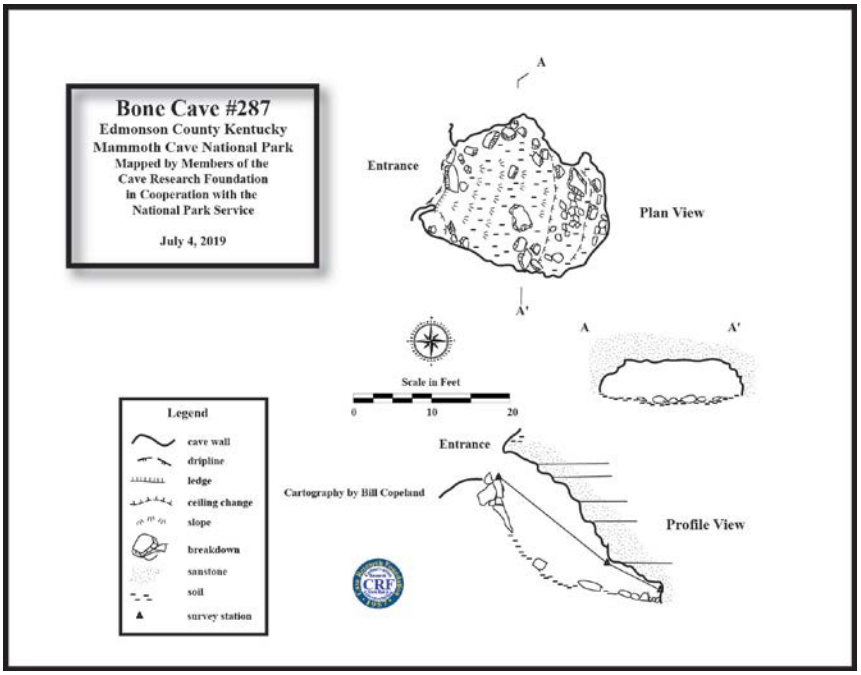
Brill Cave (just off the path going to the Austin Entrance) was the year's biggest surprise. It had been on my list to survey for quite a while. Elisabeth Winkler and I finally checked out the entrance on a ridge walking trip. The entrance pit was much deeper than I expected (27 feet). During the next expedition, a trip was scheduled to Brill and the results were encouraging. There was a lot more cave there than the old timers thought there was. At the time of this report, there is over 160 feet of cave, and has a depth of 65 feet with plenty of leads. There is also evidence that someone had been in this cave before (arrows and rock cairns were found). These trips might have been by either Floyd Collins or Bill Austin.

At the end of 2019, we had a total of 435 known small caves. Of those:

- 1 had a collapsed entrance
- 2 had entrances filled in by the National Park Service
- 7 only need a final map
- 13 have ongoing surveys
- 173 need survey (majority of these are north of the Green River)
- 239 have been completed

We also have 53 caves that are believed to exist but need further field verification. An intern hired by Lillian Scroggins of Science and Resource Management of the Park did quite a bit of field work in the fall of 2019, and supposedly found at least 6 new caves, but at the time of this writing, I have not seen the report.





Cumberland Gap National Historic Park

Kentucky, Tennessee, and Virginia

Charles Finney

2018

The Cultural Resources Survey (CRS) team had several expeditions in 2018. 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 the 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.

Considerable 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 were reported to the National Park Service (NPS).

Three major activities were conducted in 2018. The CRS team continued working on public presentation of findings. On January 5, 2018, Charles Finney presented a poster at the 2018 Annual Meeting of the Archaeological Institute of America in Boston, titled "Enabling virtual public access to archaeological features in the caves of the Cumberland Gap National Historical Park" (Figure 1). CRF researchers Stuart Daw and Joe Settles were coauthors. While in Boston, Finney met with a local 3D printing expert to discuss 3D printing of replicas of cave walls and features to enhance *ex situ* accessibility.

In the spring, CRF JVs Mike Crockett, Charles Finney, and Joe Settles assisted the NPS and a contractor (former Chief Ranger Dirk Wiley) in producing a video highlighting the cultural history of Gap Cave. This assistance included background research, planning meetings, and recorded interviews. The result was a 15+ minute video which premiered on Labor Day weekend and which is to be played for public viewing in the Visitor Center at Cumberland Gap. CRF JV Terri Brown assisted in a companion video on the natural history of the cave.

In August, CRF JVs Charles Finney and Joe Settles collaborated with three descendants of two prominent local residents whose graffiti signatures are frequently found throughout Gap Cave and elsewhere. Finney and Settles led Luke Bauserman and his uncles D. Austin Rehl and W. Jared Rehl to several places in the cave, including deep

Figure 1. Poster at the Annual Meeting of the Archaeological Institute of America, Boston [2018–01–05].

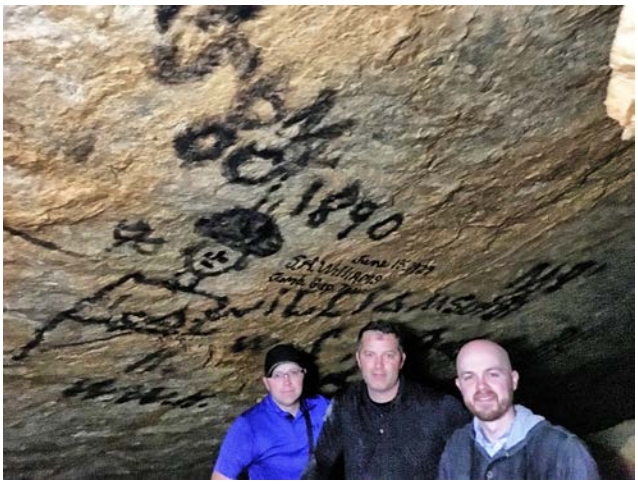


Figure 2. Jared, Austin, and Luke (L-R) beneath signatures of S.A. Williams Senior and Junior [2018–08–26].

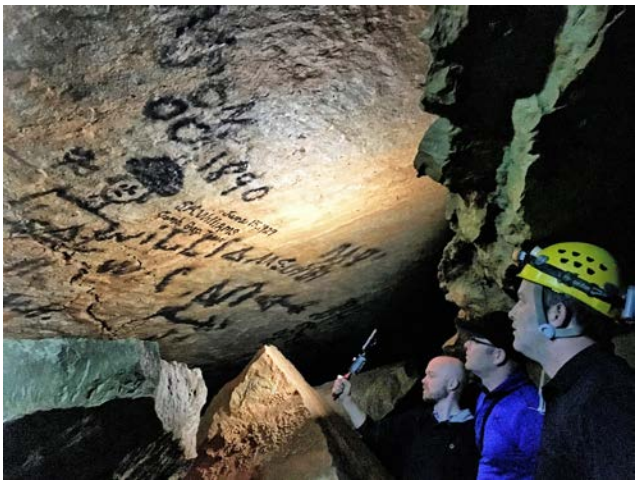


Figure 3. Luke, Jared, and Austin (L-R) viewing signatures of S.A. Williams Sr and Jr [2018–08–26].

into the cave near Hell Hole where their great-grandfathers Sterling Austin Williams, Senior and Junior, had left their signatures (see Figures 2 and 3). Here is an except from the trip report:

The signature of "Amos" (usually in double quotation marks) is prolific and prominent throughout Gap Cave (probably within the top 5 most numerous), but with limited peripheral information was difficult to attribute to a specific individual. In late 2013, Joe Settles identified this "Amos" as Sterling Austin Williams Jr (SAW Jr) of Cumberland Gap, by analyzing his distinctive writing style. In early 2014, during the course of background research, Charles Finney contacted Luke Bauserman on the ancestry.com site regarding the use of Luke's photographs of SAW Sr. Charles and Luke exchanged photographs and other biographical information. The CRF Cultural Resources Survey (CRS) team, on 2013–10–26 near CRF survey station JQ16 near Hell Hole, had observed a candle-soot signature of SAW Sr, probably from 1890–10–11, and immediately adjacent a carbide-soot signature of SAW Jr, dated 1929–06–15. SAW Sr had died two years before the SAW Jr signature.

In August 2018, Luke contacted Charles, saying that he had new photographs and other information regarding the father and son, and that he and his uncles would be visiting Cumberland Gap on August 26. Because this date fell within the scheduled CRF expedition weekend and was regularly permitted, the CRS team offered to show Luke and his uncles various "Amos" signatures within Gap Cave and to continue information exchange. Luke and his uncles, Austin and Jared, are the great-great grandson and great-grandnephews of SAW Sr. The names Sterling and Austin are still used within the family.

The two parties met at the O'Dell House Research Station at noon on August 26. Stuart Daw oriented Luke, Austin, and Jared to CRF CUGA operations and safety considerations, and enrolled them as CRF Joint Venturers, using the temporary form, and had them review and sign the White Nose Syndrome and Low Impact Caving forms. All cavers then geared up to enter the cave. Stuart accompanied the team to the lower (Gap) cave entrance but did not enter.

The team called the Tunnel at 1350 and entered the cave via the lower entrance. They proceeded to the jump off point, stopping to view signatures at the Rat Passage and in the Signature Room. The team arrived at the signatures of the father and son around 1600. Several photographs of Luke, Austin, and Jared were taken near their ancestors' signatures.

Along the way, the team observed several other signatures and graffiti which had not previously been documented during CRS surveys. These will be researched and documented.

On the way out, the group proceeded out through the upper (Soldiers) cave, visiting the Music Room and the Dance Floor. The team exited the cave via the upper (Soldiers) entrance and called the Tunnel at 1845.

A result of the information exchange between Luke and CRS team is that much more is known about SAW Sr and Jr, particularly regarding their interaction with the cave when they lived proximately in Cumberland Gap town. Additionally, the CRS team will look out for a signature of "Peaches", written by SAW Sr, which was the nickname of Fleda Stella Williams, the sister of "Amos".

2019

Summary

Cartography

- Powell Mountain Blowhole—continuation of prior-year surveys

Geology

- Installation of sondes/instrumentation in various locations in Gap Cave

Cultural Resources

- Work to begin integrating artifacts and graffiti into Park GIS

List of JVs

- Bob Alderson
- Terri Brown
- Evin Carter
- Stuart Daw
- Charles Finney
- Lindsey Hayter
- Bob Hunter
- Adam Jones
- Vincent Leray
- Nathaniel Mann
- Matthew Niemiller
- Cheryl Pratt
- Joe Settles
- Dave Socky
- Levi Trumbore
- Kirk Zigler
- Joe Zokaites

There were a good number of first-time volunteers on temporary JV agreements.

Plans for FY2020

Cartography

- Powell Mountain Blowhole—will probably continue, usually in the March expedition
- Activity has been reduced quite a bit following the removal of overnight access to the Research Station; out-of-state team looking for alternative accommodations in the area

Geology

- Continue hydrological survey of Gap and other caves in the Park

Cultural Resources

- Continue work to integrate with the Park GIS

Charles Stuart Daw

March 16, 1950–July 2, 2019
Fellow, NSS (14944)
Fellow, CRF
Stuart passed away after a 12-year battle with cancer.

Stuart was a stalwart participant with the CUGA expedition from its inaugural trip in May 2003 till his death, rarely missing a month. He loved bringing students to learn about caves and the importance of scientific research.

Stuart Daw.

Cave Hollow—Arbogast Cave Survey Project

Monongahela National Forest, West Virginia

Dave West

FY2018

October 21, 2017. Six persons undertook the second trip into the system via the Arbogast entrance. One party surveyed 692 feet in the cave and 72 feet on the surface. A Northern Red salamander, a 3½-inch-long crayfish, aquatic isopods, pigmented amphipods, two tricolored bats, camel crickets, cave crickets, and many orb-weaver spiders were observed. Graffitti was also noted; some of it dating to the period of closure.

The next set of trips occurred on November 4, 2017. Three parties surveyed in Arbogast Cave, and one attempted to survey Arbogast Pit, which is not known to connect to the system. The group attempting the pit did not fit, so they examined other pit entrances into which they did not fit either. The three in-cave parties surveyed 1,851.935 feet closing a few loops in the process. Three big brown bats, two tricolored bats, and one unidentified myotis bat were observed. One white millipede, one terrestrial isopod, three aquatic isopods, two pigmented amphipods, cave crickets, orb-weaver spiders, a harvestman spider, and heleomyzidae flies were observed.

Three parties entered Arbogast Cave on December 2, 2017. Multiple copies of *Cave Life of the Virginias* had been obtained and were provided to each party. They surveyed 1,398.085 feet. Two tricolored bats, one big brown bat, one black beetle, two pigmented millipedes, one pseudoscorpion, pigmented amphipods, cave crickets, feces (probably racoon), an orb-weaver spider, and another spider 2mm, with a pale abdomen and brown legs, were noted.

Gathered for the first survey trip to Cave Hollow Cave in over 30 years, and we had the wrong key! L-R: Jay Balakirsky, Dave West, Dennis Melko (kneeling), Karen Willmes, Katey Bender (hanging on gate), Aaron Bird (kneeling), David Socky, and Wayne Perkins. *Jay Balakirsky*

Crayfish. *Aaron Bird*

Trips in January, February, March, and April were canceled due to snow-covered roads.

The May 5, 2018, trip occurred on Cinco de Mayo. Two parties attempted to get in the cave but discovered that the keys provided did not fit the lock. They left the gate area and ridge walked in the area. One pit was found that requires further investigation.

The June 2, 2018, trip was canceled due to high water over the low water bridge leading to the cave area.

On July 21, 2018, one party surveyed in from the Ribcage entrance. They surveyed 215.18 feet. Banded crickets and orb-weaver spiders were observed. Numerous bones were observed, including many rib bones, presumably cattle or deer.

August 18, 2018 saw a single party finally enter the Cave Hollow entrance. They located the nearest survey station placed from the Arbogast entrance and surveyed 250.97 feet. They noted one cave cricket, much graffitti (some of which is from the late 19th and early twentieth centuries), a broken bottle, and more feces (probably racoon).

On September 15, 2018, five people split into two parties in the Arbogast entrance. They surveyed cutarounds

Historic graffitti. *Dave West*

near the Warm Room and the C. Weiland Room, then regrouped and proceeded to the Pebblehenge Room where they surveyed both routes to the stream and the stream that parallels the room.

A total of 5,270.51 feet of survey have been accomplished during this period, bringing the total length of the survey to 6,510.81 feet. Numerous biological and cultural observations have been made. All despite being denied access by various issues for half the year. It is hoped the weather will be more cooperative in the coming year. 20 individual volunteers contributed 757 hours during the period.

FY2019

In 2019, we made nine trips to the Cave Hollow—Arbogast Cave system (CHAC). Forty person-trips contributed 602 hours of travel and field work. Dave Socky invested 216 hours in cartography, and he and Dave West contributed another 105 hours administering the project. 8,554.77 feet of survey was accomplished in the year, bringing the current survey length to 15,065.58 feet.

Jay Balakirsky, Wayne Perkins, Dennis Melco, Bob Hoke, Karen Willmes, and Dave West formed two teams in November for a bit of surface work and then survey toward the Golden Spike Room from the Arbogast entrance. We accomplished over 208 feet of survey and introduced Dennis to the Tate's Compass brand when a broken plastic imitation Brunton was found. As we all know, he who has a Tate's is lost.

In December, Dave Socky, Jason Delafield, Wayne Perkins, Karen Willmes, and Dave West formed two teams that would work close to one another. We accomplished over 921 feet of survey in the Cave Hollow main stream and a passage above it. Dave and Karen observed what appeared to be large, white, blind salamanders. They had legs that looked too short to be useful on land and swam more like a fish than a salamander. Unfortunately, the camera was packed away, and no photo of the creatures was taken.

The next trip was in March, when Dave Socky, Wayne Perkins, Coleman McHose, Hope Brooks, Eric Pelkey, Jay Balakirsky, and Dennis Melco surveyed over 1,103 feet of survey, bringing the surveyed cave closer to the Golden Spike Room.

A night trip was planned for April, so we could survey to the Cave Hollow entrance while the bats would be out feeding. Wayne Perkins, Bob Hoke, Marissa Loftus, Karen Willmes, and Dave West entered the cave around 11:20 p.m. and began surveying downstream. After a bit over 381 feet of survey, we found ourselves directly below a cluster of bats that we had not expected. We aborted the trip and headed out, getting to bed around 4:00 a.m. The blind salamanders seen in December were not in evidence.

In May, Dave Socky, Bob Hoke, and Dennis Melko surveyed over 870 feet upstream from the Pebblehenge Room toward Lake Susan. Returning to where the May trip had ended late in the day and seeing no bats, they completed the remaining 350 feet to the Cave Hollow entrance. No blind salamanders were observed.

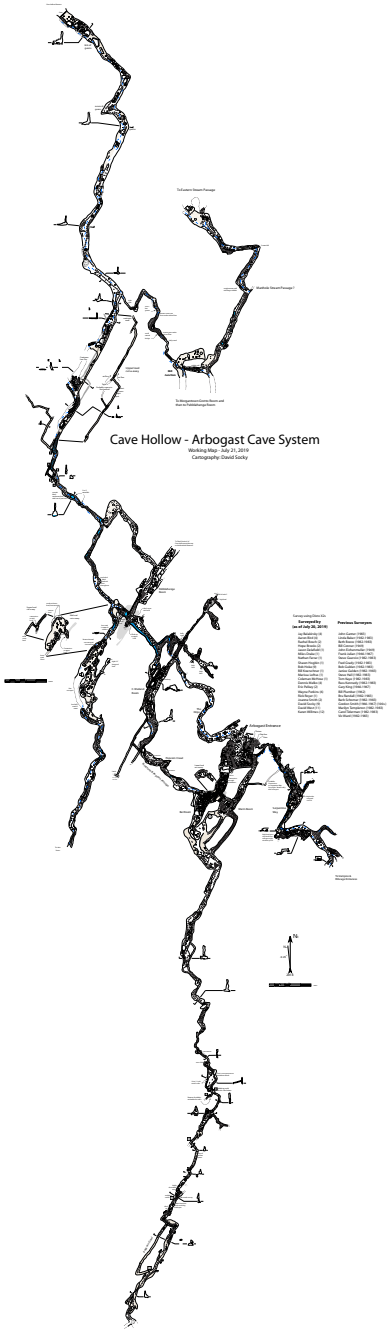
In June, Dave Socky, Bob Hoke, and Karen Willmes surveyed to the 360 Room and beyond from the Cave Hollow stream while I rested my back at the Alpine Lodge. They accomplished over 1,100 feet of survey before sketcher burnout set in. Efforts to obtain photos of the blind salamanders continued to be stymied as only Spring Salamander larvae were observed.

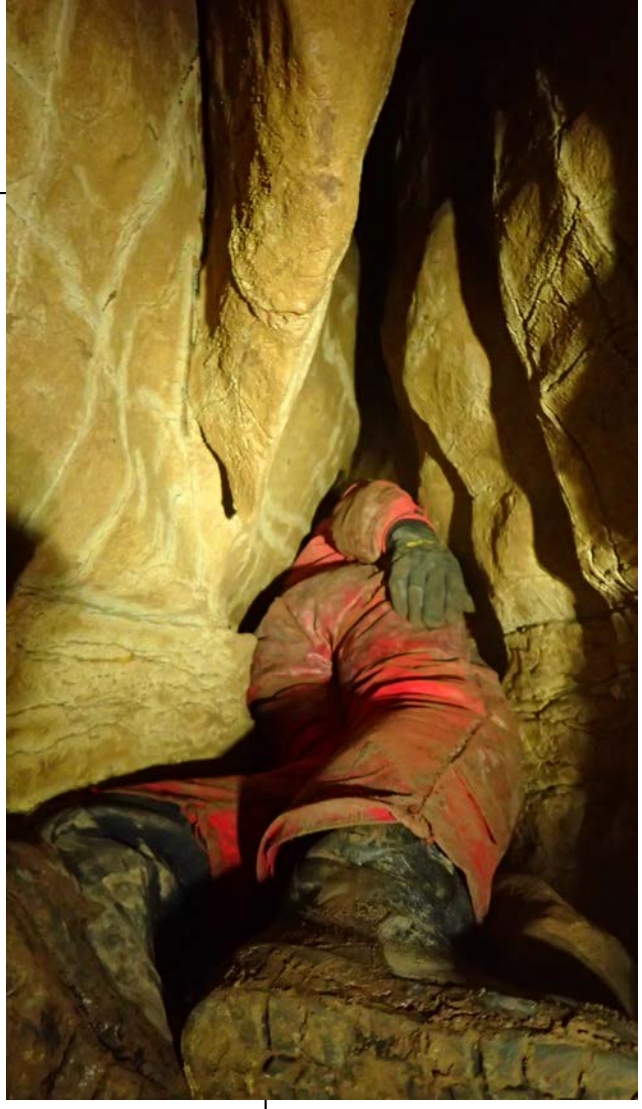
July is the one month when neither the Arbogast nor the Cave Hollow entrance may be used as this when the Virginia big-eared bat pups are being reared. A flood event before the trip severely damaged the road up to the cave area, as well as the driveways to the caves. Dave Socky, Karen Willmes, and Dave West entered at the Ribcage entrance to continue the Serpentine Way survey. After seven stations and just over 44 feet of survey, we reached a point where neither Dave would fit. This area will need to be completed from the Arbogast entrance.

In August, we were able to field two teams in the cave. Dave Socky, Bob Alderson, and Chris Coates continued from the June survey in the Manhole section while Bill Koerschner, Karen Willmes, and Dave West surveyed a loop to the 360 Room through the Morgantown Grotto Room, and continued toward the Pebblehenge Room. The two teams got almost 1,470 feet of survey.

Dave Socky, Bob Alderson, and Bill Koerschner went in September with the goal of reaching the Golden Spike Room. They accomplished this with about 947 feet of survey, surveying some side leads along the way.

All in all, it was a very productive year. We appreciate all of the assistance from the Monongahela National Forest in accommodating this effort to better document this important bat cave system.





Chris Coates checking a high lead. *Dave Socky*

Bob Alderson sketching.
Dave Socky

Hamilton Valley Report

Pat Kambesis

Hamilton Valley Manager

2017–18

Comment on HV finances

Hamilton Valley income saw a decrease this year. One of the Karst Field Studies classes did not make it and two additional university field trips were canceled that usually use our facility. The CREP program that we had been enrolled in for many years has been canceled (loss of $1300) as well.

Hamilton Valley expenses increased slighted because of a required inspection by our insurance company that required upgrading part of our fire suppression system, the purchase of new filters, and installation of lighted exit signs in the main and archive buildings. Our annual fire inspection required the replacement of some of our bunk room fire extinguishers to meet code.

The land management committee decided that they wanted to pay someone to mow the lawn instead of me doing the mowing. They hired our hunters to do this. They show up in force 2–3 times/ month with two 48-inch wide lawn mowers equipped with clippings bag and they do a very professional looking job on the lawn. Cave Books pays for this service, but I do not know how much.

Elizabeth Winkler is now the second signatory on the HV checking account.

Trailer Status

I showed the trailer twice this year and thought we had a taker. I referred the petitioner to John Feil but have not heard if arrangements have been made to remove the trailer.

Inspections

On December 11, 2017, an inspector from our insurance company came to HV to look at fire safety equipment i.e., fire extinguishers, fire suppression system, safety lights and electrical boxes. I walked him through all of our HV buildings including the bunk rooms and utility shed—he took lots of photos.

All of our fire-related stuff had been recently serviced including all fire extinguishers in the bunk rooms. I bought extinguishers for the utility building and one for the care-taker's house. I also had all of the safety lights inspected and replaced where necessary, so we were good on all of those.

Post-inspection requirements included having our stove hood and vent cleaned and inspected, new filter system, installation of vapor proof lights over the stove, additional exit signage, and batteries. We are required to keep all cooking grills at least 10 meters from the buildings and to store them when not in use. Any fire pits need to be at least 30 meters from any building—which means we can't have a fire pit at all.

We were asked if HV had a company-monitored fire alarm system (the fire alarm near the coffee maker is just wall decoration). When Superior came to service all of our fire safety stuff, they recommended that we didn't really need to have a company-monitored fire alarm system unless it was required by our insurance. This was not specifically required by the insurance company, but if it ever is, Superior does have such a service, and they can install necessary equipment.

New Acquisitions at HV

Cave Books purchased a big screen TV and installed it at the back of the dining room of the main building. The reason they did this is because Cave Books is in the process of putting together CRF's library collection which will go in the classroom on the shelves at the back of the room. The concern is that random users of the classroom might remove valuable library books.

A new whiteboard was installed next to the TV. This was to declutter the back of the room.

New Sales Tax Law in Kentucky (which applies to non-profits as well)

On July 1. 2018, Kentucky instituted a new tax which might affect HV rentals.

Campsites/Campgrounds/RV Parks

Amendments to KRS 139.200 (2) (a) add **rentals at campsites, campgrounds, and recreational vehicle (RV) parks as accommodations** subject to 6% Kentucky sales tax. Sales tax is applicable on the rental of any rooms, lodgings, or accommodations furnished by these campsites as well as by any hotel, motel, inn, tourist camp, tourist cabin, or any other place in which rooms, lodgings, or accommodations are regularly furnished to transients for a consideration. The tax shall not apply to rooms, lodgings, or accommodations supplied for a continuous period of thirty (30) days or more to a person. The rental of campsites, campgrounds, and RV parks remains exempt from the state and local transient room taxes.

How does this apply to HV? I met with our university legal person who says that CRF is exempt from the sales tax because we are educational in nature. I have also reviewed the website https://taxanswers.ky.gov/Sales-and-Excise-Taxes/Pages/default.aspx) document (https://revenue.ky.gov/News/Publications/Sales%20Tax%20Newsletters/Sales%20Tax%20Facts-May%202018.pdf) that outlines who is subject to the tax. As per the website, the sales tax does NOT apply to the following:

Items Excluded from the Sales Tax

Admission to events held by nonprofit organizations that have an educational or training purpose, such as art classes or church camps, as well as events held by primary and secondary schools. College scholarships will also **not** be subject to the sales tax. We do not have to pay this due to our educational and training purposes.

HV Caretaker Responsibilities

At the 2017 CRF Board meeting, the HV director was asked to make a list of HV caretaker responsibilities.

2018–19

Comment on HV finances

The US Government shutdown from December 22, 2018 to January 25, 2019 had an impact on Hamilton Valley income. All of the big group "Non-CRF" users who typically use our facility between January and March canceled their reservations in late December due to the uncertainty of the length of the shutdown (most of them work with Mammoth Cave National Park either for educational field trips, research projects, or as volunteers). We got our first big group of 2019 at the end of March. Also, one of the Karst Field Studies classes was canceled (we had three scheduled) because the class did not meet the required minimum of eight students.

We currently have 10 big non-CRF groups (> 20 people) scheduled to use HV between late October 2019 through March of 2020 which will help us out a lot next fiscal year-as long as another government shut-down is not threatened or actually happens.

Trailer Status

We finally have someone who wants to take the trailer off of our hands and move it to their property about 5 miles from HV (Steve Miller). John Feil needs to be on site when they move the trailer and they will contact him when they get a firm date. They will hire a professional trailer moving service to do the job.

Insurance Review

I tried to re-schedule a visit with our insurance again at his request, but he has never followed-up with me on it. He had originally stated that he wanted to re-evaluate our insurance needs but I have never heard back from him on that.

Caretakers Agreement

Based on input from various CRF Board Members, the Caretaker's Agreement that I provided last year has been updated and is ready for Board review. It includes Caretaker responsibilities as well.

Hamilton Valley Work Weekend

We had two work weekends this year but volunteer attendance was very low. However, we were still able to do some deep cleaning at the main facility and the Hamilton Valley Management Team was also able to complete some of their outside objectives. Our next scheduled work weekend is the weekend of November 15, 2019.

CRF Northwest Synthesis

John Tinsley

Northwest Operations Manager

2018

The field year for 2018 was impressively productive with at least 9 expeditions occupying the Research Center; three of these were multi-day affairs led by Scott House, Ed Klausner, and Dave West. One centerpiece was the International Vulcanospeleological Symposium, July 22–26, which attracted about 60 attendees to the Winema Lodge near Tulelake and Lava Beds National Monument (LABE).

Caves of Modoc National Forest (Bill Broeckel)

This project is aimed at those caves that ought to have been included in the Monument when it was created but that were excluded from the Monument owing to considerable super-adjacent timber resources. Among the geologically interesting aspects of this project are the series of vents spawning the basalt of Valentine Cave flow (basaltic andesite, actually) and a sizeable tract of ground where the basalt of Valentine Cave disconformably overlies the basalt of Mammoth Crater. Bill Broeckel made several trips to Lava Beds in 2018 and is winding up the survey of Steamboat Frank Cave, a most significant lava distributary system that he discovered. This newly-found system is the key to recognizing where the earliest flows of the eruption of the basalt of Mammoth Crater actually went. He continues to prospect for caves along the vent areas of the basalt of Valentine Cave. Specifically, additional geologic studies are planned for 2019 in Steamboat Frank Cave, owing to its geologic significance for the model of the eruption of the Mammoth Crater basalt flow. Bill and Judy Broeckel also assisted with the House and Klausner/West expeditions in 2018.

Bill Broeckel. *Mark Jones*

Paul McMullen and Elizabeth Miller surveying from entrance to entrance. *Ed Klausner.*

2019

The 2019 field season was a highly productive year for CRF operations at Lava Beds, both externally and internally. Pursuant to enabling motions by the CRF Board of Directors, the former Lava Beds operation has been reorganized and re-named "CRF Northwest" to include the exciting new mapping and inventory project at Craters of the Moon in Idaho headed up by Mark Jones as well as the longer-established operations at Lava Beds and at Modoc National Forest led by Bill Broeckel. John Tinsley will continue as operations manager and designated herder of the CRF activities and personnel.

At CRF Northwest, we mustered seven expeditions at Lava Beds (LABE) and two expedition to Craters of the Moon (CRMO, Jones). There were 53 caves surveyed at LABE and 32 at CRMO, yielding 7,555 feet of survey at LABE and 8,884 feet of survey at CRMO.

Project Realignments at Lava Beds during 2019

1. *Valentine Cave Flow Cave Mapping* reorganized. Heather McDonald found her circumstances did not make it advisable for her to continue as head of the Caves of the Valentine Flow project. She has resigned in favor of John Tinsley and Bill Broeckel taking it over. Tinsley wrote a new proposal proposing a partnership arrangement with Lava Beds management, and it was approved. The new project is titled, *Survey and Inventory of Caves of the Basalt of Valentine Cave Flow.*

2. *Photomonitoring of Selected Cave Features at Lava Beds*, by Bill and Peri Frantz, has been discontinued. Bill and Peri have relocated to New Hampshire and are not in a position to continue this valuable work. They have left the project in the hands of Pat Seiser with Resources Management at Lava Beds. CRF will work with Pat to update these files as may be needed. Bill and Peri had updated all the photo-points prior to their relocation, so this work is stable for now.

3. *Monitoring of Selected Ice Caves at Lava Beds*. The retirement of Bill Devereaux has left this project without a champion. Resources Management has taken over the organization of this work. Initiated in the early 1980s, prior to the advent of CRF in 1989, Mike Sims and Bill Devereaux together have assembled one of the more long-lived data sets in the files there. They elected to continue the work under CRF's umbrella in 1989, when Janet Sowers organized the formal CRF studies there. A delightful update was provided by Mike and Bill at the 18th IVS meeting in 2018. It is interesting to note that the caves being surveyed have changed as ice has progressively disappeared from a number of the caves, or has shifted deeper subsurface.

Karen Willmes getting ready to survey. *Ed Klausner*

Skull Ice Cave remains stable. CRF personnel will assist Pat Seiser or her successor with these surveys as needed.

4. *Craters of the Moon (CRMO) Inventory and Mapping Project* (Mark Jones, Principal Investigator)

This highly promising study is newly organized by Mark Jones and thus far it has received enthusiastic support. As it is based in Idaho, the CRF Board has broadened the operations area to include CRMO and henceforth the old Lava Beds operations area will be CRF Northwest. Mark Jones summarizes the CRMO project elsewhere in this volume.

Caves of the Valentine Flow

Heather McDonald

Principal Investigator

During the continuing 2018 field season, owing to lack of available field personnel, there was only one trip totaling six person-days.

On Sunday, July 1, Bill Broeckel, Judy Broeckel, Matt Leissring, Heather McDonald, Bruce Rogers, and Liz Wolff hiked out to Arkansas and Steamboat Frank Caves on the southern boundary of the Monument. Surveys and GPS measurements helped determine that the entire extent of Arkansas Cave, a cave previously surveyed by Bill Broeckel as part of his CRF project, is actually located within the Monument boundary, and thus is part of this project. They did not enter Arkansas Cave and only located entrances.

Heather and Matt assisted significantly with the 18th International Vulcanospeleological Symposium leading several field trips.

Basalt of Mammoth Crater, Craig Cave Mapping, and Caves of the Basalt of Valentine Cave Flow Projects

John Tinsley

Principal Investigator

2018

This research originated in 2014, when Tinsley proposed re-mapping Craig Cave and Craig Temple Cave; deliverables to include plan and profile maps, cross-sections, and the supporting survey data. Analysis of a rock sample confirmed that the basalt exposed in the ceiling overlying a reddened, baked paleosol in Craig Cave atop the so-called terminal breakdown pile was the basalt of Valentine Cave, by virtue of its elevated titanium content, a finding consistent with other analyses of that flow obtained by Dr. Julie Donnelly-Nolan of the U.S. Geological Survey during her mapping of Medicine Lake Volcano. Additional rock chemistry analyses show that the basalt of Valentine Cave (bvc) also (1) invaded Craig Temple Cave, partly blocking the present entrance, and (2) comprises the upslope blockage that presently terminates Craig Temple Cave. Apparently the bvc lava invaded the Craig/Craig Temple conduit through a skylight located upslope, in addition to forming the three lava cascades exposed on the west wall of the present entrance to Craig Cave.

With the discovery of Steamboat Frank Cave (SFC) by Bill Broeckel, and the multiple episodes of lava eruptions that it preserves internally, a geochemical sampling program was designed to test whether or not the internal eruptions recorded in SFC were phases of the ~35,000 year old basalt of Mammoth Crater (bmc) of Donnelly-Nolan and Champion, 1987) or not. It turned out that all SFC samples in the upper part of the cave were chemically most similar to bmc samples in Donnelly-Nolan's geochemical database. More significantly, these samples were especially high in silica and potassium indicating an early eruptive phase of lava that had reacted with (and assimilated) rocks having continental crust affinities; similar lava compositions occur near the vent of Mammoth Crater. Thus, SFC was a conduit for such potash-rich and silica-rich lavas linking the Mammoth Crater source area with a couple of orphan samples located along the eastern limit of the bmc out east of Big Sandy Butte, outside the Monument.

Sampling of the last lava to pass through major tubes feeding each of the five major lobes of the bmc flow was accomplished by taking proximal and distal samples of pahoehoe lava on the floors of those tubes. These lava samples from major conduit caves plugged a major void in the regional geochemical database, because virtually all Donnelly-Nolan's samples are from surface outcrops.

The new geochemical sampling results enable volcanologists to identify an eruptive history for the basalt of Mammoth Crater. The most assimilated chemistries, and thus the presumed earliest erupted bmc lavas, occur in the Mammoth Crater vent area and along the easternmost aspect of the bmc flow complex via SFC. The Craig Cave flow was active subsequently. The Headquarters lobe

Mark Jones searching for caves in Elmer's Trench. *Ed Klausner*

(including the Cave Loop caves), and the Skull Cave lobe are chemically similar, and show abundant signs of mixing with more primitive lavas in the magma chamber; however elements of the Skull Cave flow truncate structures formed by the Headquarters lobe lavas, so the Skull Cave lobe is assigned a slightly younger position than the Headquarters lobe.

The Balcony Boulevard and Elmer's Trench lobes have chemistries also indicative of mixing, but did not vent from the Mammoth Crater areas, but rather erupted from bmc vents further downslope, along the Bat Butte, Bearpaw Butte, and Modoc Crater trend, and may be in part coeval with Skull Cave lobe lavas, or more likely are slightly younger. The youngest lavas geochemically are those that are the most differentiated gravitationally with elevated iron and magnesium contents. As time is required to gravitationally separate these components within a magma chamber, volcanologists reason that this bmc lava, comprising the northwestern-most lobe that extends out past Mt. Dome beneath the Callahan flow and other post-bmc flows, are the last lavas to be erupted during the bmc event. Studies of the Earth's secular paleomagnetic field recorded by the bmc lava show but a single field direction for all of Duane Champion's samples. This negligible degree of dispersion requires the eruption of as much as 5 km^3 of bmc lava which took no longer than 3 to 4 decades to accomplish. Tinsley presented these results at the 2018 International Vulcanospeleological Symposium convened at Winema Lodge near Lava Beds NM in July of 2018 (Donnelly-Nolan and others, 2018). Work to refine this model continues.

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; easily the 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 geologic map showing only the Lava Beds National Monument's geology]
3. *Emplacement of the basalt of Mammoth Crater*, by Julie Donnelly-Nolan, John Tinsley, and Duane Champion (USGS, Menlo Park, CA. [abstr]. 2018, International Vulcanospeleology Symposium, Winema Lodge, Tulelake, CA. Tinsley assembled the talk and delivered the presentation.

2019

Geochemical Trends in the Basalt of Mammoth Crater (bmc) Flow

The initial results of the study were presented by Tinsley at the 18th IVS meeting in 2018, and used geochemical models of magma body evolution to determine the likely order in which the lobes of the Mammoth Crater flow developed. That interpretation was based on a suite of surface rock samples obtained from proximal and distal locations in each of the lobes of the bmc flow. After conferring with Dr. Julie Donnelly-Nolan of the USGS, Tinsley set about sampling the third dimension of the bmc, by obtaining shallow, intermediate and deep samples from Sentinel Cave and from Post Office Cave in the Cave Loop/Headquarters flow lobe, mainly because the mapping by Liz Wolff and Ed Klausner respectively showed the nether regions of those flows reached the greatest subsurface depths and hence enabled access to the greatest thickness of Mammoth Crater lava. If we cannot see any useful trends in those samples, it is unlikely that they are present in the other, more shallow flow lobes. A dozen samples were obtained and are awaiting analysis through the offices of Donnelly-Nolan.

Survey and Inventory of Caves of the Basalt of Valentine Cave Flow

Following approval of the proposal restructuring this study initiated by Heather McDonald, Tinsley spent a couple of days in the files at LABE headquarters making copies of the recon cards as an initial guide to what was out there, and found 92 features, shelters, grottoes, or caves known to management. Time permitted only mapping of 3 caves in 2019. Prior work by CRF mappers in other lobes of the Mammoth Crater flow show that the number of known caves increases by about 40% after a concerted effort at systematic exploration and resurvey is conducted.

John Tinsley and Lori Shultz, working alphabetically through the recon cards, surveyed aptly named Antler Grotto (V655) at 42 feet, Basement Cave (V345) at 112 feet in the upper passage; a lower level with an unstable point of entry remains for future survey. Elements of the trench system associated with Basement Cave rival the width dimensions of Valentine Cave itself. Tinsley and Paul McMullen started a survey of Crissy's Cave, a segmented flow conduit. The first segment contained 77 feet. Total new survey was 230 feet. Much work remains.

Cave Loop Resurvey Project

Lava Beds National Monument

Liz Wolff

Principal Investigator

2018

The Cave Loop Resurvey Project was instigated following a rescue from Catacombs Cave. Then-current maps did not show the lowest end of the cave. Following the rescue by cavers, Superintendent Craig Dorman requested the cave be resurveyed, complete with a vertical profile and more information than was included on the current map. Since then, the Park has requested high quality resurveys of all the caves on Cave Loop that are open to the public. These have been completed. Focus has now shifted to many of the unimproved, associated caves found on or around Cave Loop.

Associated Loop caves surveyed in 2018 include Maze, L-288(?) dubbed Peek-a-Boo Hole by the finder, and Frontage Road Cave. Maze Cave has seen 12 cavers who put seven days into the cave in 2018. The upper level has been completed with 496.8 feet of survey. The lower level has 886.4 feet surveyed so far, and about that same amount of passage still needs to be surveyed. Total resurvey for Maze Cave to date is 2315.7 feet.

A visual survey for secondary minerals was conducted and some possibly unusual ones found and photographed. Old carbide dumps have been noted. Many insects, rodent nests and one rubber boa have also been noted. In the lower level, a room was surveyed that contained pools of water with floating mats of silver "slime," a gold or silver bacterial coating usually found on walls and ceilings.

Peek-a-Boo Hole (L-288?) was located and surveyed to 71.2 feet with two leads remaining for very small cavers, with walking-sized passage beyond constrictions. In the same area a line of shallow sinks was checked, but only one sink contained an entrance that proved to be worthwhile. The small cave was not surveyed but has an estimated 60–70 feet of passage in a low room. Frontage Road Cave was completed in two trips for a total of 191.3 feet.

To date the Cave Loop Resurvey Project has resurveyed 44,513.95 feet (8.43 miles) in 39 caves, beginning with caves open to the public. Of those 39 caves 15 are improved with stairs and trails. Original surveys have been done in four known, but previously unsurveyed caves totaling 538.4 feet. Five caves were discovered and mapped; these five surveys total 395.8 feet.

A pet project of past surveyors has been to find the point that the Hercules Leg/Juniper branch of the lava flow left the main trench. Provisionally that point is around Gail Cave and/or Ovis Bridge, as shown on an overview map. Over the winter of 2017–18, Liz began putting together an area map of Cave Loop. Working with Dave Riggs, NPS physical scientist, she acquired locations and maps of additional caves on the Loop that didn't need resurveys, and "recon" cards of caves that still need initial surveys. An overview map was drawn onto a Google Earth image. "Finished" caves are in black (upper levels) and grey (lower levels); and red is used for caves and passages that need either resurvey or initial surveys. Many openings or supposed openings need checking, also marked in red. An entrance noted, but misplaced on the air photo, was searched for and not located. The overview map shows all surveyed, resurveyed and sketched caves for a grand total of 10.25+ miles in an area 4965' N–S × 3860' E–W.

Memorial Day 2019 Expedition

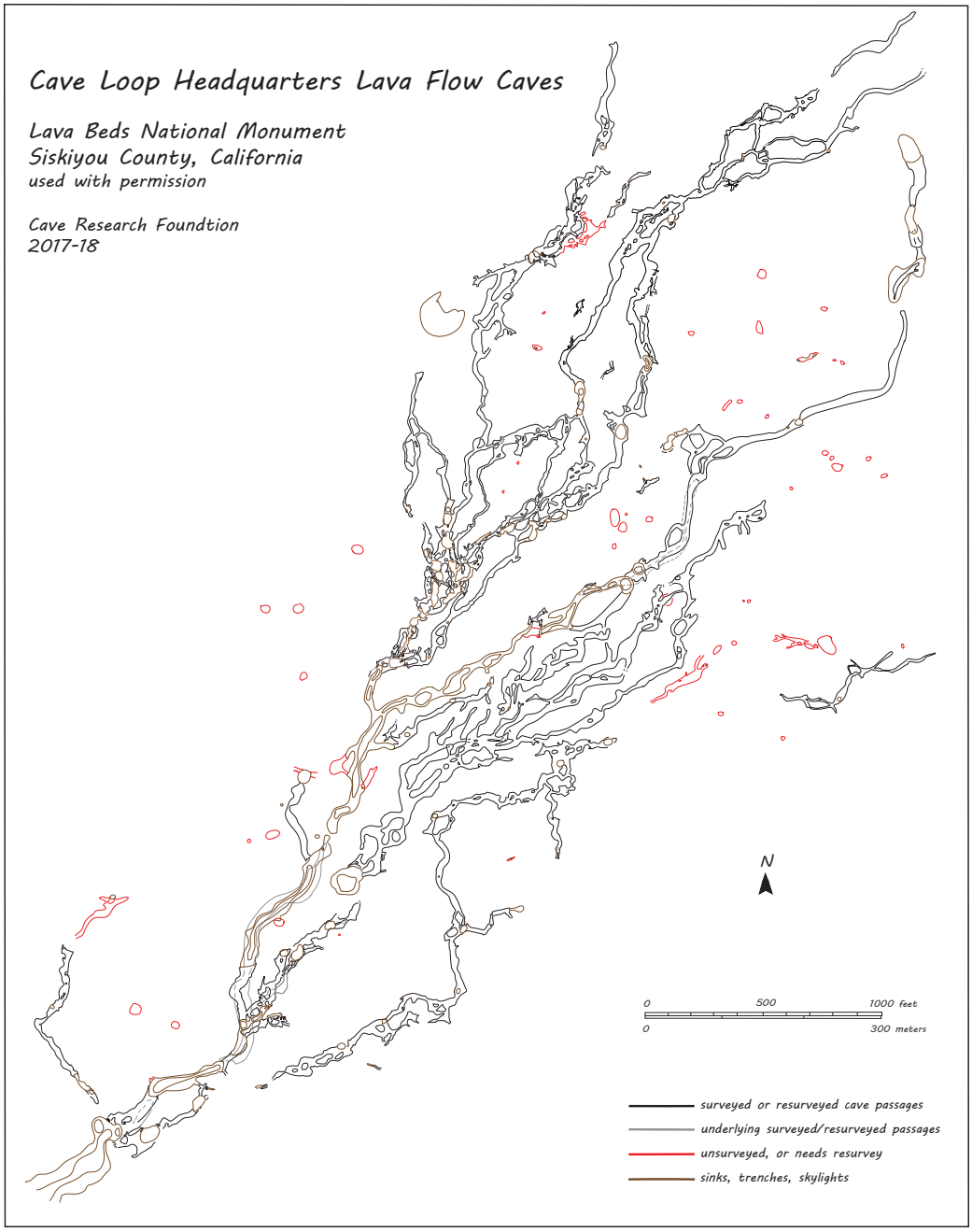
Participants: Arley Kisling, Breanna Kisling, Matt Leissring, Heather McDonald, Liz Wolff, Jim Wolff; guests Angela Hooker, Steve Kandra, Dave Martin; NPS Pat Seiser and Cathy Buckingham.

Objectives: Check blowing lead in Dog Cave, locate and begin survey of Rivulet Cave; complete survey in Maze Cave, and survey Underpass Bridge, Sentinel Bridges and Teaser Cave.

Findings

Saturday, May 25: Following Pat's safety and WNS briefing and discussion, Liz, Jim, Pat, Bre, Arley, Steve, and Dave hiked to Dog Cave for Pat to check the possible dig; it wasn't stable and headed toward the smallest entrance. While the crew was checking Dog Cave, Liz, Bre, and Steve hiked downhill to the obvious sink and easily located Rivulet Cave. Steve squeezed into the small vertical entrance and took a look around. He exited by the low horizontal exit.

By then the Dog Cave crew met us, we GPS'd the entrance and Arley, Bre, and Liz dropped into the cave. This first small room is half dirt floored and half breakdown. Through a low connector the main body of the cave is



reached. The rest of the crew dropped in to join us. Jim, Steve, and Dave looked into the braided passages and chose the route up the roomier side passage, while Arley and Bre read instruments with Pat's help. This side passage has a small connector back to the main passage. The side passage, on a smooth remelt ledge, goes about 100 feet. Time was getting away from us so we left the survey here and exited the cave after surveying 57.8 very magnetic feet. It started to rain again just as we returned to the cars.

Matt and Heather had arrived at the RC shortly after all of us had left for Rivulet and opted to survey Teaser Cave, which is located across the trench from Gasoline Alley. They completely surveyed the cave to a length of 120.1 feet.

NSS Weed Convention Planning and Preparations: That evening, we were joined by Bill Broeckel, Bill Devereaux, Doug and Tabitha Viner, Ed and Virginia Bobrow, Melanie Jackson, and Steve Hobson (all of Shasta Area Grotto, SAG); NPS Miranda Allen and guest Matt Bowers (Mother Lode Grotto and chair of the Weed NSS Convention) who would be making a proposal for SAG to host field trips at the 2021 NSS convention to be held at Weed, California. A short SAG meeting was held by new chairman Steve

Hobson and attended by most of those present. SAG is the principal repository of solutional as well as lava caves in the convention's geographic area, and thus SAG will be coordinating the convention's cave visitation. Never too early to start planning.

Sunday, May 26: Snow in the morning set back the schedule for getting out in the field. Matt gave a survey briefing and some description of the cave to all who were there. Then Matt and Heather led Angela, Steve, Dave, and Cathy into the lower level of Maze Cave to continue the survey. For Angela and Cathy it was their first time on a survey trip; Steve and Dave had a little experience from Saturday. They all read instruments, set stations, and Dave took a stab at keeping the book, doing a creditable job. The two teams brought back 159.2 feet of survey. Bill D and Jim and Liz did some cleaning and left for home shortly after noon.

July 4–8, 2019: Cave Loop Resurvey Project, Basalt of Mammoth Crater, and Caves of Valentine Basalt Flow

CRF Participants: David Martin, Lori Schultz, John Tinsley, Jim Wolff, Liz Wolff

NPS Participants: Pat Seiser and Travis Sizemore

Objectives: Three research proposals were active as five CRF joint venturers and two NPS resources management personnel sallied forth.

- The Cave Loop Resurvey (Wolff) Project surveyed Underpass Bridge; they also sought to locate and survey caves situated west of Cave Loop Road.
- The Basalt of Mammoth Crater geochemical study (Tinsley) sought to collect rock samples from the upper, middle, and lower levels of Post Office Cave and to assist the NPS in retrieving Post Office Cave data loggers.
- The Caves of the Valentine Basalt study (Tinsley) sought to locate and commence surveying known caves of the Valentine basaltic andesite flow.

Findings

Thursday: Liz met with Pat Seiser to review the Powerpoint presentation that Liz will present at the forthcoming Western Regional meeting and to discuss objectives for this expedition. John arranged to obtain the recon cards for known caves from the Valentine flow from NPS files, and then commenced searching those records.

Friday: Jim, Lori, and Liz surveyed Underpass Bridge (L700) to 86.3 feet in length, leaving a surface station to tie into both Frontage Road Cave (L710) and Rumblin' Cave (L439). At one point Lori climbed down one of the breakdown pits to see how deep it would be.

Meanwhile John spent the morning completing his search of the NPS files for cave names and accession numbers for caves of the Valentine flow that ultimately will need to be surveyed and inventoried. Ninety-two caves emerged in result of the initial search of reconnaissance card files.

Saturday: Jim, Liz, and David hiked the flow west of Cave Loop Road to find known caves and survey them if warranted. They completed sketch maps of four surface tubes totaling 95 feet.

A fifth known caves was surveyed and named Eyes Up for its two small skylight entrances. The skylights drop five feet to a dry sand floored passage. Both ends of the cave are breakdown blocked. A lava cascade three feet high interrupts the sand floor. After the cascade the sand floor is damp. Eyes Up (L441) totaled 67.8 feet in length.

John and Lori surveyed Antler Grotto (V655) and Basement Cave (V345). Antler Grotto yielded about 42 feet of passage and is aptly named. The upper level of Basement Cave had 112 feet of passage; a lower level remains for future survey. Elements of the trench system associated with Basement Cave rival the width dimensions of Valentine Cave itself. Total survey for the day was 154 feet on the Valentine flow project.

Sunday: Jim, Liz, and David went to the vicinity of Underpass Bridge to survey another small cave located beside the Cave Loop Road, Rumblin' Cave. This cave is a surface tube that passes under the road, which rumbled as cars passed over, hence the name. Rumblin' has a small entrance with a dirt crawl leading to an intact apron that skirts one wall for about half the length of the circular cave, the other wall is composed of breakdown. At the end of the apron, an upper level crawl above a lava fall leads into a sealed chamber. After the end of the apron a breakdown-blocked passage enters the chamber and ultimately leads to the breakdown blocked end of the cave. A total of 66.5 feet was surveyed.

Meanwhile, John, Lori, Pat, and Travis visited Post Office Cave, so John could obtain samples of lava from upper, middle, and lowest levels of the cave and Pat and Travis could retrieve several Hobo data loggers from Post Office Cave. All objectives were achieved, and the party exited after about 2.5 hours underground.

Following their short survey, Liz, Jim, and David returned to the Research Center to do some clean up and then depart for home. Tinsley and Shultz sorted survey data, tended to accumulated email, then overnighted, and departed for home on Monday morning, after finishing cleaning the Research Center.

- Total CRF person-days on site: 15
- Total CRF person-travel days: 5
- Total survey footage: 469.5 feet

Modoc National Forest Project

California

Bill Broeckel

Bill Broeckel in a newly found cave at Lava Beds. *Mark Jones*

2018

The goal of the project is to identify and describe caves of Modoc National Forest. This tends to be a fairly low-key endeavor operating on the fringes of the usual CRF expeditions based at the research center (RC) at Lava Beds National Monument. All of the caves involved thus far have been volcanic in nature.

2018 started off with a May expedition. On May 27, 2018, Louis Guilin, Selena Johnson, and Bill and Judy Broeckel returned to Arkansas Cave. We surveyed into the northeast canyon-like passage that Mark Jones found on an earlier trip. This went nicely for over 100 feet to end at a "too small" entrance which we identified on the surface with flagging ribbon on a stick. This task was completed pretty quickly, so we had some extra time to poke around. We ran into an old feeble caver guy wandering around lost. He had heard all his life about Berthas Cupboard since he was a kid. He wanted to see it before he died. Against better judgment, we took him on a short tour through the nice part of B.C. This absolutely made his day, and he was very grateful as we said our goodbyes.

July 1, 2018, Judy and I returned to Steamboat Frank to push the remaining leads. There were no big surprises. The most likely lead started as a promising climb down into a roomy lower level, then going up flow and away from the major intrusion situation that shows up a little further down the main borehole. Tricky route finding around breakdown boulders gave way to a passage with original tube wall on the left and more breakdown pushing in from the right. This became increasingly difficult until we gave it up and successfully extricated ourselves. Time running short, we hurried back and intercepted our rescue team at the trailhead. They were worried about us, but all's well that ends well. Cleaning up leads added hundreds of feet and pushed the total known extent of the cave to over a mile.

The next day we did a surface tour of both Arkansas and Steamboat, with Bruce Rogers, Liz Wolff, Matt Leisring, and Heather McDonald. Bruce pontificated on Arkansas, declaring it to be a lava tube. It was hot already when Bruce and Liz returned to the RC. The rest of us persisted to Steamboat Frank, moved some loose rocks away from the vertical entrance and took down all the surface flagging ribbon. Internal ribbon still needs to be removed. Both Arkansas and Steamboat Frank also still have some minor details that need to be gathered in for final mapping. Later in July, Lava Beds hosted the International Volcanospeleology Symposium (IVS). CRF personnel officially or unofficially conducted tours to a few of the longer tubes outside of the Monument such as Mammoth and Berthas Cupboard.

2019

2019 started with some random ridgewalking on April 21, 2019. A new cave area showed up at an isolated small trench segment that yielded two small caves. McBubble Cave is a low blob or bubble chamber accessed by a single little skylight. Rubiks Tube is merely a bridge across the trench, but the bridge contains short wings. Both caves were only 39 feet long. Judy functions as my spotter for this sort of nonsense.

The next day, Miranda Allen, Lava Beds intern, joined me to do an easy cave out by Arkansas. However, we encountered a single bat near the entrance and backed off. Our bats are extra sensitive this time of year. So, we cast about and found another cave nearby we could survey. It wasn't so nice. It was a crawl over broken rock, and we called it Pinch Hit Cave. Later on, this was connected to another similar cave next to it by swivelling a thin slab of rock. Total length is currently 84 feet. It should go over 100 feet if we can wiggle around a breakdown pillar without bringing down the house.

For now we are temporarily on hold but still looking forward to more Lava Beds expeditions and Modoc adventures in underground discovery some time post-pandemic.

Balcony Flow

Lava Beds National Monument

Dave West

Principal Investigator

Mark Jones at Lava Beds. *Paul McMullen*

2018

In April 2018, Dave West, Karen Willmes, Elizabeth Miller, Mark Jones, and Paul McMullen worked on the surveys of the Balcony Flow, mapping six caves and one grotto, as well as accomplishing 4,139.325 feet of surface and trench survey. The grotto and three of the six caves were previously undocumented.

In October the same group were joined by Dawn Ryan and Mark White and continued work on the Balcony Flow, mapping eight caves and three grottoes along with 2,636.36 feet of surface and trench survey. Two of the grottoes and four of the caves were previously undocumented.

When the Balcony Flow project began, we were supplied with locations of 42 caves, 3 grottos, and 3 natural bridges. Of these, we have mapped to date 27 caves, 3 grottos and 3 natural bridges. We were later provided with locations of an additional two caves, of which we have mapped one. In addition, we have mapped many previously undocumented features: 18 caves and 16 grottos. Total underground survey to date is 12,025.14 feet (2.28 miles). We have also surveyed 23,678.63 feet (4.49 miles) of collapses, trenches, and overland surveys. During the October expedition, we identified another cave and three more entrances that require future examination. Much work remains.

Dave West sketching in Bandersnatch Cave. *Mark Jones*

April 2019

We arrived at the Monument at various times on Monday, April 22. Karen Willmes and I arrived last after everyone else was in bed. We would have our usual group consisting of Ed Klausner, Elizabeth Miller, Mark Jones, Paul McMullen, and for the first time with our group, Bob Osburn.

Having reached a portion of the flow with fewer caves, much of this expedition was spent on the surface, surveying 4,898 feet of trench collapse. The survey of Hidden Surprise cave was completed. Occupational Therapy and Soft & Dry caves were surveyed, and the survey of Natural Light cave was begun. We also tidied up a few survey errors from prior expeditions and eliminated five leads as not caves by the Monument's definition of forty feet. Honeycomb Hollow was visited, but the hive was far too active to be safely approached. That will have to wait for colder weather.

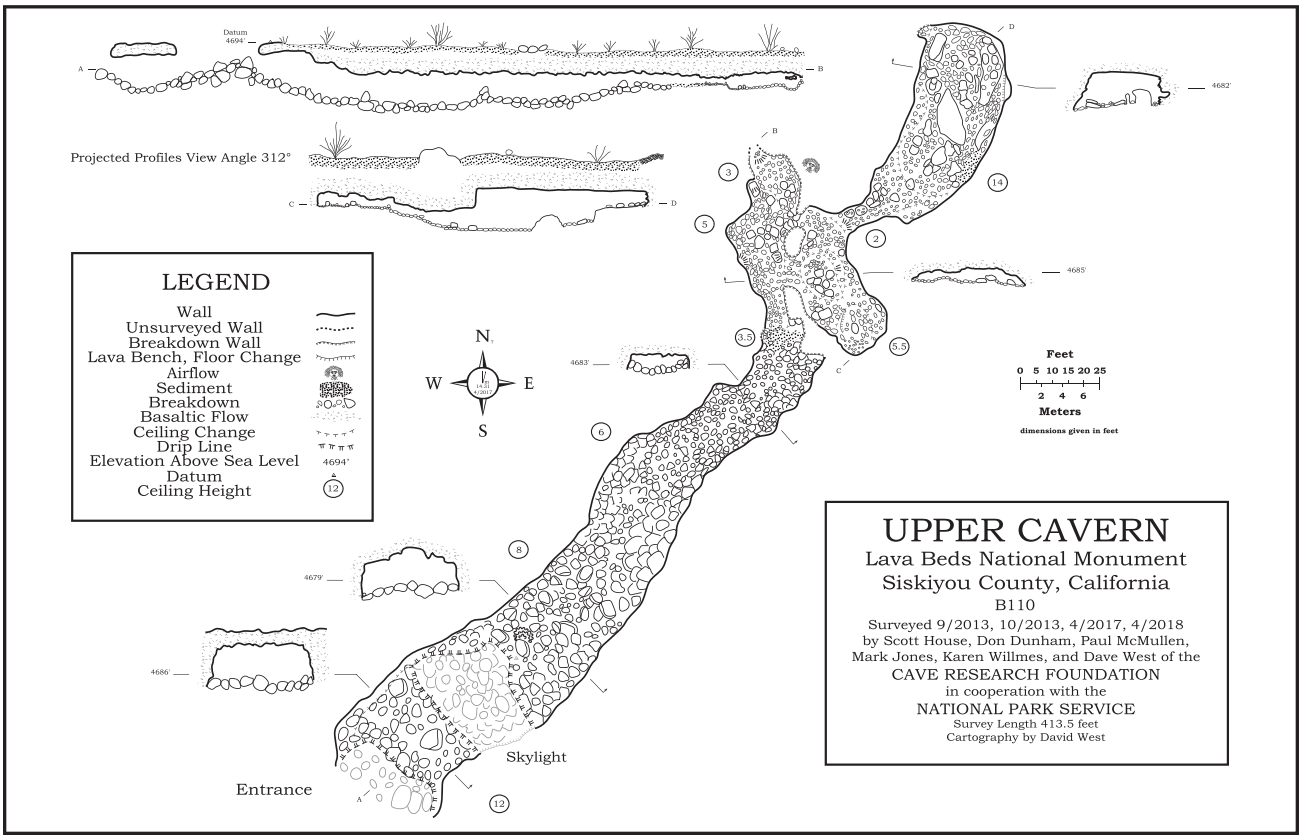
October 2019

A total of five CRF members (John Tinsley, Dave West, Karen Willmes, Mark Jones, and Paul McMullen) addressed three areas of CRF projects during this expedition. Three and a half days were needed to survey

Paul McMullen uses a standoff to reduce magnetic interference with the compass. *Mark Jones*

Ed Klausner. *Mark Jones*

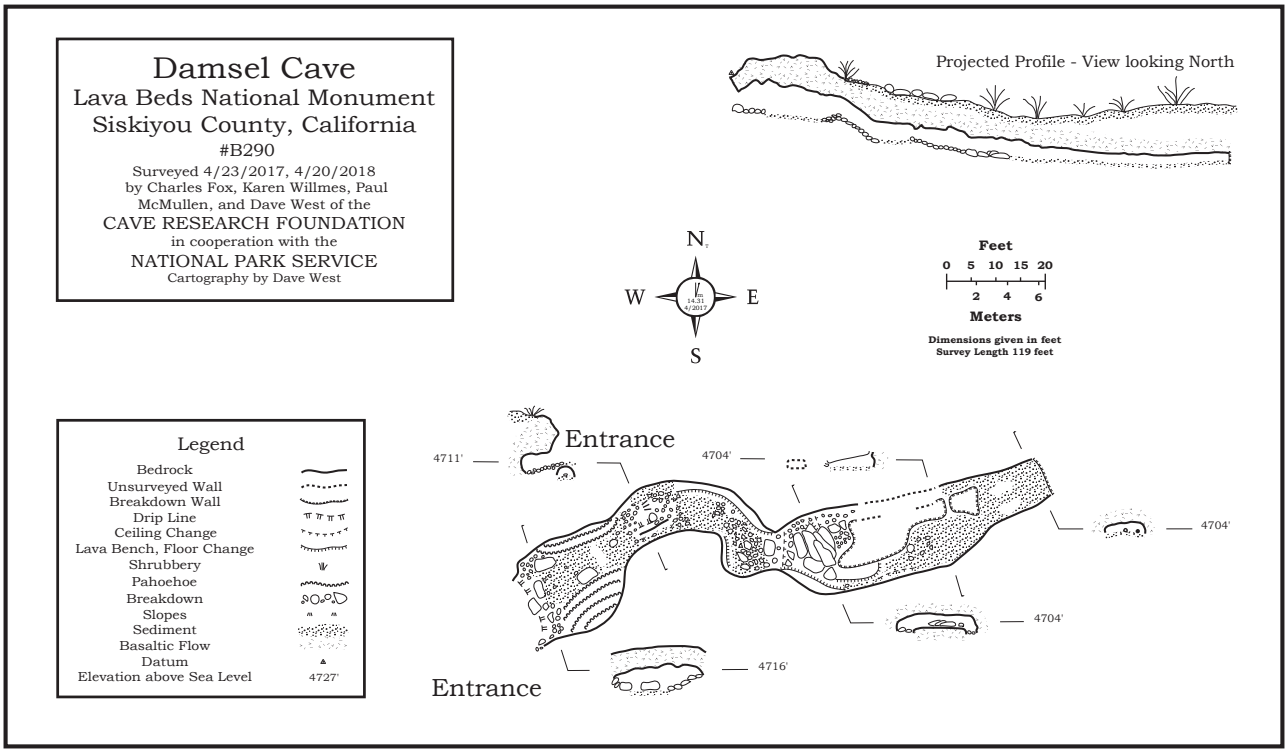
Bandersnatch Cave in Elmer's Trench, one of the Monument's Inventory and Monitoring caves. We made a drip line connection to Monument Road Cave in the process. In the Balcony Flow three days were spent surveying the various features of Honeycomb Hollow and a portion of the surface trenches, observing that the actual honeycomb in the cave had been removed. One day was spent in the Valentine Flow continuing work in Basement Cave and Crissy's Cave, the latter being a Townsend's bat maternity site where the bats were not present at the time. Mark Jones also assisted with the Monument's ice monitoring program.



Karen Willmes. *Mark Jones*

Miranda Allen gets advice from Bob Osburn. *Mark Jones*

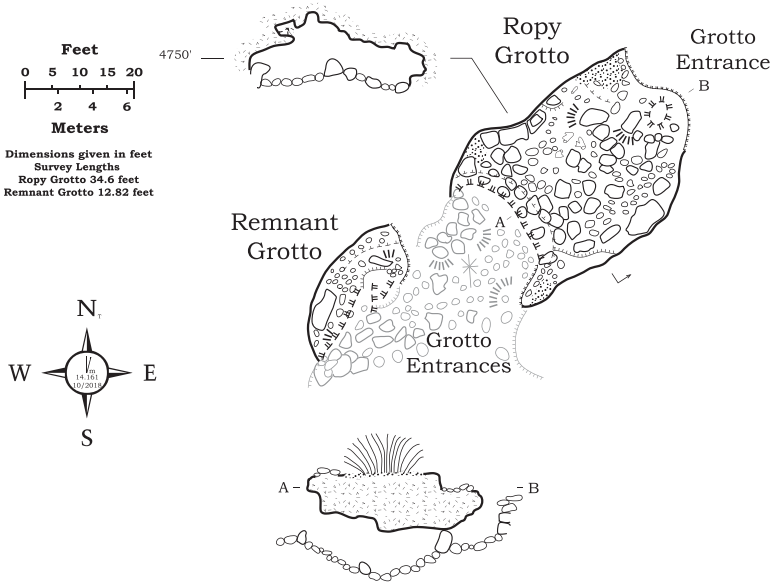
Dave West doesn't quite fit out the skylight. *Mark Jones*



Ropy Grotto
Lava Beds National Monument
Siskiyou County, California
#B060
Surveyed 10/14-15/2018 by
Dawn Ryan, Mark White, Karen
Willmes, and Dave West of the
CAVE RESEARCH FOUNDATION
in cooperation with the
NATIONAL PARK SERVICE
Cartography by Dave West

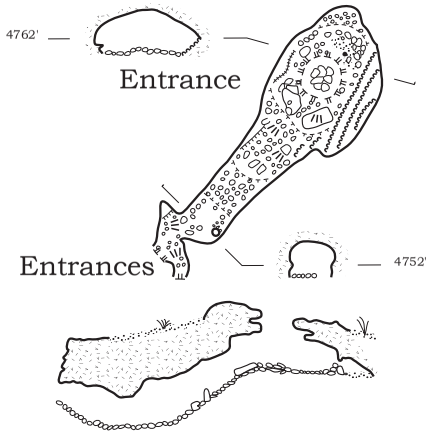
Legend

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



Profile View 325° ↖

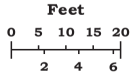
Mossy Knoll Cave
Lava Beds National Monument
Siskiyou County, California
#B240
Surveyed 5/5/17 & 4/21/18
by Mark Jones, Elizabeth Miller,
Karen Willmes, and Dave West of the
CAVE RESEARCH FOUNDATION
in cooperation with the
NATIONAL PARK SERVICE
Cartography by Dave West



Profile View 297°

Legend

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



Dimensions given in feet
Survey Length 53.44 feet

South Castle Flow

Lava Beds National Monument

Scott House

Principal Investigator

Two expeditions were mounted, one in each year. All cave maps have been drafted, although a few need to have additional features added. All locational information, descriptions, and cultural information are entered into a database.

Scott House figuring out what cave is which. *Mark Jones*

May 5–7, 2018

Participants in 2018 included Scott House, Don Dunham, Mark Jones, Patti House, Bill Broeckel, and Judy Broeckel. In three days of field work, we surveyed eight caves in the South Castle Flow, generally a few hundred feet north of the old fire road including:

- Cinco de Mayo Cave (new) – 150 feet.
- Coyote Comfort Cave – 250 feet.
- Frozen Wave Cave – 240 feet.
- Shepherd Shelter (new cave) – 40 feet.
- Under the Sea Cave – 173 feet.
- A-Oho (Modoc for battle) Cave – 650 feet.
- Parallel Evolution Cave – 420 feet.
- Que Mosso Cave – 275 feet.

At least six new caves were found; they were not entered beyond the entrance because we did not have time to survey them.

All data has been entered into reduction programs, and the database we maintain on the Castle Flows is in the process of being updated. Cultural occurrences are also included.

March 24–April 1, 2019

Participants: The bulk of the survey and inventory work was done by Scott House, Don Dunham, and Mark Jones. Other occasional participants included Dean Hill, Taavi Tajali, and John Tinsley.

Work focused on an area in the South Castle Flow but generally along or north of the old fire-line road, now an unofficial trail. Nineteen caves were surveyed and inventoried; the total survey footage was 3,599 feet.

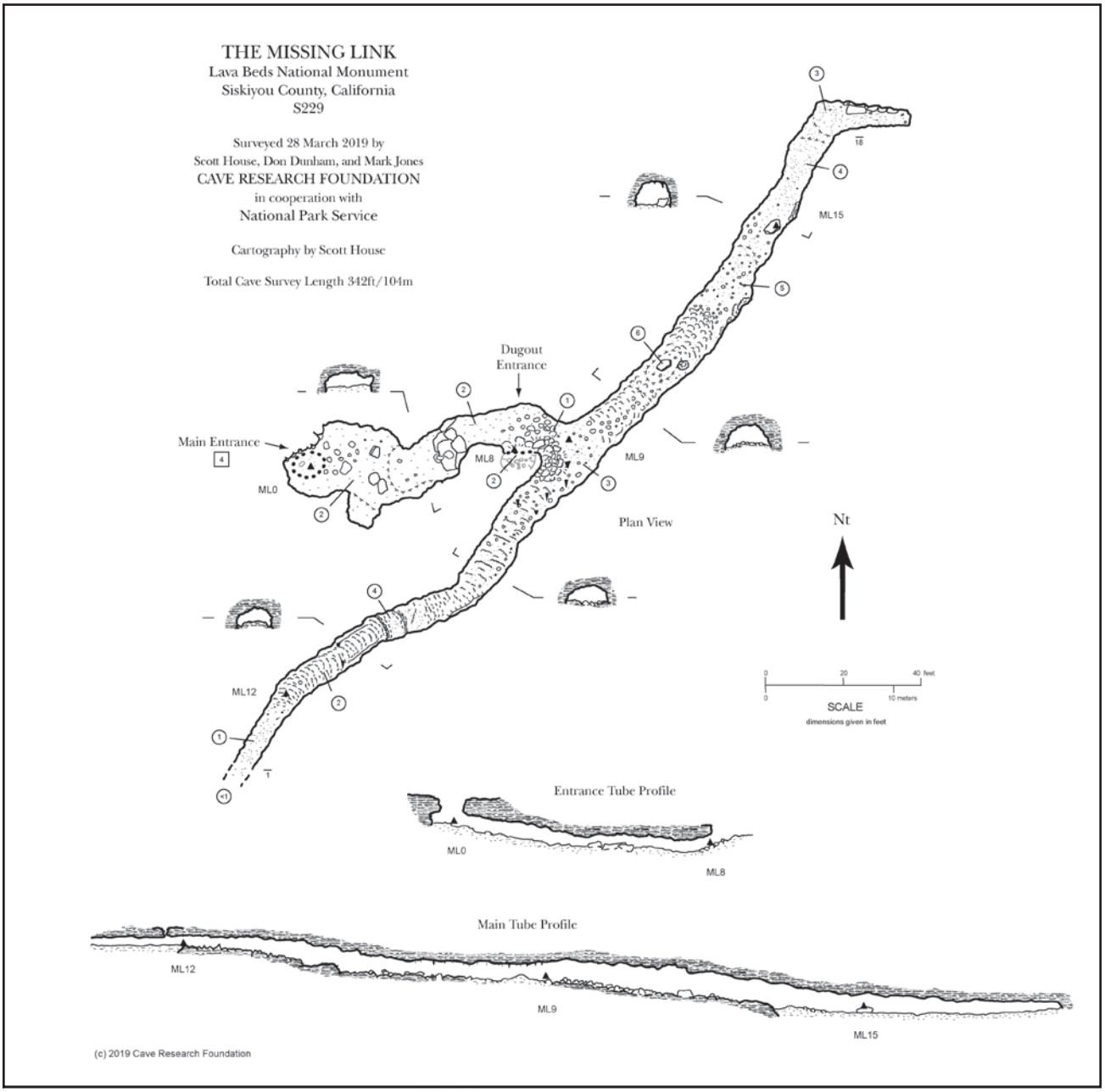
- S165: The Stone Tent – 26 feet.
- S166: Patpátli Tube – 168 feet.
- S239: Broken Blister Hole – 100 feet: *New cave.*
- S235: Bushy Sink Cave – 177 feet: *New cave.*
- S220: Backdoor Bridge Cave – 78 feet.
- S221: Short Grotto – 60 feet: *New cave.*
- S230: Greenhouse Cave – 431 feet.

- S232: Monkey Wrench Cave – 199 feet
- S224: Pendant Portico Cave – 73 feet.
- S229: The Missing Link – 352 feet: *New cave.*
- S228: Tilted Pillar Cave – 300 feet.
- S210: Sheep Skull Cave – 300 feet. *A new entrance found the previous day was connected to this cave.*
- S194: Coralloid Crawl Cave – 200 feet.
- S198: Wide Tube Tunnel – 140 feet.

Scott, Don, Mark, and Dean surveyed and inventoried:

- S208: Ladybug Lair – 55 feet (but only Dean fit).

The Missing Link and Don Dunham. *Mark Jones*



- S226: Every Which Way Cave – 90 feet but it continues.
- S222: Western Front Cave – 380 feet: *New cave.*
- S166a: Patpátli Tube – 229 feet. *This cave went under road and was connected to S166 by Jones. Total length of both was 397 feet.*
- S185: B. Grimm Cave – 182 feet. *New cave.*
- S182: Roadside Den – 59 feet. *New cave.*

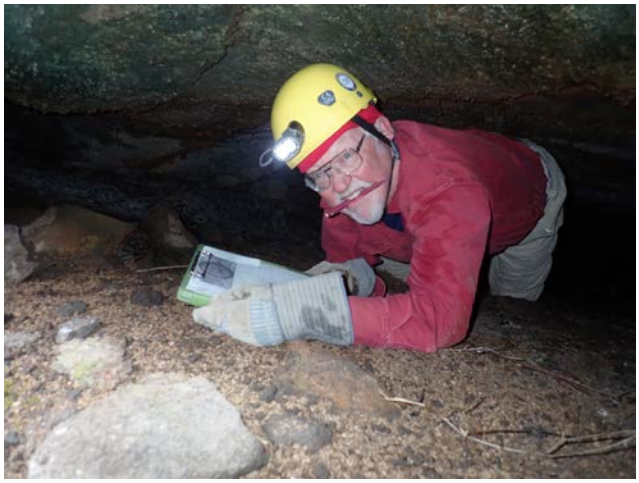
Several potential caves previously located were too short and lacked other useful qualifiers for cave management. "Seldom Seen" (S202) is too short and insignificant to be considered a cave (it is a collapsed cave with eight "entrances"), and we removed it from our list. We will continue to track it as a "lead."

Seven Townsend's big-eared bats (*Corynorhinus townsendii*) were found in various caves. Cultural and use descriptions were written and the FileMaker database was updated during the week. All survey data was entered during the field week.

Our thanks to the Monument staff for facilitating our work, providing housing, and loaning equipment, bedding, and boot repair materials.

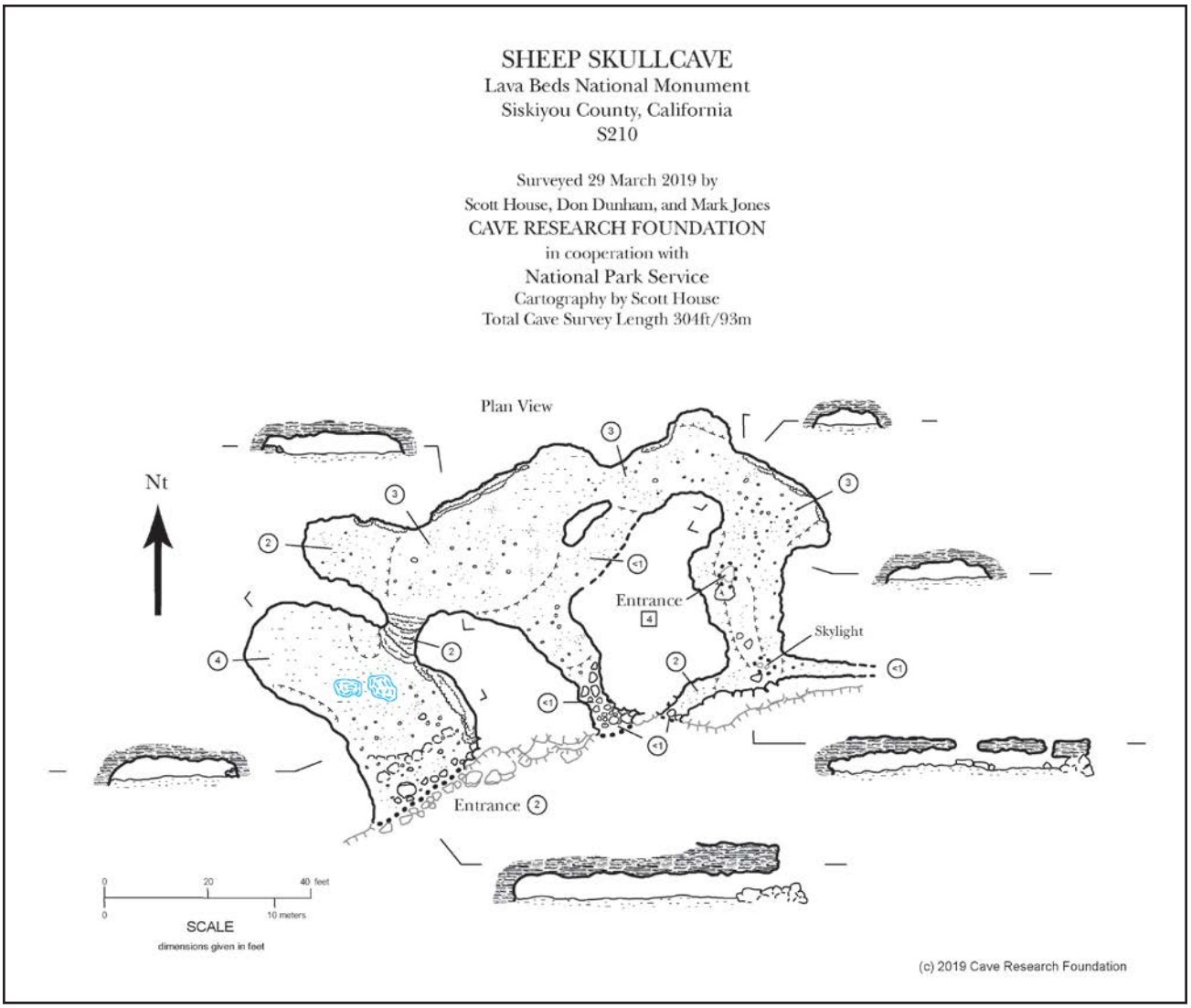
Blistered rocks gave B. Grimm Cave its name. *Mark Jones*

Big eared bat. *Mark Jones*



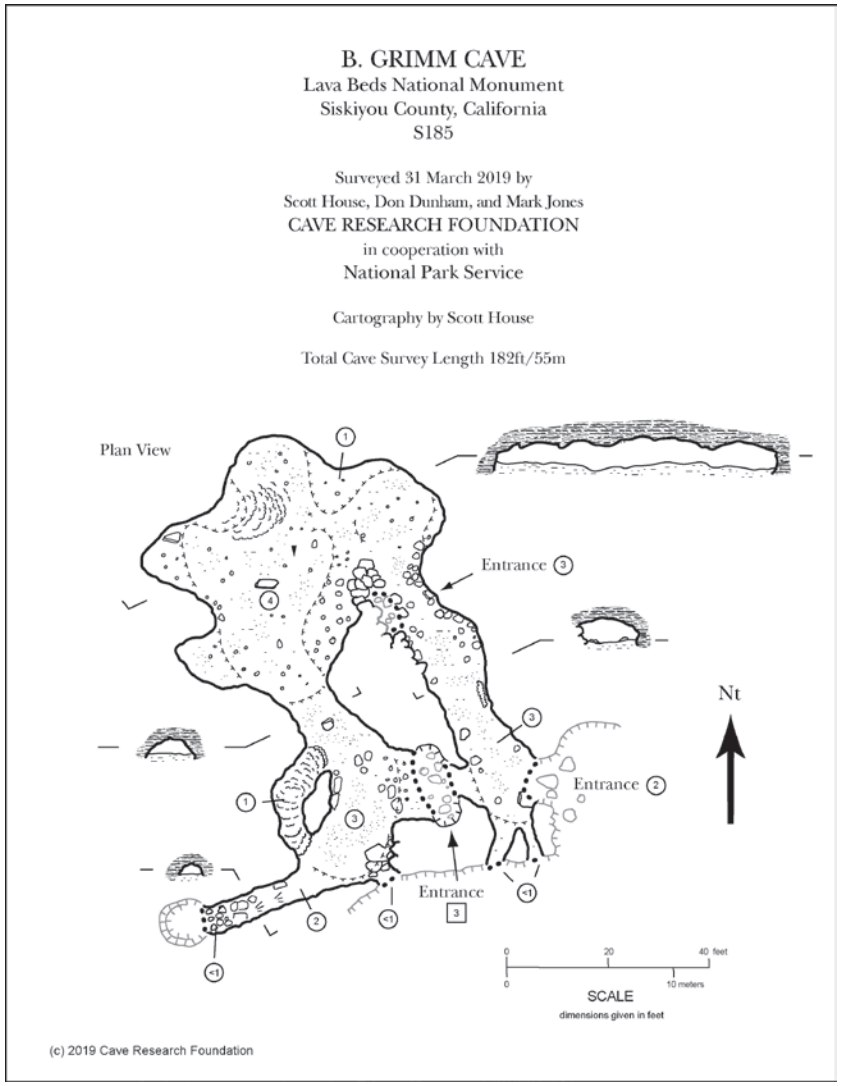
Surveying Titled Pillar Cave. *Mark Jones*

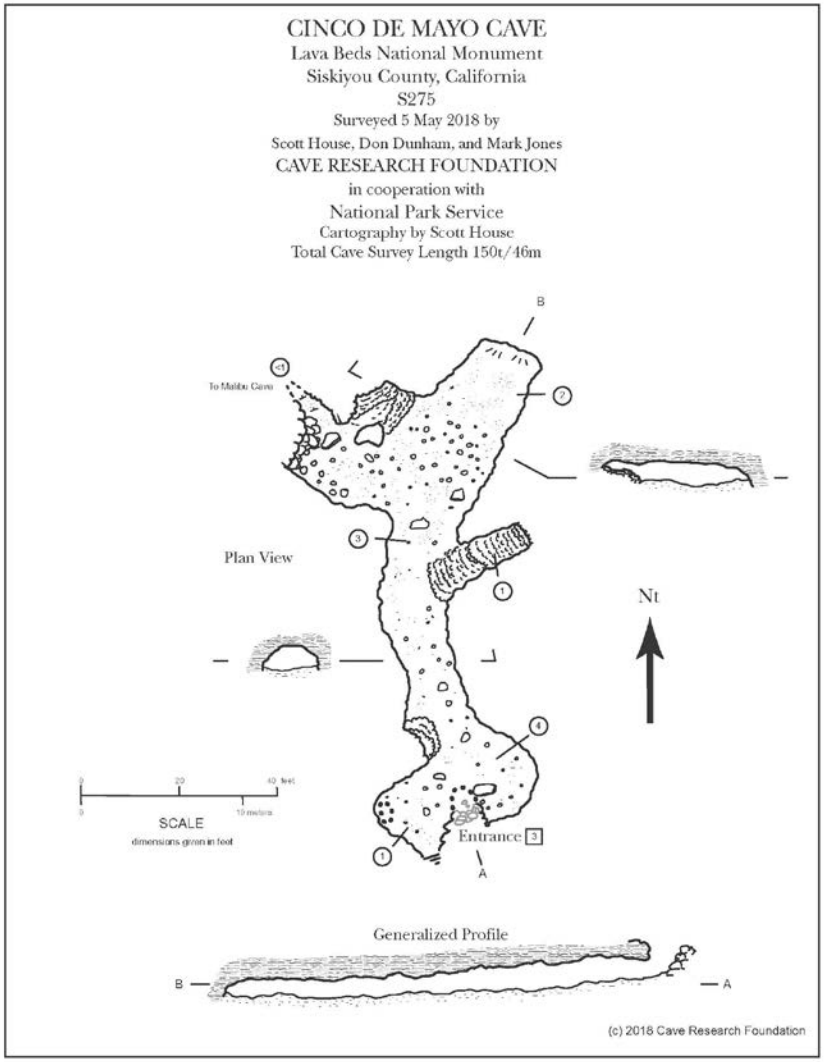
Bill Broeckel at Que Mosso. *Mark Jones*



Don Dunham enjoying Frozen Wave Cave. *Mark Jones*

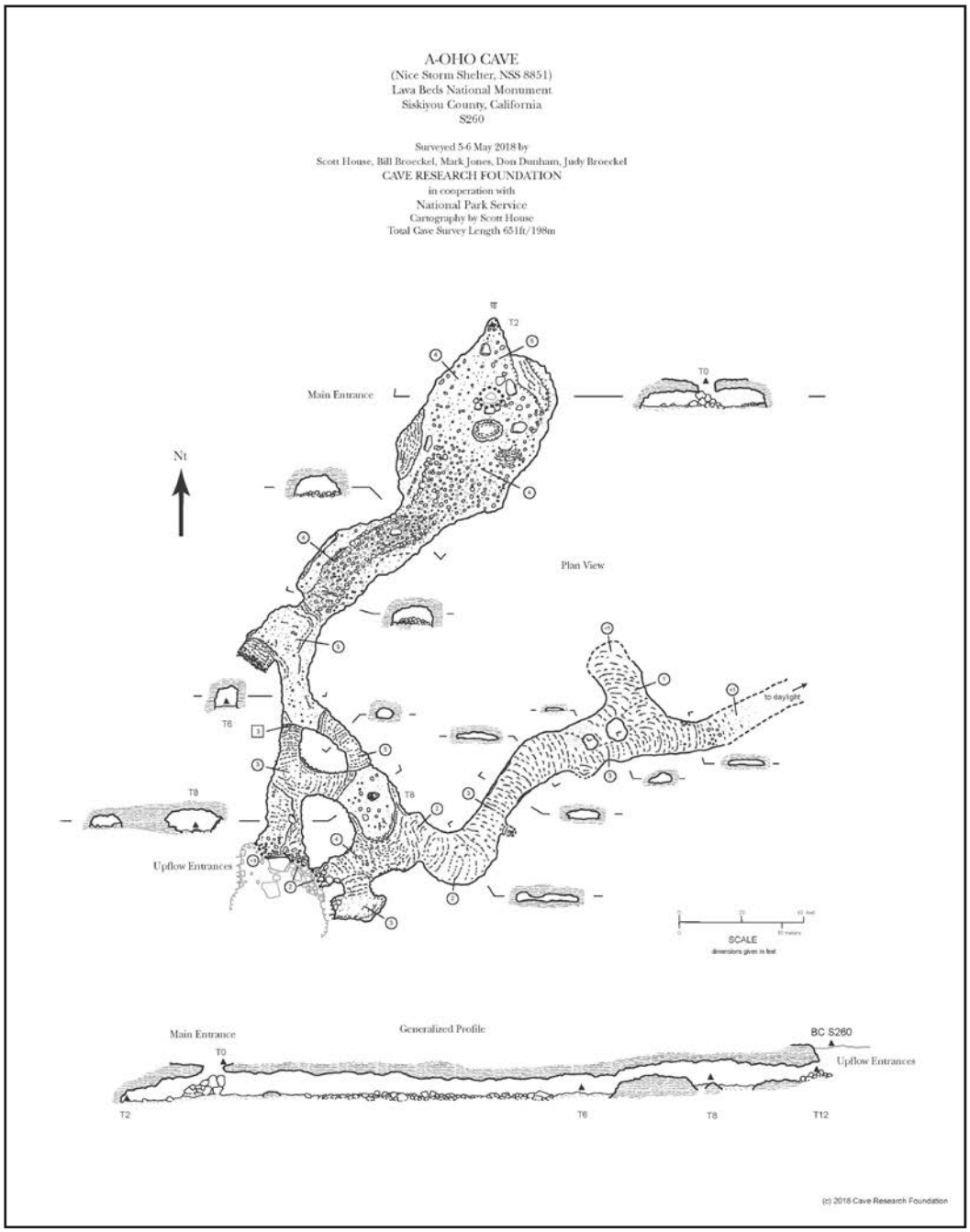
Data gathering at a cave entrance. *Mark Jones*


B. GRIMM CAVE
Lava Beds National Monument
Siskiyou County, California
S185
Surveyed 31 March 2019 by
Scott House, Don Dunham, and Mark Jones
CAVE RESEARCH FOUNDATION
in cooperation with
National Park Service
Cartography by Scott House
Total Cave Survey Length 182ft/55m
Plan View
Entrance 3
Entrance 2
Entrance 3
Nt
SCALE
dimensions given in feet
(c) 2019 Cave Research Foundation


CINCO DE MAYO CAVE
Lava Beds National Monument
Siskiyou County, California
S275
Surveyed 5 May 2018 by
Scott House, Don Dunham, and Mark Jones
CAVE RESEARCH FOUNDATION
in cooperation with
National Park Service
Cartography by Scott House
Total Cave Survey Length 150t/46m
To Malibu Cave
Plan View
Nt
SCALE
dimensions given in feet
Entrance 3
Generalized Profile
(c) 2018 Cave Research Foundation

The South Castle Flow and Hardin Butte. *Mark Jones*

Pushing a tube in Cinco de Mayo Cave. *Mark Jones*



Elmer's Trench and Down Flow Post Office Cave

Lava Beds National Monument

Ed Klausner

Principal Investigator

2018

In 2018, two trips were taken to Lava Beds National Monument in support of the Elmer's Trench and Down Flow Post Office Cave research projects. One in April was held in conjunction with Dave West's Balcony / Boulevard project. We were joined by Elizabeth Miller, Karen Willmes, Mark Jones, and Paul McMullen.

The six caving days were divided between Elmer's Trench and Down Flow Post Office Cave. All in all, we spent 176 person hours in the field and completed the survey of 16 caves and started the survey of two others. Of the 15 caves surveyed in Elmer's Trench, 10 were new finds. A total of 2,509 feet of cave survey was completed along with 778 feet of trench profile, and 1,017 feet of surface survey was used to tie new caves to known cave locations (brass caps). One new cave was found downflow from Post Office Cave.

A second trip was taken in October with two other principal investigators present (Dave West working on Balcony / Boulevard, and John Tinsley working on Craig Cave and Craig Temple). We were joined by Elizabeth Miller, Karen Willmes, Mark Jones, Paul McMullen, Pic Walenta, Bill Broeckel, Dawn Ryan, and Mark White. Intern Miranda Allen helped survey after work on most days. We again spent six field days at Lava Beds.

Ed Klausner on book at Lava Beds. *Mark Jones*

In Elmer's Trench, 11 caves were surveyed, 7 of which were new finds. In downflow Post Office Cave, 4 caves were surveyed of which 2 were new finds. There was a total of 1,689 feet of cave survey, 1,170 feet of trench profile, and 514 feet of surface survey. 184 person hours were spent surveying for these two projects.

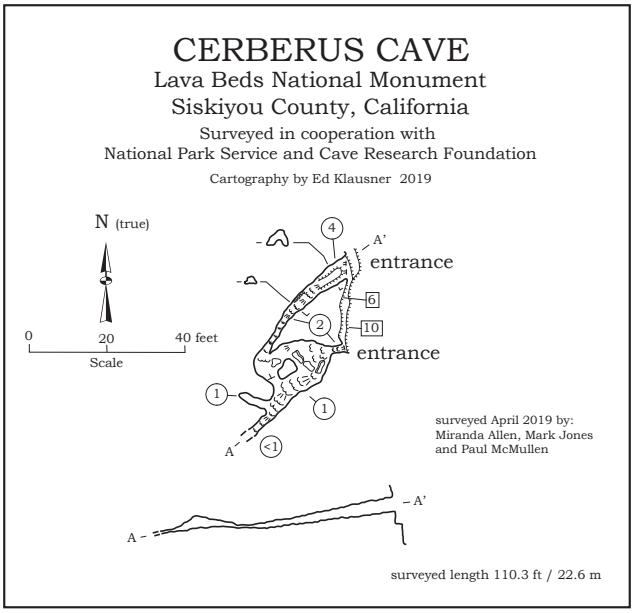
Lava Beds dusted with spring snow. *Mark Jones*

April 22–29, 2019

The April expedition actually started two days before Dave West and I arrived because Mark Jones was here doing volunteer work and took Miranda Allen out to survey. They surveyed two newly found caves in Elmer's Trench: Crown of Thorns Cave and Baked Potato Cave.

Most of us arrived April 22 and started surveying on April 23. On the first day, Mark Jones, Bob Osburn, park intern Miranda Allen, and I went to Dragon's Head Cave to finish the survey. We completed 425.5 feet of survey. We then went down flow to finish Schonchin Cave and also Schonchin Well, finishing both of them. There were lots of ice stalagmites in Schonchin Cave and it was rather cold. We found a dead bat that was covered in part by fungus. We

Elizabeth Miller at Lava Beds. *Mark Jones*



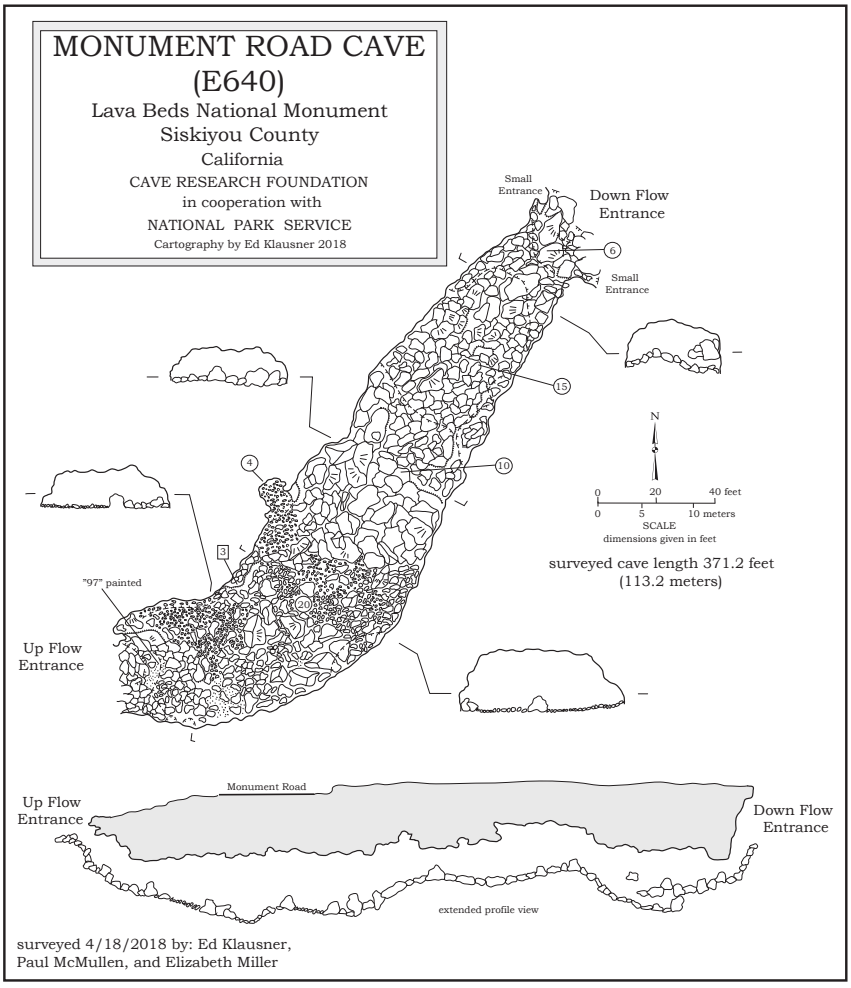
inverted a plastic bag to gather up the bat and brought it back to the freezer for WNS testing.

On day two, Mark Jones and Paul McMullen joined me in Elmer's Trench. We started out doing some of the caves recently found but not surveyed. Shattered Crate Cave was our first stop and in half an hour we completed surveying this 54.3 foot cave. Next small cave was Down and Dirty Cave which we again surveyed in a half hour. We got 47.7 feet of survey.

Next was a cave that turned out to be Tight in the Middle Cave. This was estimated to be 40 feet in the recon cards. We found it to be 121.5 feet. We got the extra footage by finding an additional entrance that tied into the tight spot.

Next was Popcorn Palace. We surveyed 354.8 feet before we got too cold to continue. We found a new pit that was 14 feet deep but not free climbable, so we will have to return with a cable ladder.

Since we were cold, we decided to do a small cave that would be warmer. We located a previously found, but new to the monument, cave. We named it Tree Frog Cave for the resident at one

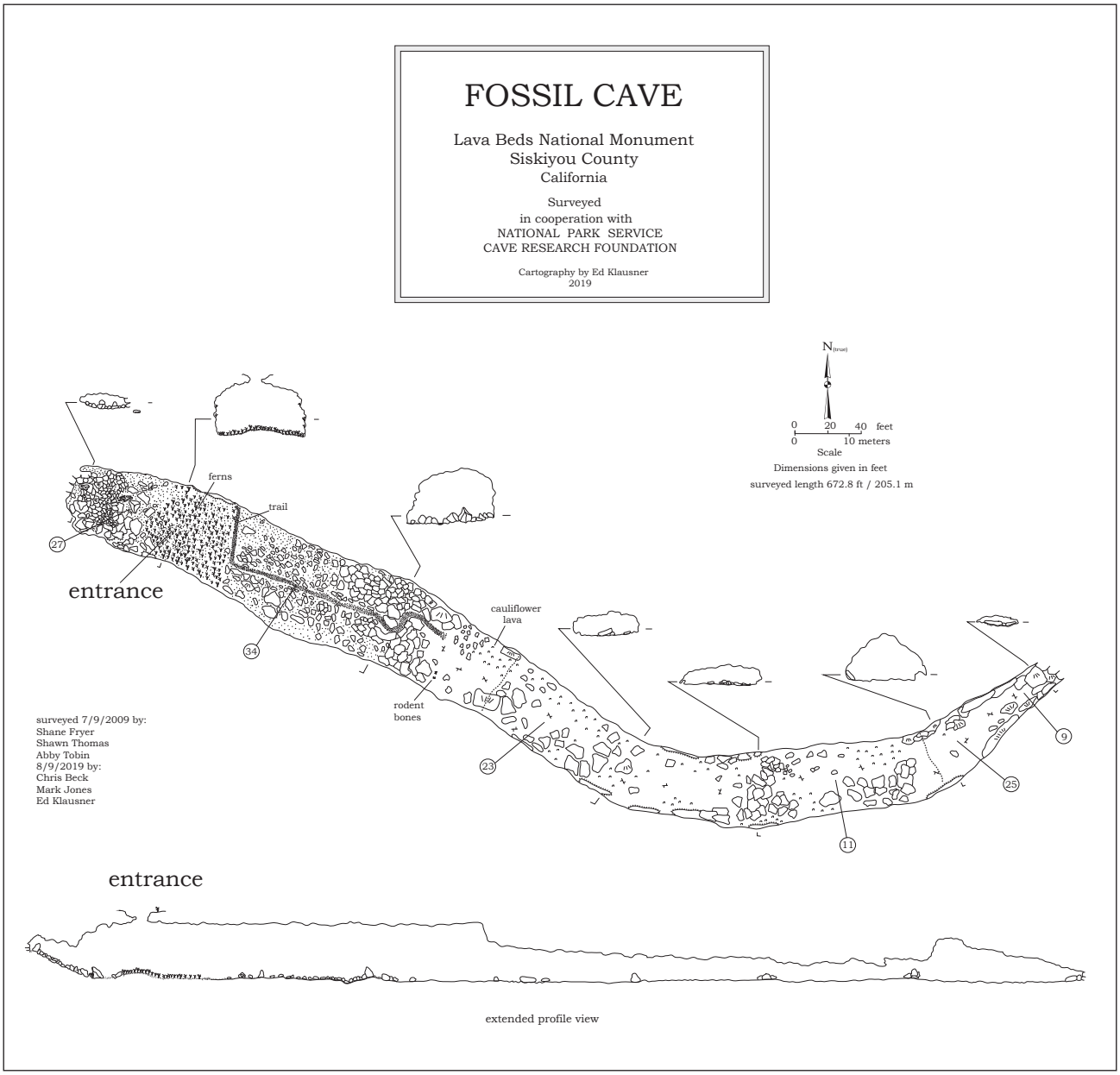


Paul McMullen with DistoX2 at Lava Beds. *Mark Jones*

Miranda Allen. *Mark Jones*

of the entrances, but later found that it was Ramieta Cave. The cave had three entrances and a remaining, too tight lead that had cold air coming out of it. We completed 86.2 feet of survey before we headed back to the RC.

Thursday was the day for a meeting with the Monument, so Mark Jones and Paul McMullen used the time to



search for more caves in Elmer's Trench. They did find one. They returned to pick me up at the Research Center and we headed to Popcorn Palace with a cable ladder. We did drop the small pit with the cable ladder and got six survey shots in a rather unstable area. Anyone returning here should be really cautious about the loose rocks (ceiling, floor, and walls).

Next, we headed to where we left off yesterday and finished the area. Finally, we headed back to an area that we found yesterday, but didn't finish. This turned out to be a rather complex area and required dropping down about 10 feet in one area and 5 feet to a terminal shot. All in all, we got 247.8 feet of survey giving 602.6 feet of total survey for Popcorn Palace. The recon card said it was a measured 329 feet.

In the evening, intern Miranda Allen and Mark Jones went to two additional caves and surveyed Dirt Floor Cave and Spidercorn Cave.

On Friday, the fourth day of the expedition, Mark Jones and Paul McMullen again joined me in Elmer's Trench. We continued north of Fleener Chimney road by going to Rubble Trouble, found in 2018, but not surveyed due to the presence of a bat. This is a cold cave and there was plenty of ice on rocks and a few ice mites. It doesn't seem like permanent ice. In all, we surveyed 198.9 feet.

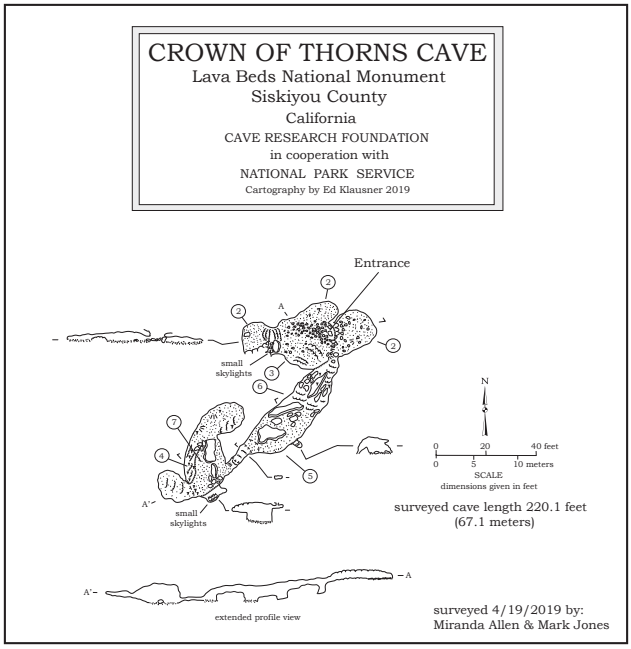
After surveying Rubble Trouble Cave, we checked several caves noted as "possible" and found none were longer than 25 feet in length. Eventually, we reached a noted lead and found it to be a legitimate cave. Since we found a tree frog inside, we named it Tree Frog Cave. It was 63.3 feet in length. Next up was another potential cave and it was named Fleener View Cave. In three survey shots we got 53.3 feet of survey in this new cave.

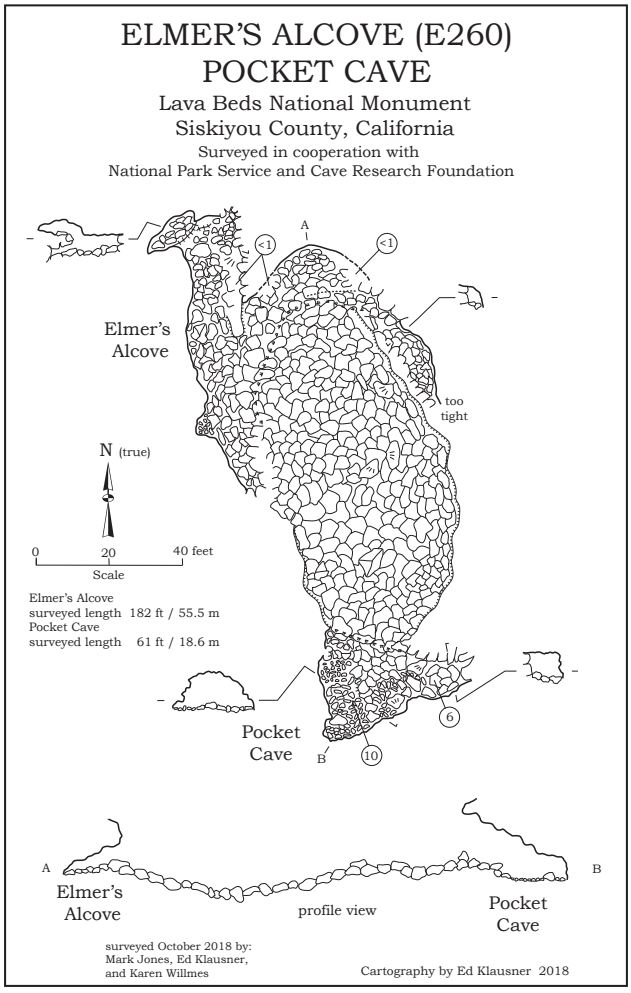
On the way back to the car, we passed Spidercorn Cave. It seems like an alcove was missed and we added to the survey for a total of 58.4 feet.

After work, Miranda stopped by and she, Mark, and Paul went to the Fleener Chimney area and surveyed a cave Paul found last year. They named it Cerberus Cave and got 110.3 feet of survey.

On Saturday, April 27, our fifth day of the expedition, Elizabeth Miller and Karen Willmes joined me on a trip to Elmer's Trench. Our first objective was to survey One Cave, Two Caves. We got 65.06 feet of survey with the three segments of cave. Next, we went to survey another known cave, Elmer's Attic. It was estimated to be 100 feet in one place and 200 feet in another, so our 154.83 feet was right in the middle. This is an interesting cave in that it had a nice pahoehoe floor with a low stretch of one-foot-high passage. It then broke out to 9 feet high that, unfortunately, only lasted for about 15 feet.

Finally, we went to survey Spiders, Snakes and Planks, Oh My Cave. We found the entrance, but could not fit in the cave.





In the evening, Miranda stopped by to go out with Mark and Paul and surveyed Pothole Cave at 60.7 feet of survey

On our last day, Elizabeth Miller and Bob Osburn joined me for a trip down flow of Schonchin Well. We started Schonchin Well and did a surface survey to Cellar Cave. Next, we continued the survey down flow and found a new cave that we did not survey. At the far end of the trench (which we surveyed) we found a 140-foot cave (also surveyed) that we named Wren Cave. Finally, we searched down flow for a while and found nothing before we headed back to the Research Center.

Our thanks to Katrina Smith and Pat Seiser for the support you've given to this project.

Cave survey:

Post Office Flow:

- Dragon's Head—139.2'
- Schonchin—414.1'
- Schonchin Well—162.5'
- Wren—140.7'

Total survey Post Office flow 856.5'

Mark Jones rappelling and Ed Klausner sketching. *Chris Beck*

Elmer's Trench:

- Crown of Thorns—220.1'
- Baked Potato—78.1'
- Shattered Crate—54.3'
- Down and Dirty—47.7'
- Tight in the Middle—21.5'
- Popcorn Palace—602.6'
- Ramieta—86.2'
- Spidercorn—58.4'
- Dirt Floor—44.2'
- Rubble Trouble—198.9'
- Tree Frog—63.3'
- Fleener View—53.3'
- Cerberus—110.3'
- One Cave, Two Caves—65.1'
- Elmer's Attic—154.8'
- Pothole—60.7'

Total survey E. Trench 2019.6'

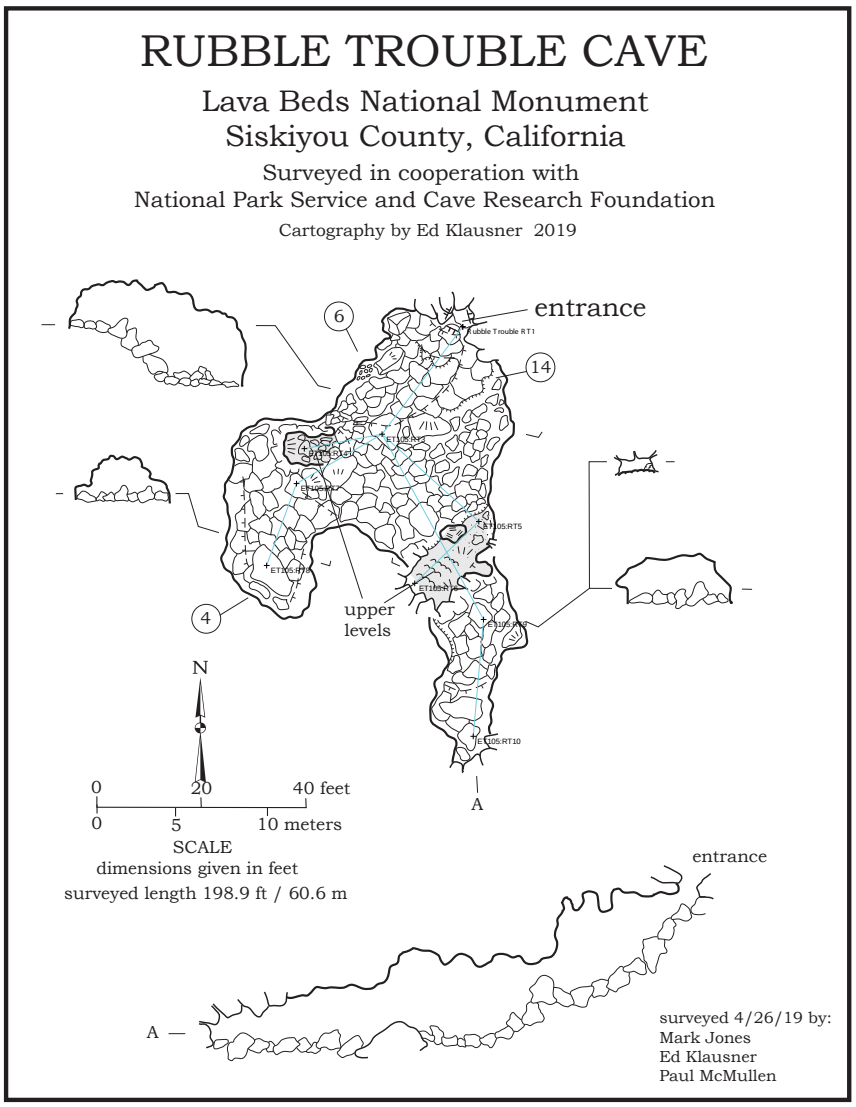
Surface survey:

- Schonchin to Schonchin Well—63.5'
- Schonchin Well to Wren—640.6'

Total surface survey: 704.1'

New Caves in Elmer's Trench:

- Crown of Thorns
- Baked Potato
- Shattered Crate
- Down and Dirty
- Rubble Trouble
- Tree Frog
- Fleener View
- Cerberus
- Pothole



New Caves down flow of Post Office Cave:

- Wren

Two caves completed from last expedition (Dragon's Head and Schonchin) plus 18 additional caves surveyed.

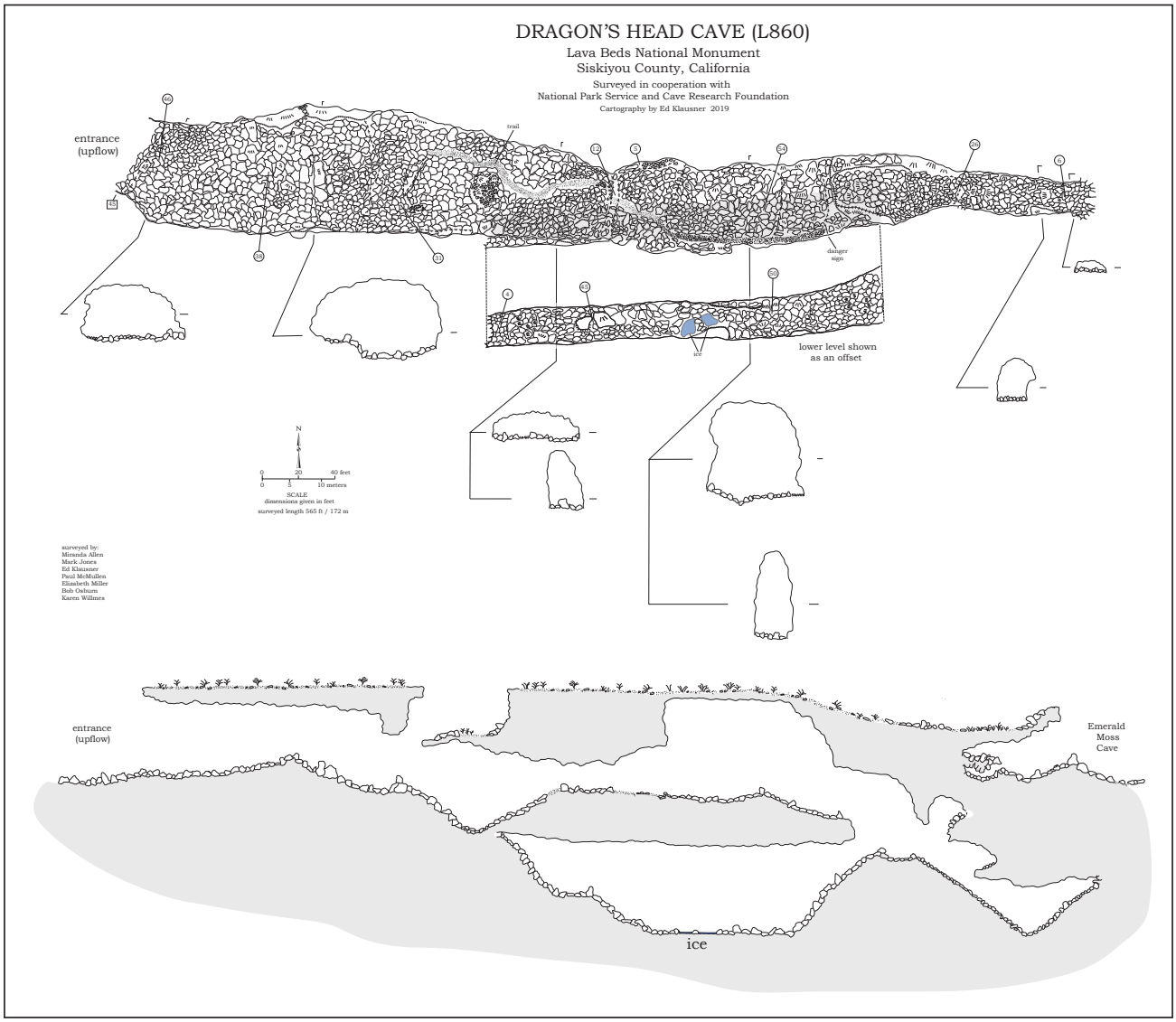
Total hours: 165:35

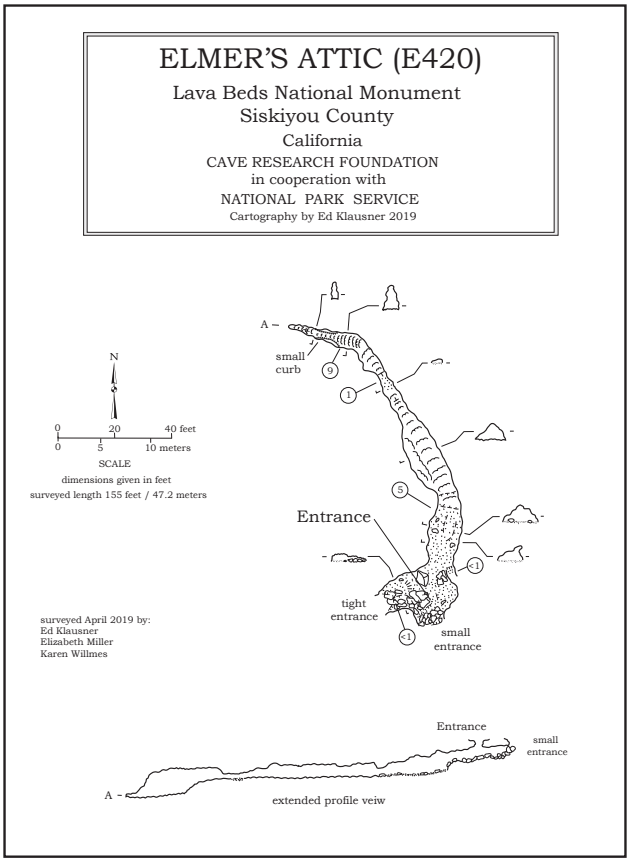
Miranda Allen's hours are counted above, but she is an intern and this may be useful for her future applications. Her hours of survey, including sketching, are 16:00. This does not include the hours she spent surveying with Mark Jones before the expedition.

Dragon's Head Cave. *Mark Jones*

August 8–11,2019

Larry Welch had a radon study that he was conducting at Lava Beds National Monument and I joined him to assist in carrying his instruments and helping him finding locations





Karen Willmes checking a lead. *Mark Jones*

within Post Office Cave. His protocol called for placing the instruments on day one and retrieving them on day four. That left days two and three for other objectives. On the day of arrival, Mark Jones and Miranda Allen surveyed Turtle Shell Cave and Turtle Shell Cave Annex. On day two, we resketched the plan view of Fossil Cave for the Monument. On day three, we surveyed caves in Elmer's Trench before a thunderstorm drove us out of the field.

Of the four caves, all were new to the park.

Cave survey:

Elmer's Trench—All New Caves:

- Turtle Shell Cave—49.5'
- Turtle Shell Cave Annex—42.7'
- Rainy Day Shelter—56.0'
- Child's Play Cave—31.1'

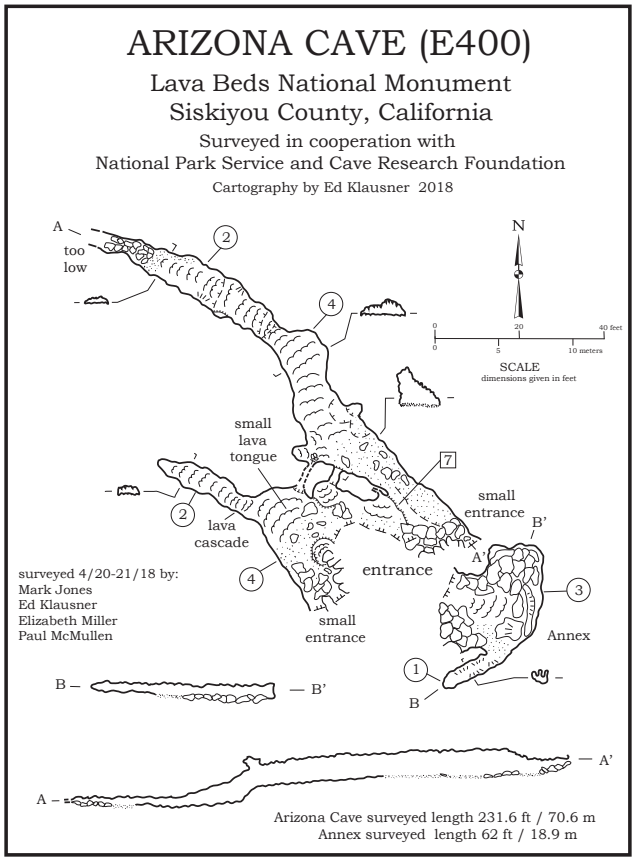
Total survey Elmer's Trench: 179.3'

Surface survey:

- Pothole to Turtle Shell—32.2'

Total surface survey: 32.2'

Total hours: 25



The 18th International Vulcanospeleological Symposium

July 21–26, 2018

John Tinsley

Manager, CRF-Lava Beds Operations

The biannual 18th International Vulcanospeleological Symposium (IVS) was convened at Winema Lodge, just a few miles north of Lava Beds National Monument. The IVS drew about 60 persons from around the world; attendees enjoyed excellent food, fabulous geology, stimulating technical sessions, and fine opportunities for exploring and experiencing the region's hundreds of lava tube caves and other volcanic features, the rich cultural history, and unfortunately, some seriously bad air conditions owing to the many wildfires scattered about northern California, Oregon, Washington, and as it turned out, British Columbia.

Personnel of the Cave Research Foundation, whether or not explicitly wearing a CRF hat, played many key roles in the symposium, including presenting papers, leading field trips, providing some evening musical entertainment, and enjoying mixing with folks from around the world. Personnel of the Redwood Grotto, NSS, were the main organizers of this IVS, with Mary Rose, Scott Linn, and Bruce Rogers among others playing mainstay roles. Peter Bosted generously stepped in and assembled and chaired the technical program when the original chairperson had her leave cancelled owing to the then-raging Kilauea volcano eruptions on Hawaii's Big Island. Several CRF folks stayed at the Lava Beds Research Center and commuted about 15 miles each way to the symposium; this pulled down their costs a mite and took some of the pressure off the Winema Lodge's accommodations, as they were pretty much at capacity.

Following the welcome party on Saturday evening of July 21, the next five days followed a basic plan of breakfast from 7–8:30 a.m., technical sessions from 9–12 noon, lunch from 12 to 1 PM, then the afternoon was given over to field trips, usually 4 to 5 different trips. Dinner at Winema Lodge then was from 7 to 8 p.m. On Tuesday, the dinner was a catered BBQ at the Lava Beds Amphitheater near the campgrounds. This included a fine meal, music and singing led by Bill Frantz and John Tinsley with able assists from attendees who also inherited the ham gene. As dusk deepened, the National Park Service (NPS) folks broke out their telescopes and folks viewed everything from the full moon to major planets. Owing to the full moon and the haze, checking out assorted galaxies was not happening, but with the three telescopes, including a solar telescope, a good time was had by all.

Afternoon field trips ranged widely in topics, and included not only the main Cave Loop caves commonly exploited by tourists, but also included NPS–interpreter-led tours of Symbol Bridge and Big Painted rock art caves, Captain Jack's Stronghold (principal site of the 1873 Modoc War), the WWII Segregation Center (Tulelake Japanese internment site), a tour of the Freudian Complex on the south side of Medicine Lake Volcano led by Liz Wolff. Heather and Matt Leissring led several field trips. Canoe trips toured the Upper Klamath basin and reservoir, including totally fine birding; Petroglyph Point with its myriad rock art displays; a NPS-led tour of Fern Cave (extremely closely controlled visitation there, owing to cultural sensitivities); and a fabulous presentation by historians analyzing the sources of conflicts in the Klamath Basin down through the decades, be the conflicts cultural, economic, or ecological.

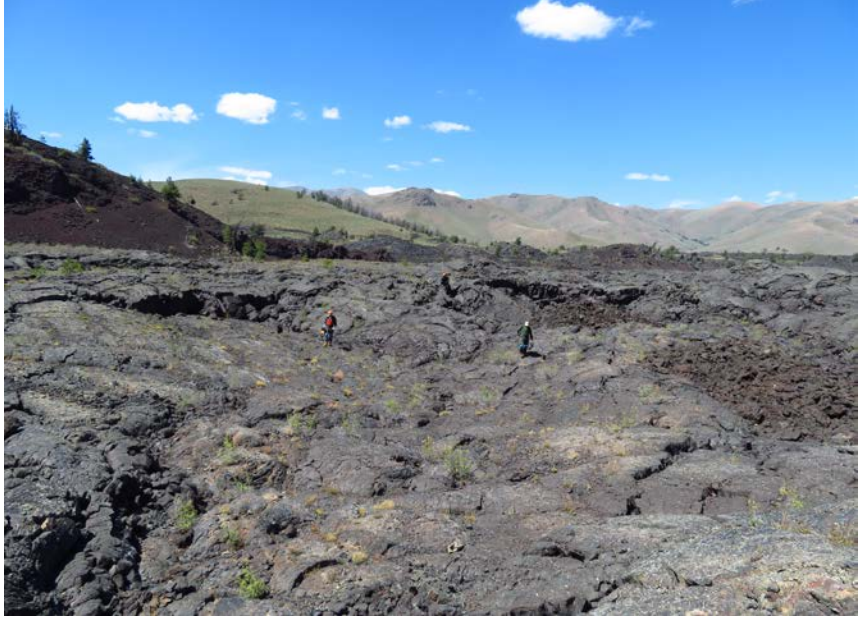
Among the items or booty at the IVS was a set of cave maps, a well-designed guidebook and an abstracts with program volume that helped keep everyone on track. Peter Bosted conscripted several people to lead respective technical sessions, and not only to introduce the presentations but also to summarize the session at the closing of the presentations. This helped keep everyone focused on the main points made by the presenters.

Those desiring more information about the IVS, visit the IVS website at www.vulcanospeleology.org.

Craters of the Moon National Monument

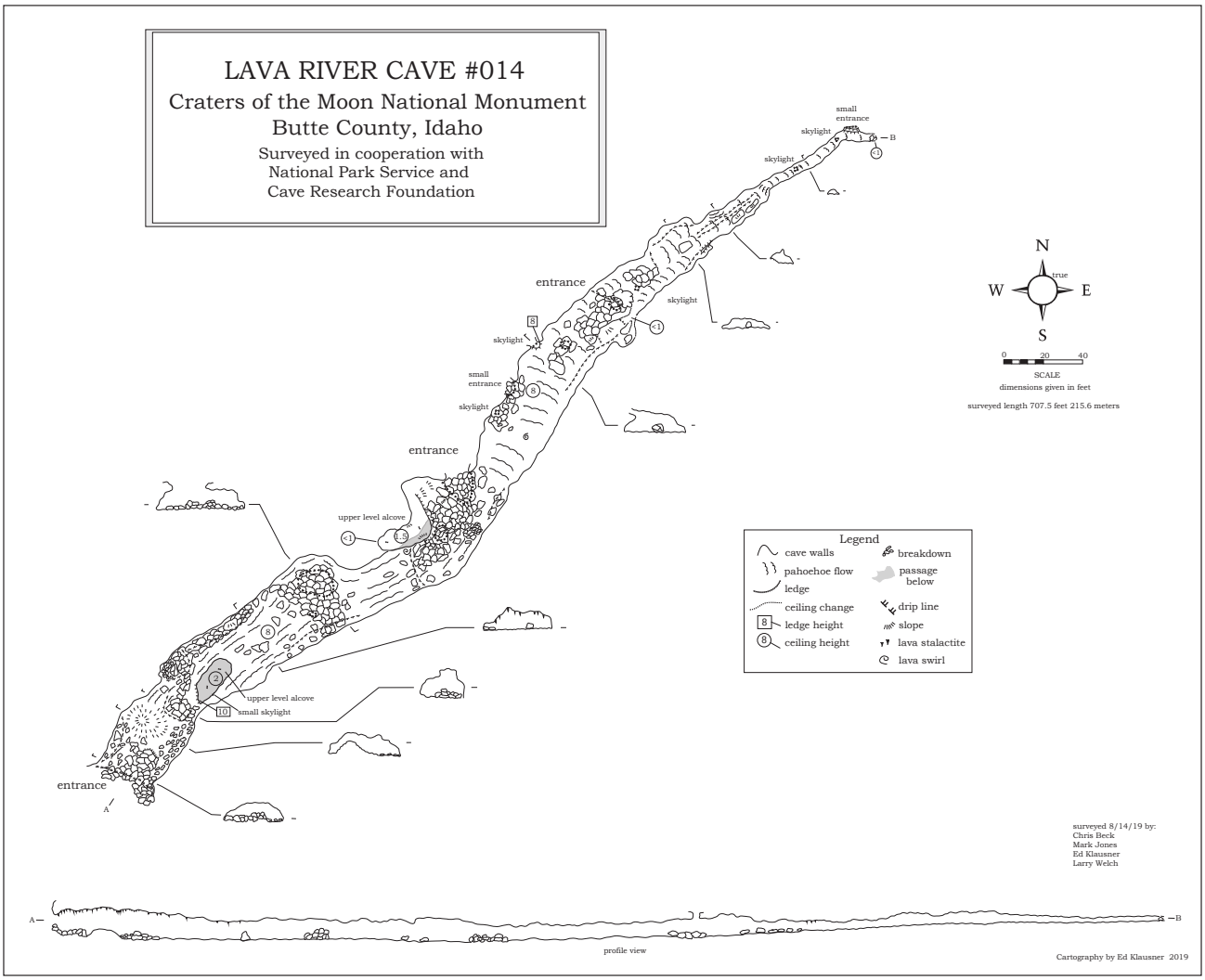
Butte County, Idaho

Mark Jones



Craters of the Moon. *Chris Beck*

Craters of the Moon National Monument and Preserve in south central Idaho has over 500 known lava features that range from diminutive surface tubes to the enormous Great Rift. While the number of caves has steadily increased, no dedicated systematic mapping or inventorying has been undertaken. Mark Jones spearheaded this new CRF project with much appreciated assistance from Ed Klausner and Dave West. This work was facilitated through Todd Stefanic, the wildlife biologist at the monument and Mauro Hernandez, Wildlife Biological Technician.



The first Expedition in May 2019 had Eve Barnett (park intern), Jenn Ellis, Mark Jones, Paul McMullen, Gabe Taylor, Dave West, Craig Williams, and Karen Willmes operating out of the research yurt. Participants traveled over 17,000 miles to participate in this six-day expedition. Dave mainly focused on the caves in the northern end of the monument while Mark surveyed those around the Lava Loop. The highlights of the week were the confirmation of archeological and historical evidence in some of the caves, a biological inventory of all the caves, the completion of Screaming Jaws of Death Cave, and the surveys of Nick Cave and Rio Grande Cave.

In August Larry Welch had scheduled a radon study at both Lava Beds and Craters of the Moon that also involved Chris Beck, Mark Jones, and Ed Klausner. During this abbreviated expedition two more caves were surveyed with Lava River Cave clocking in at over 700 feet. Ed was so aghast with the map of Horseshoe Cave (Figure 1) that he demanded that we rectify the situation. Figure 2 is the result of the resurvey.

The final expedition involved Brenda Goodnight, Mark Jones, Dennis Novicky, Joe Vasko, and Fred Wilkinson. Fred's residence in Canada pushed this into the international expedition category. The first several days were spent around the Lava Loop where two caves stood out. The first was the pocket-sized Pond Cave at only 89 feet. Despite being small it offered a unique oasis that slaked the thirst of the local fauna. A video in the Visitor Center shows a bat on the wing lapping a drink from this cave. The other, Surprise Cave, was quite different with over four hundred

Larry Welch. *Ed Klausner*

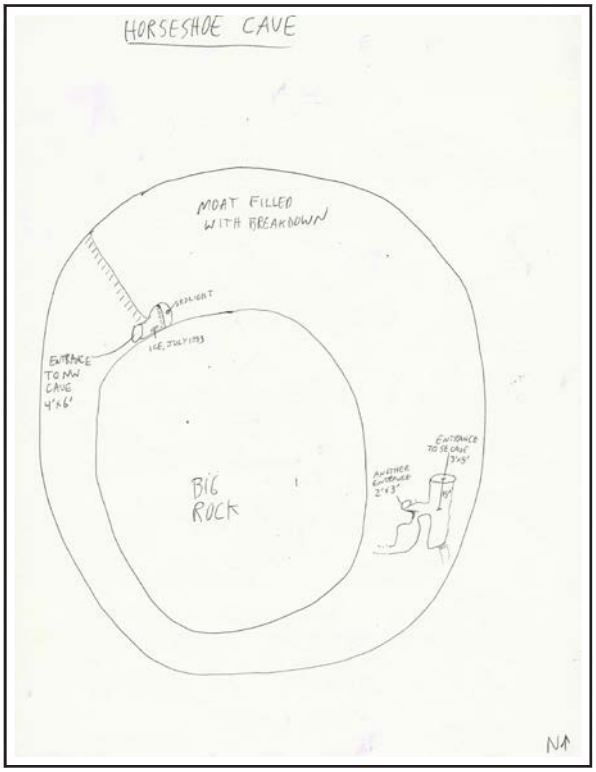


Figure 1.

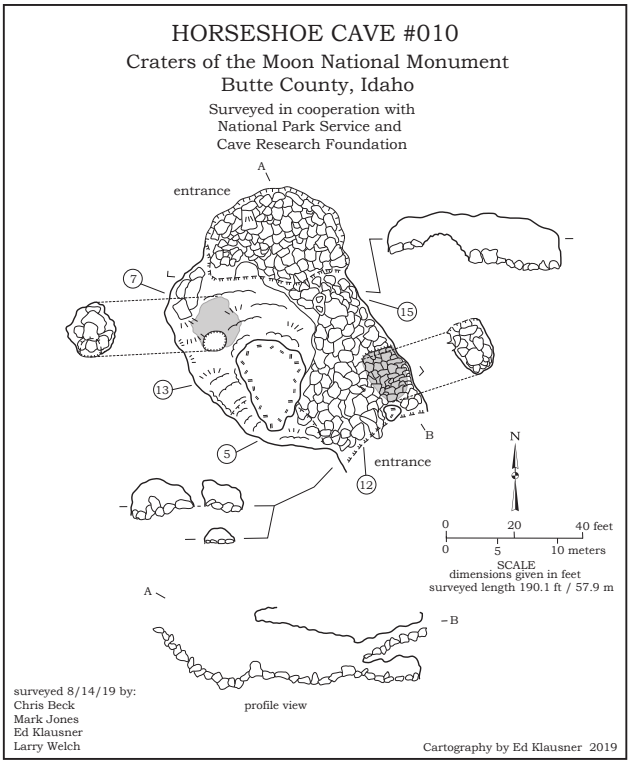
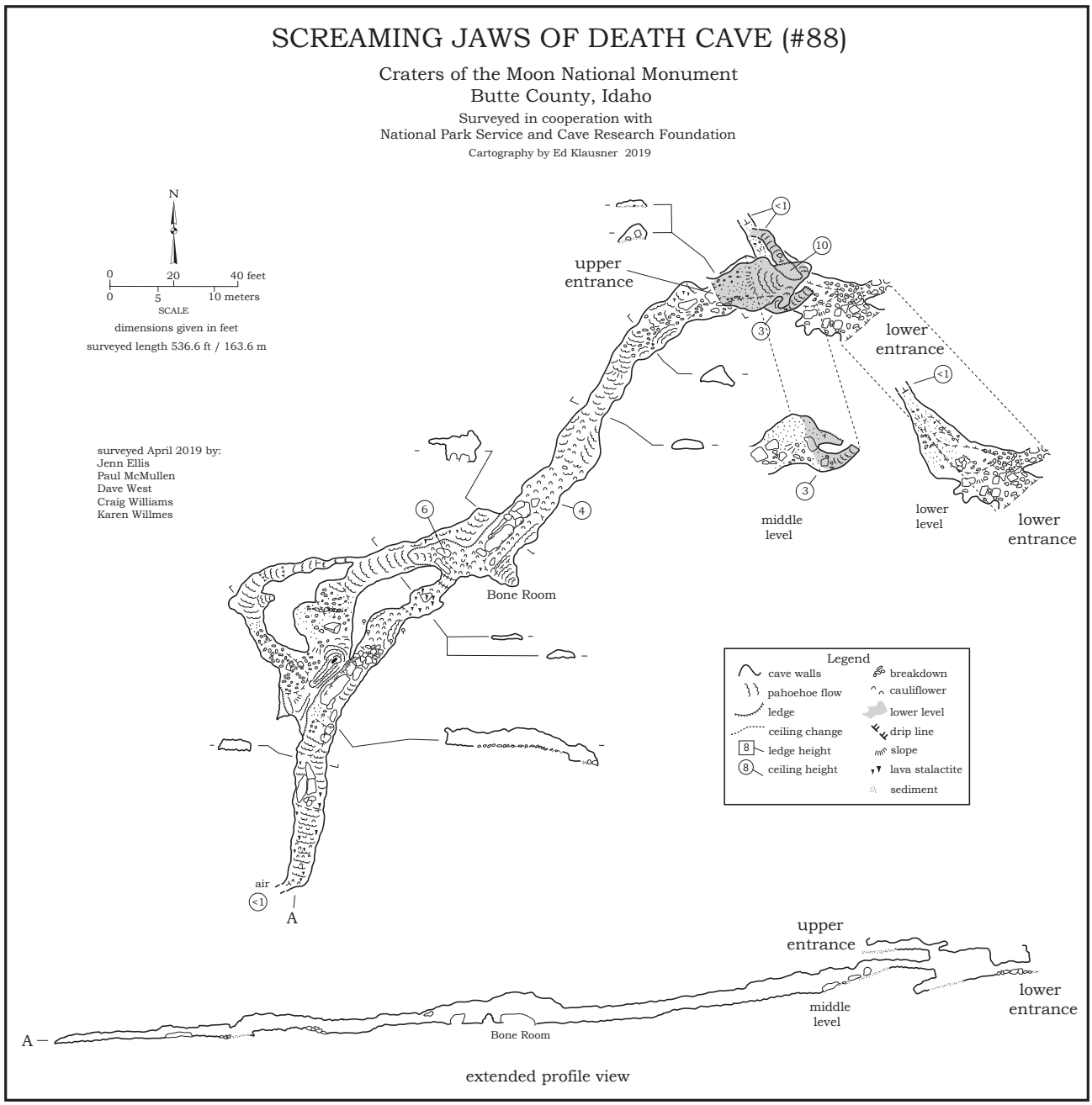


Figure 2.

Campsite and yurt. *Ed Klausner*

feet of roomy passage that also offered water to its visitors although much of it appears to be frozen most of the year. An unidentified pink slime mold was noted near this feature that needs to be researched.

During the second half of the expedition the group moved to Wapi Park in the extreme southern end of the monument. Here North and South Expedition Cave, connected by a tight, rocky crawl combined for over two thousand feet of well-decorated lava tubes. The most interesting formation was where two tube-in-a-tube flows intersected forming an X on the floor. Mirroring the



success at Lava Beds two major expeditions proved to be very successful and will be planned in the future.

A synopsis of the year is as follows:

May Expedition

- Flow Throat Cave—109 feet
- Moonshine Cave—63 feet
- West Moonshine Cave—25 feet
- Screaming Jaws of Death Cave—534 feet
- Nick Cave—745 feet
- Rio Grande Cave—488 feet
- Holiday Cave—121 feet
- Bloody Knees Cave—550 feet
- Three Rooms Cave—214 feet
- Sunglasses Cave—71 feet

August Expedition

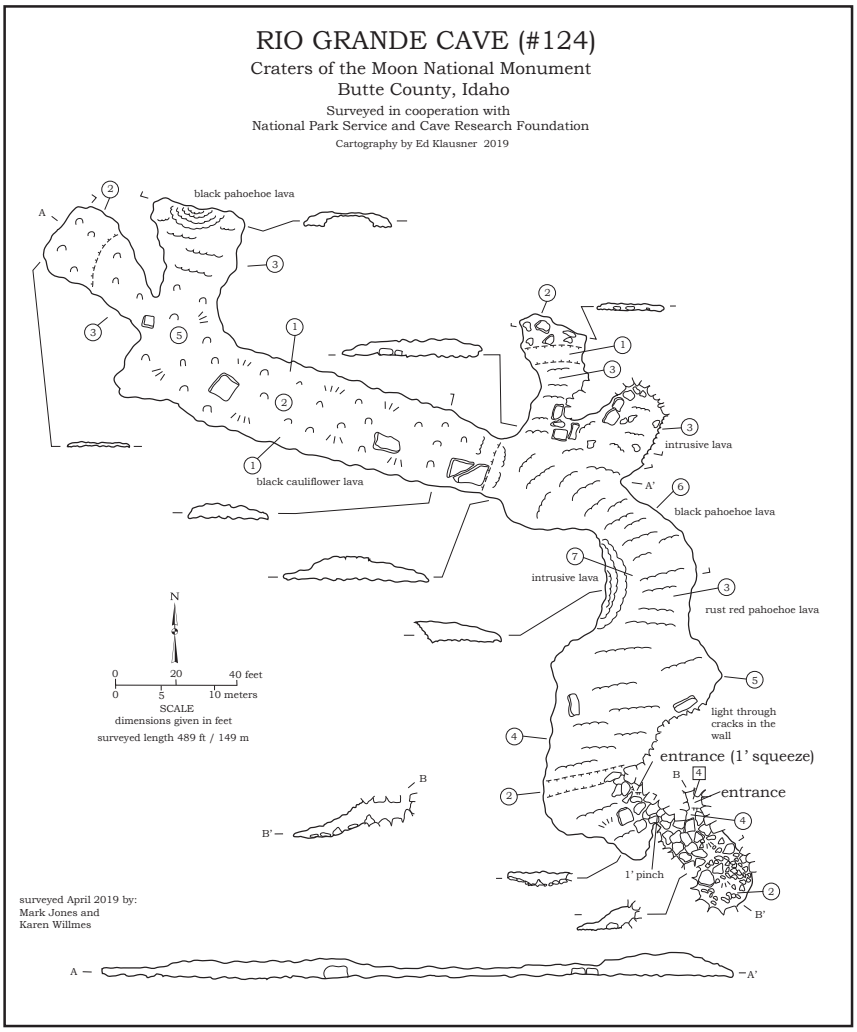
- Radon study at Rio Grande Cave & Skelebat Cave
- Lava River Cave—707 feet
- Horseshoe Cave—190 feet

September Expedition

- No Chance Cave—149 feet
- First Chance Cave—319 feet
- Don't Look Cave—95 feet
- Final Chance Cave—110 feet
- Don't Remember Cave—199 feet
- Root Cellar Cave—118 feet
- Pond Cave—89 feet
- Sagebrush Tunnel—36 feet
- Coyote Hole Blister Cave—59 feet
- Shelter Cave—45 feet
- Surprise Cave—442 feet
- Taffy Top Cave—135 feet
- Two Step Cave—201 feet
- Cinder Cave—76 feet
- Dirt Floor Cave—35 feet
- South Expedition Cave—1,301 feet
- North Expedition Cave—1,021 feet
- South Expedition Annex—86 feet
- Tight Fit Cave—55 feet
- Lariat Cave—480 feet

32 caves surveyed for a grand total length of 8,884.2 feet. This is approximately 6% of the known caves currently at Craters of the Moon Monument and Preserve.

Chris Beck and Larry Welch. *Mark Jones*



Ozarks Operations in Arkansas

2018–2019

Kayla Sapkota

Buffalo National River

The Buffalo National River, a National Park Service entity in northern Arkansas, is home to roughly 775 recorded karst features, including caves, shelters, small karst features, and reported leads. We suspect that there are many additional sites not yet discovered. The Cave Research Foundation (CRF) operates under a cooperative agreement and research permit in the Buffalo National River.

The 2018 to 2019 period was one for increased productivity and efficiencies for the CRF project on the Buffalo National River lands. Volunteer numbers held steady, and learning and development opportunities increased effectiveness of expeditions.

Salamanders in Rainy Cave. *Kayla Sapkota*

Figures

- Total Mileage: 76,601
- Total People Days: 516
- Total Survey Footage: 35,398.3
- Total Hours: 4,361.3
- Total Trips: 161
- New Public Use Monitoring Records: 251
- New Faunal Records: 955
- New Maps Completed: 107
- New Caves/Shelters/Karst Features Located: 46

Facilities

CRF continued to utilize two research stations on the Buffalo National River in order to increase reach along the 130+ mile long park land on the river. The primary facility used was the Steel Creek Research Center (SCRC), also known as the "rock house." This facility is located on the Upper District (west) and provides a good base of operations to work in the many cave and karst features in the Middle District, as well. It 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 two semi-permanent, canvas tents with heavy-duty cots.

The second facility that this project uses is the Toney Bend Research Center (TBRC), also known as the George Harp Field Station. During this two-year period, about a third of the expeditions were held at this facility, increasing our progress in mapping, monitoring, and better documenting cave and karst features on the Lower District greatly. Like the SCRC, the TBRC has a full kitchen, decontamination/laundry area, gear storage space, a living room with Smart Board technology, and three bedrooms, though there is significantly more bunkbed space inside the facility as compared to at the SCRC.

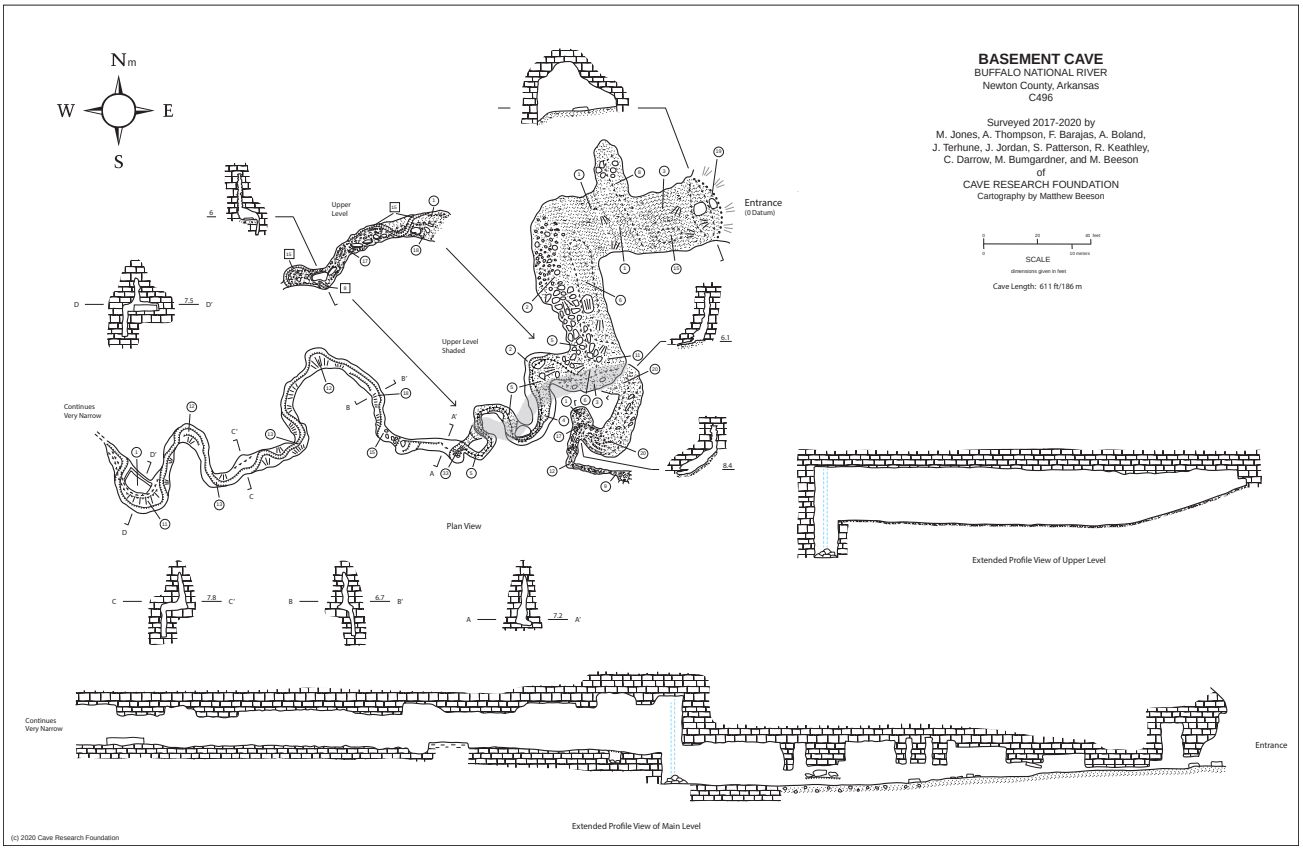
Areas of Focus

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 received training updates on biological identification during each year. Jimmy Gore, bat researcher, provided a training on bat identification with a

Aaron Thompson, Dillon Freiburger, Kayla Sapkota, Claty Barnett, and Bryan Rupar after a day of surveying in Column Cave and Pit Cave. *Bryan Rupar*

very helpful Q&A session. Mike Slay, from the Nature Conservancy, provided a presentation on cave life commonly found in the Buffalo National River area. These trainings serve as a great primer for new volunteers and a helpful update for continuing volunteers.

In other training, we continued to work with new volunteers on mapping tasks, such as instrument reading, station-setting, and sketching both in-field and at the station. As has been practice, new volunteers are placed on teams with seasoned trip leaders, who can work closely with them to learn the what/why/how of the day's objectives, as well as get acquainted with the project in general.



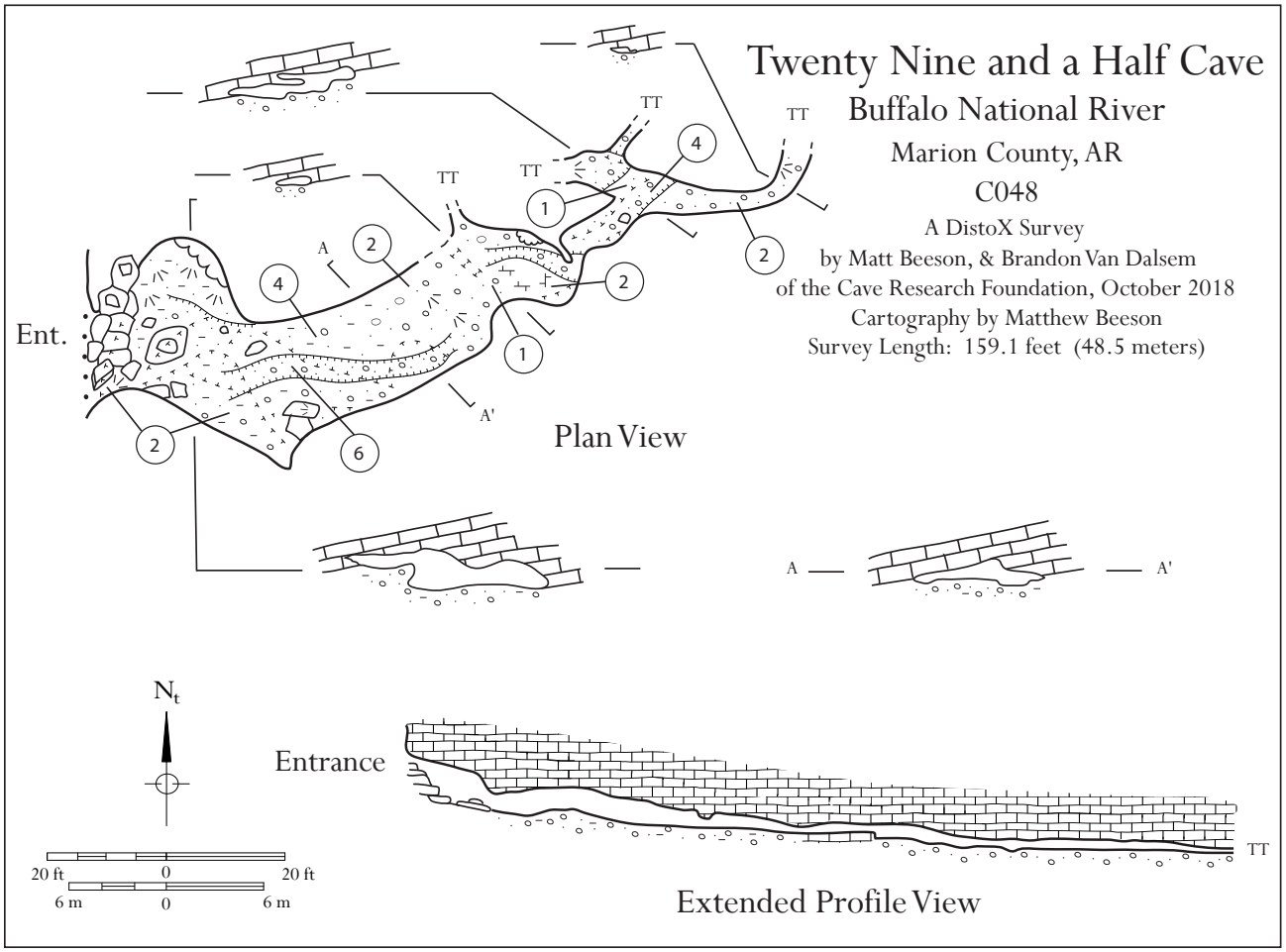
Field Trips

Expeditions were held each month, with some months having multiple expeditions, and some expeditions lasting longer than one weekend. Longer expeditions were held over the Thanksgiving holiday and in the week leading up to Christmas, which aided in CRF's winter bat monitoring efforts. 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, bio-monitoring, and mapping cave and karst features that had not been visited in some time, as well as those smaller caves known to be inhabited by bats. Visiting features that require extensive, and sometimes challenging, hikes during the cooler seasons is preferable due to lack of ticks, chiggers, and poison ivy/sumac/oak.

Each spring, a monthly expedition typically would include a float trip in order to visit caves most easily accessed by river, but in 2018 and 2019, we opted for additional ridge-walking and hiking trips to cave and karst features, due to an unseasonably cold spring in 2018 and the momentum of progress in areas that did not require watercraft in 2019.

Aaron Thompson near Wink Cave. *Dillon Freiburger*



Due to a limited visitation season (May 16–August 15), summer expeditions were dedicated to continuing the survey of Fitton Cave—Arkansas's longest cave. Limitations to the time period in which we could access this cave were due to its importance as a hibernaculum for threatened and endangered bat species. Much progress has been made on the five map sheets for Fitton Cave, with four of the sheets nearly completed, and one sheet (the furthest one from the entrances) being over halfway completed. This advancement can be attributed to experienced team leaders and sketchers, active cartographers, and effective expedition structure over a prolonged period of time.

Cartography

We added a few new cartographers to the team, sharing and teaching via in-person evening sessions before/after trips on expeditions, via Zoom, and via email as appropriate. New cartographers submitted eleven final, digital maps in total during this period.

Two-thirds of known caves (those with "C" accession numbers) have either finalized maps or survey notes and maps-in-progress. In 2018, sixty-six final maps were completed. In 2019, forty-one final maps were completed. Several longer caves were mapped, finalized, or remapped according to modern standards. These caves required multiple trips and sometimes lengthy hikes to reach.

- Back o' Beyond Cave—785 ft
- Bat Cave (Marion County)—1,311.5 ft
- Fitton Spring Cave—817 ft
- Kneebacker Cave—966.6 ft
- Stockman Cave—1,602 ft
- Summer Cave—1,554.1 ft

Additionally, CRF focused a concentrated effort on mapping all the smaller caves in several focus areas before moving to new ridges or sections of the river. This concerted approach allowed for increased data integrity with a more complete understanding and identification of caves in an area in relationship to one another. To this end, ridge walking, monitoring, and mapping efforts focused on the following areas.

- Big Hollow
- Cliff Hollow
- Duck's Head
- Lost Valley
- Rush Landin
- Tea Table Ridge

Future Work

Per CRF's research permit and cooperative agreement with the Buffalo National River, the focus will remain on biological monitoring, public use monitoring, and cartographic survey. Data in the form of locations, photos, descriptions, faunal records, trip reports, and finalized maps will continue to be shared with the NPS in order to provide a fuller picture of the cave and karst resources on Buffalo National River lands. This information may aid the NPS in future research projects, rescue situations, and project assessments.

Recruitment of new volunteers and training/updates for continuing volunteers will continue in order to grow and advance our productivity. Outreach will continue to local caving organizations, educational institutions, and the current and past volunteer base. Training on survey techniques, data collection and sketching, and digital drafting of maps will also continue, aiding in the development of future leaders and cartographers.

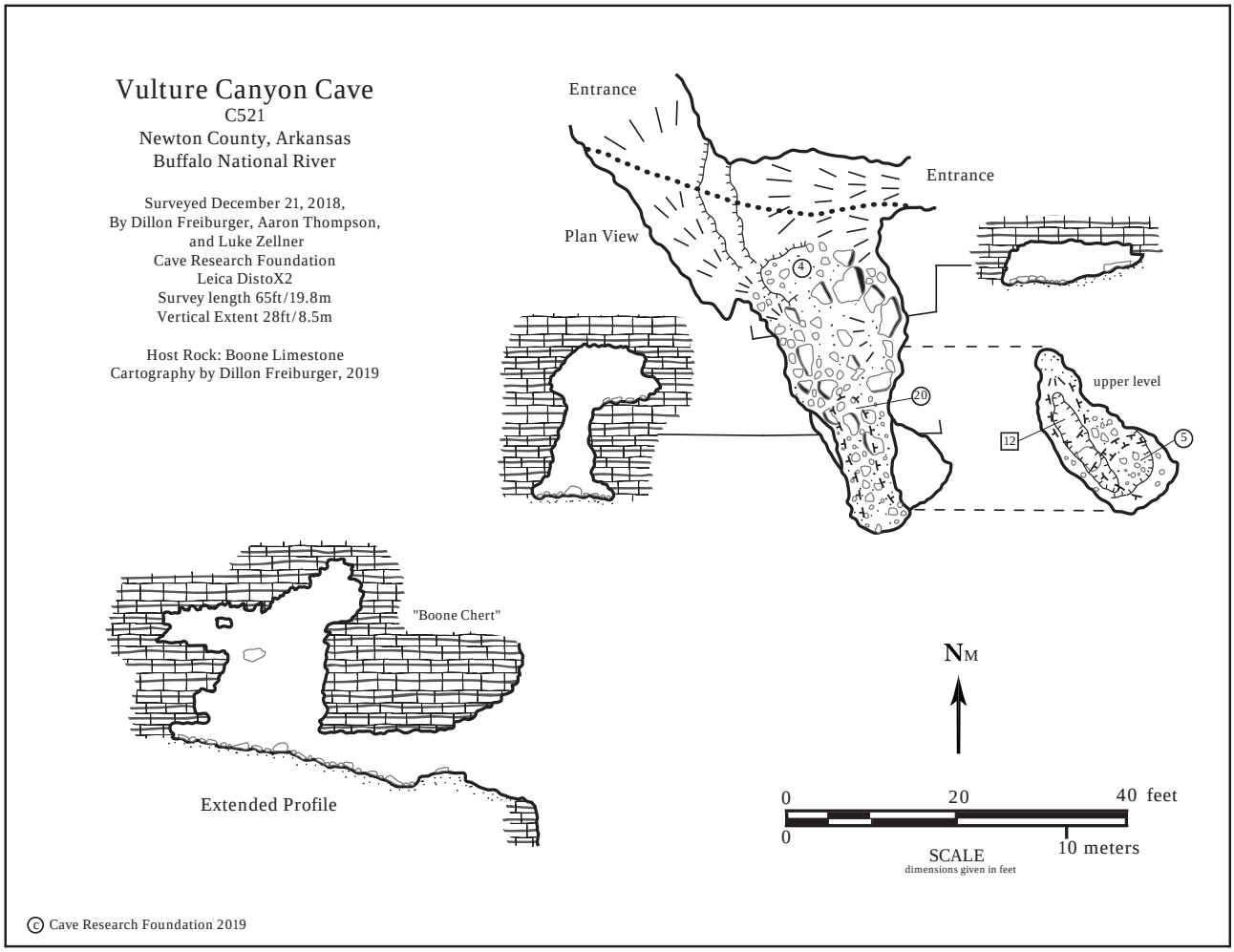
Cody Brooks, Kayla Sapkota, and Nathan Windel at the trailhead. *Mark Brooks*

Claty Barnett and Kayla Sapkota bring some trash from the cave back to the truck. *Bryan Rupar*

Dillon Frieburger sketches while Mandy Harris and Aaron Baggett look on. *Kyle Moore*

Arkansas Natural Heritage Commission

In early 2019, the CRF began working with the Arkansas Natural Heritage Commission (ANHC) to map a handful of their caves in the Devil's Eyebrow Natural Area in northwest Arkansas. Three caves were mapped during this period, including MacMerry Spring Cave, Column Cave, and Pit Cave. Three trips were made to MacMerry Spring Cave in late January and early February 2019. MacMerry Spring Cave was ultimately mapped to a length of 97.9 feet.

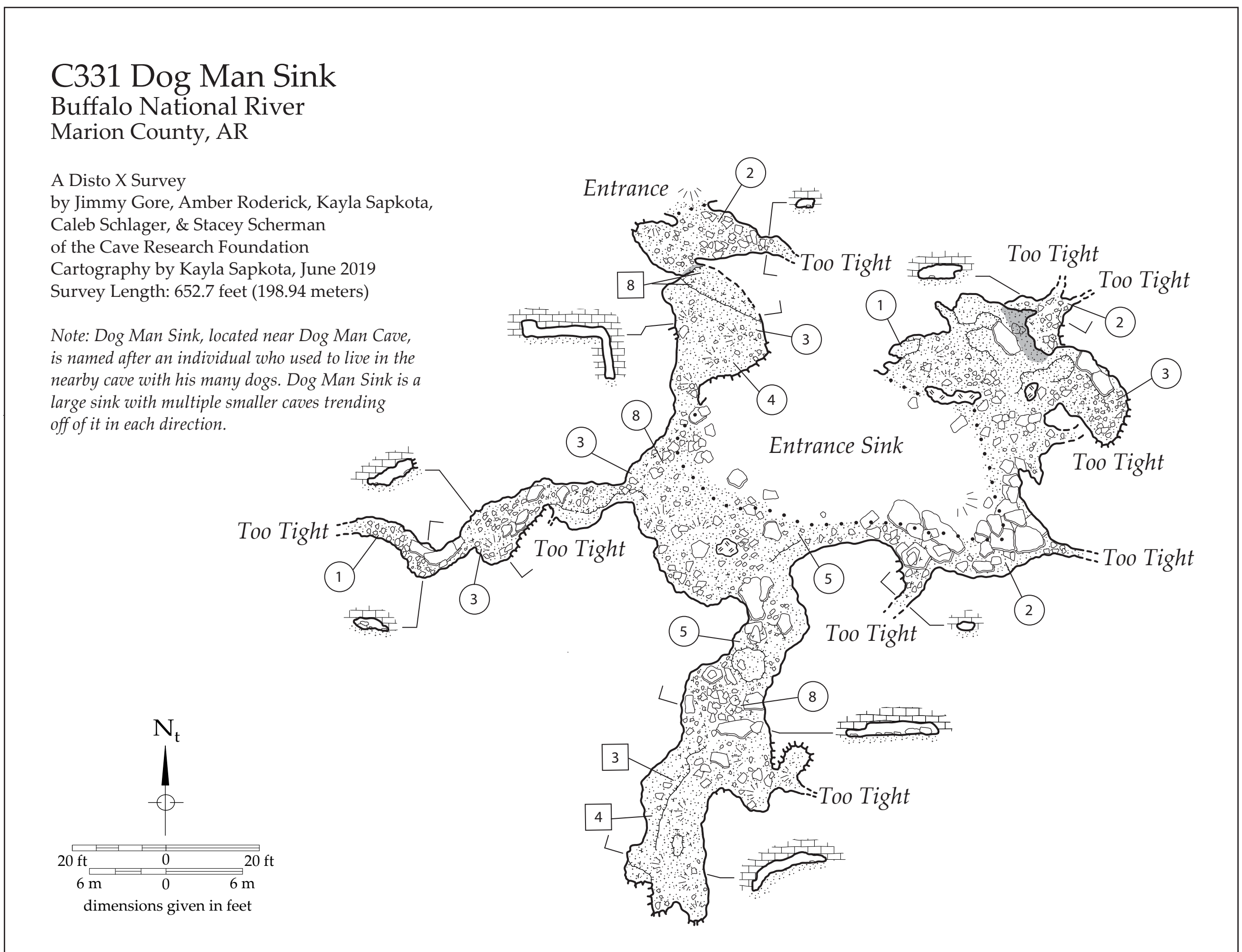


A team returned to Devil's Eyebrow Natural Area in August 2019 to locate and map the next cave. A total of 1,120.6 feet was surveyed in Column Cave and Pit Cave (situated immediately next to one another), but Column Cave will require an additional trip in 2020 to complete the survey. Biological inventories were also completed during these survey trips and the trips to MacMerry Spring Cave.

U.S. Fish and Wildlife Service

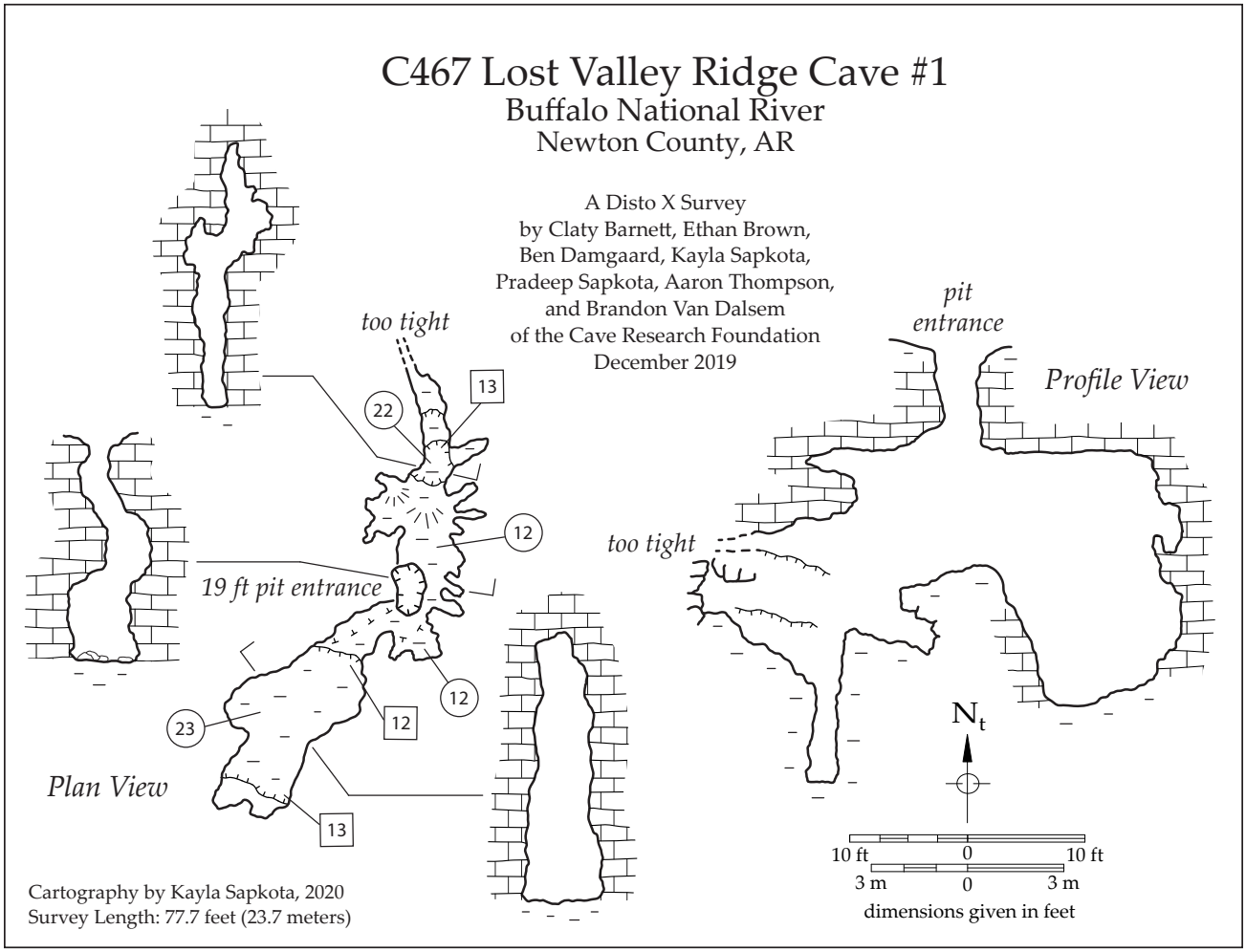
During the winter months, a few CRF volunteers assisted U.S. Fish and Wildlife Service biologists with searches for endangered Ozark Big-Eared Bat, Gray Bat, and Indiana Bat searches and radio-tracking projects.

Kayla Sapkota searches for cave life. *Aaron Thompson*



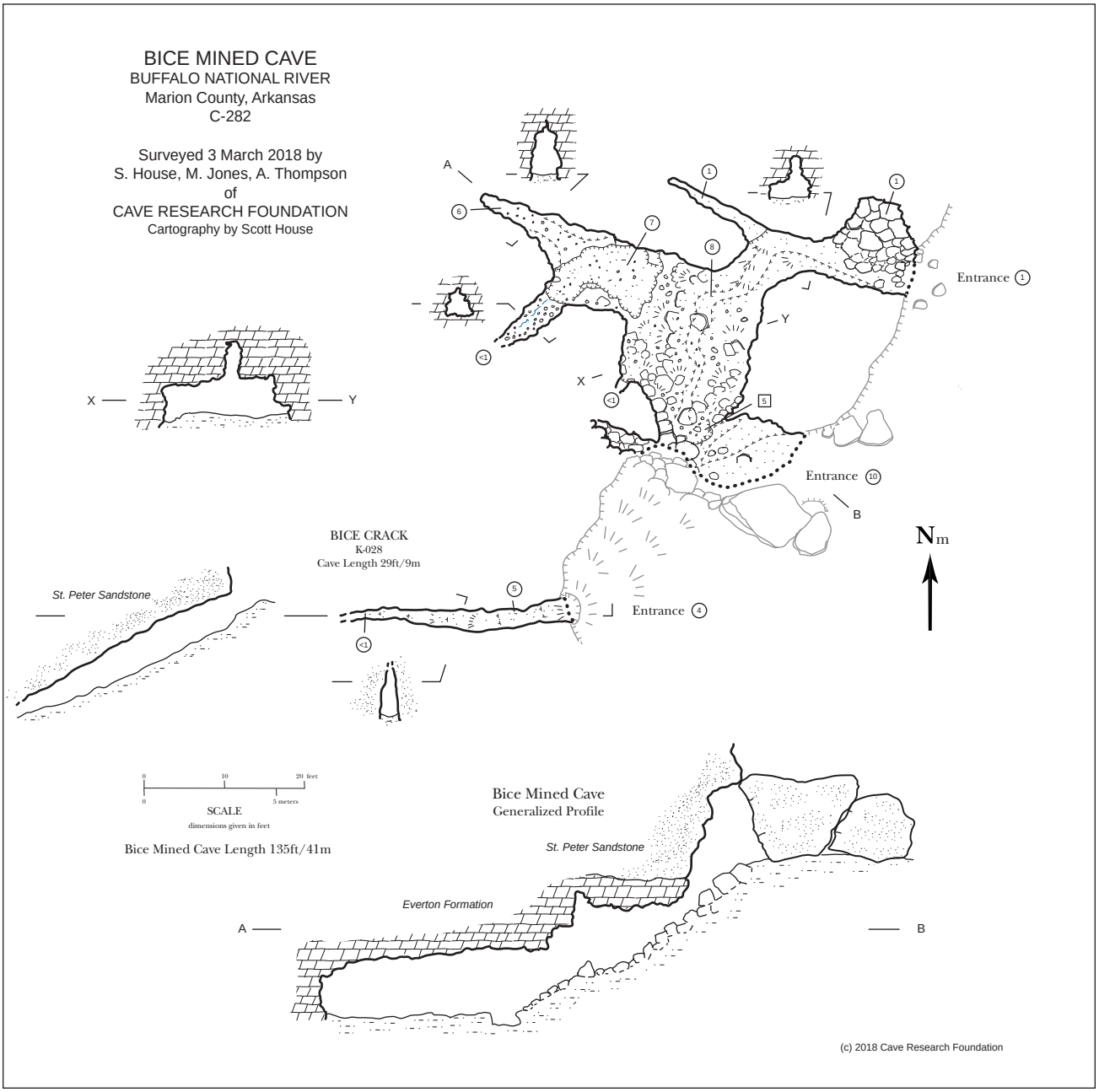
Hannah Sanders waits for the next survey shot. *Mark Brooks*

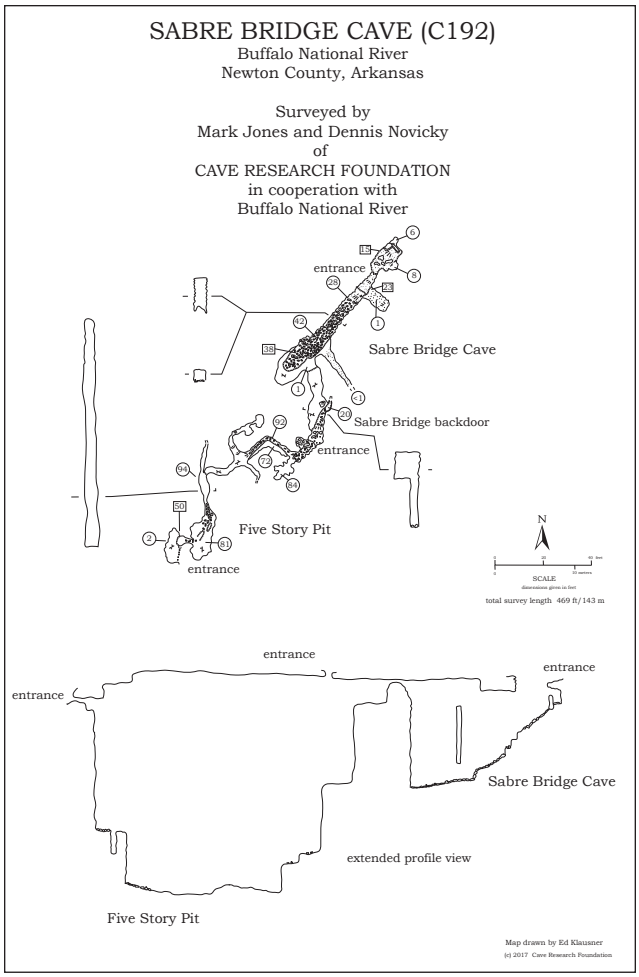
Pradeep Sapkota takes the survey shot. *Mark Brooks*



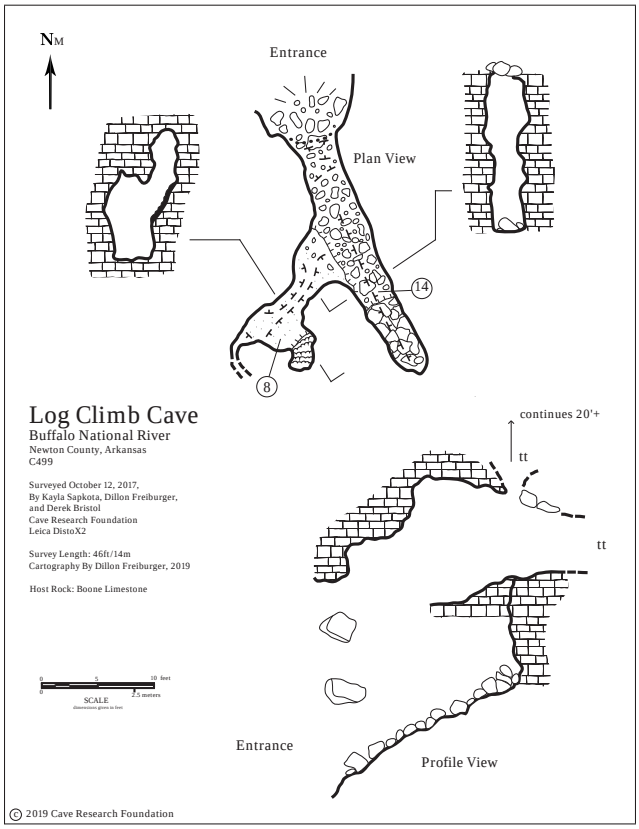
Bryant Galloway enters Beechwood Mine-Cave. *Kayla Sapkota*

Cave Salamander in Snuff Pit. *Kayla Sapkota*





Jimmy Gore holds the target for backsights. *Mark Brooks*



Aaron Thompson prepares to rig Cluster Pip Pit.
Dillon Freiburger

Summer Cave

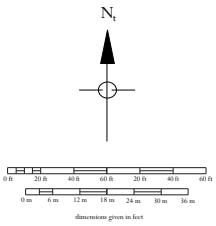
C105 / MR7411

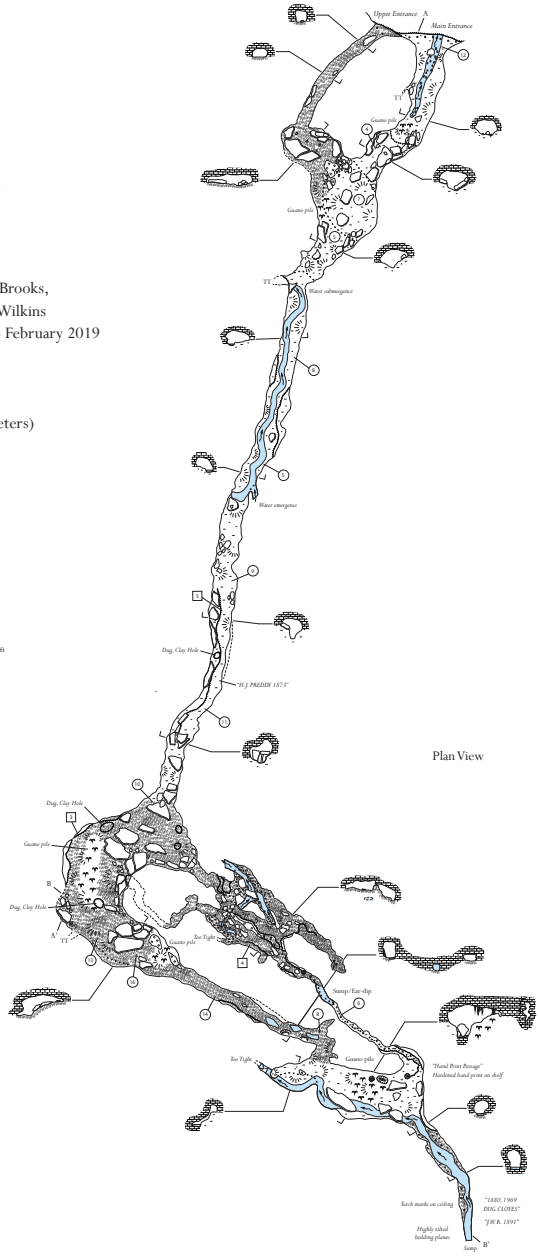
Buffalo National River

Marion County, AR

A Disto X Survey
by Cody Brooks, Mark Brooks, Sabrina Brooks,
Kayla Sapkota, Sammy Wentz, & Brent Wilkins
of the Cave Research Foundation, March 2018 - February 2019
Host Rock: Everton Fm.

Cartography by Kayla Sapkota
Survey Length: 1,554.1 feet (473.7 meters)





Plan View

Projected Profile View

Ozark National Scenic Riverways 2018–2019

Scott House

Ozarks Operations Area Manager

Operating under a cooperative agreement, CRF fielded over 100 field trips on ONSR lands in the calendar years 2018–2019. These field trips, adding up to 280 people days and nearly 2,000 volunteer hours in the field, resulted in over 200 cave monitoring visits. In addition, a number of cave survey trips were taken, normally in conjunction with monitoring.

Highlights

The number of park caves has increased only slightly (law of diminishing returns) with 349 caves being on fee simple (NPS-titled) land, another 45 on scenic easement land, and another 33 within the authorized boundaries, for a total of 427 caves within the boundaries. All information is maintained within the Missouri Cave Database, and the park is kept updated with latest versions.

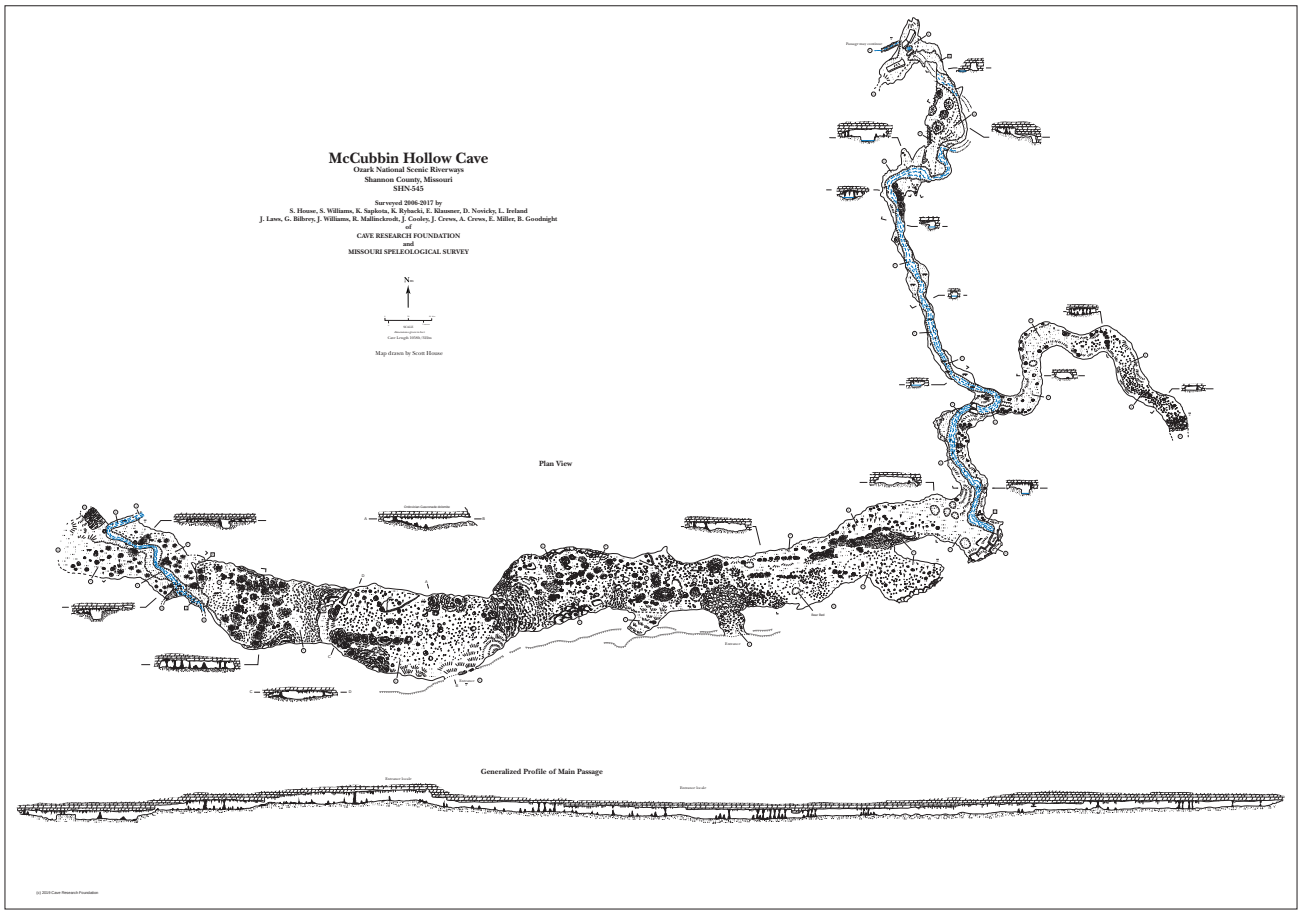
E. lucifuga eats an earthworm. *Scott House*

Scott House on Jacks Fork River. *Ken Grush*

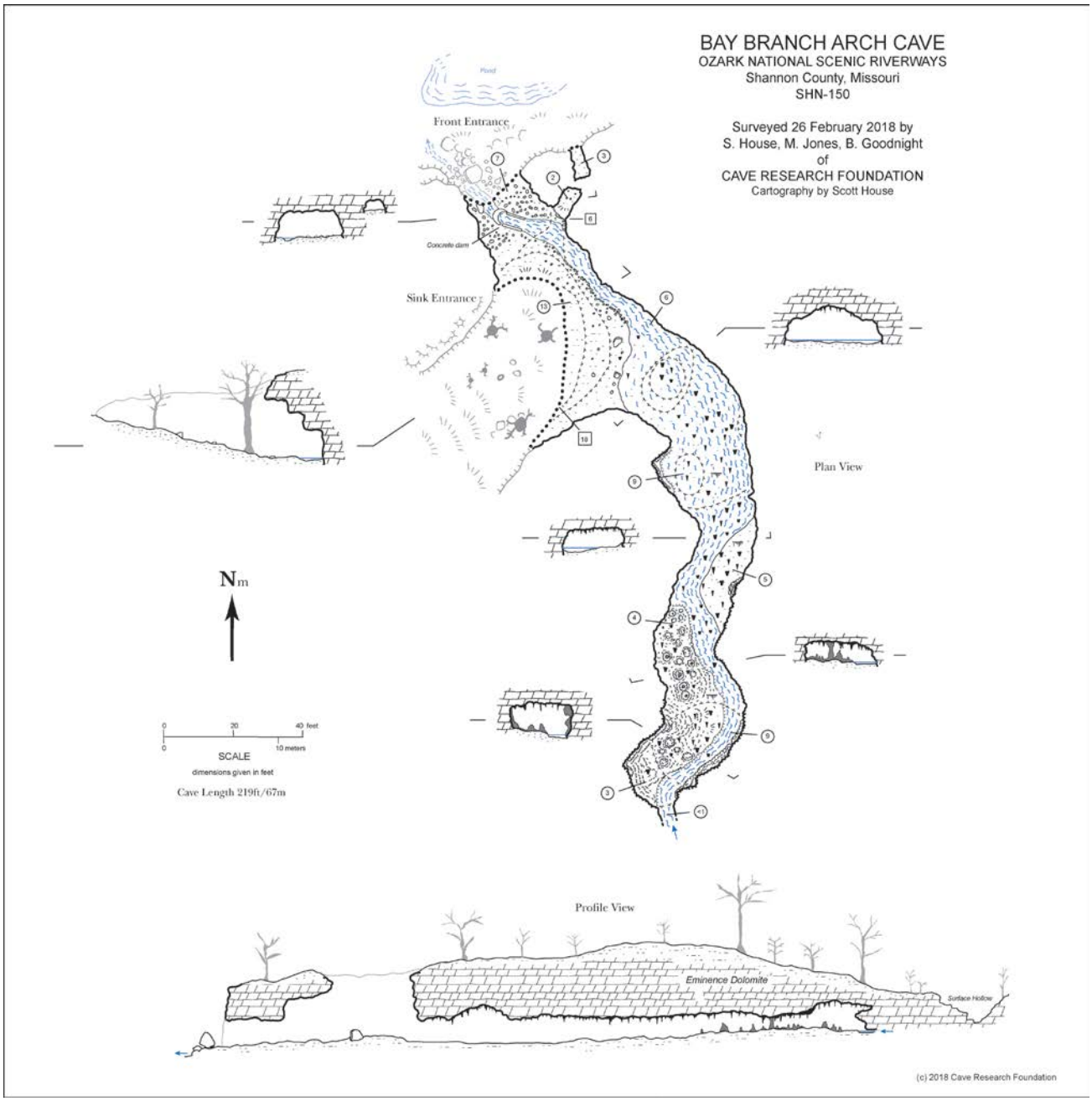
Slimy salamander in Little Granite Quarry. *Mark Jones*

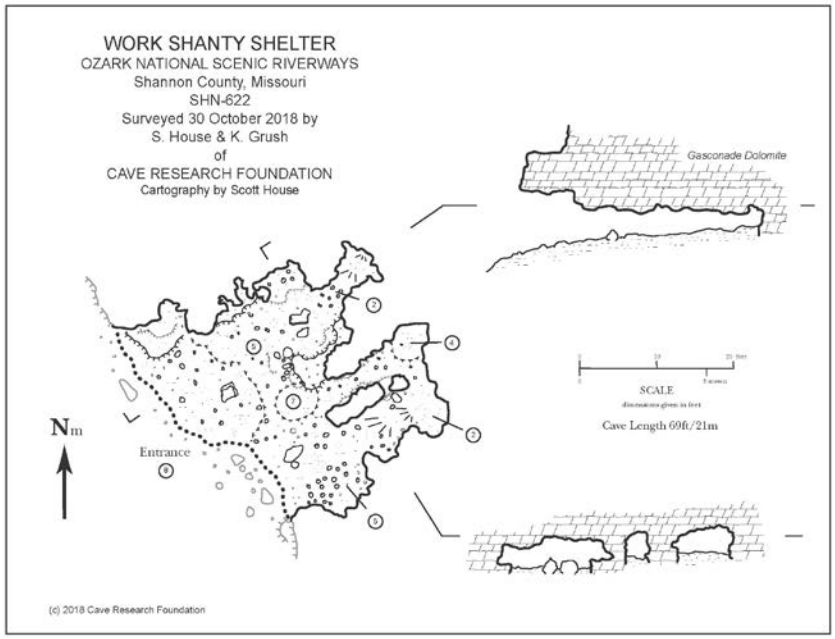
The active monitoring of caves resulted in over 430 new faunal records for the park. By the end of 2019, nearly 6700 faunal records existed for the park, approximately 1/5th of the state database total. Additional monitoring has been taking to nearby lands belonging to park partners, mostly to assess bat populations.

From Big Rock Bluff Cave. *Chad McCain*



Dennis Novicky gears up. *Chad McCain*





Bat populations continue to decline. Only gray bats (*M. grisescens*), Indiana bats (*M. sodalis*), and big brown bats (*E. fuscus*) are holding their own. A large gray bat colony in one cave was re-examined (owing to a great increase in population) and found to be constant.

Increasing attention is paid to non-bat cave species including several Species of Conservation Concern (SOCCs) such as the blind grotto salamander, Salem cave crayfish, and southern cavefish.

Detailed biological surveys were done for several caves, and a final report (by Mick Sutton) was produced in October 2019. The purpose of the study (authorized by research permit) was to obtain more data on certain important caves which had either not had a formal biological inventory or needed follow-up work to older studies.

Cartographic surveying continued in certain large park caves; however, weather has become an increasingly

Work Shanty Shelter. *Ken Grush*

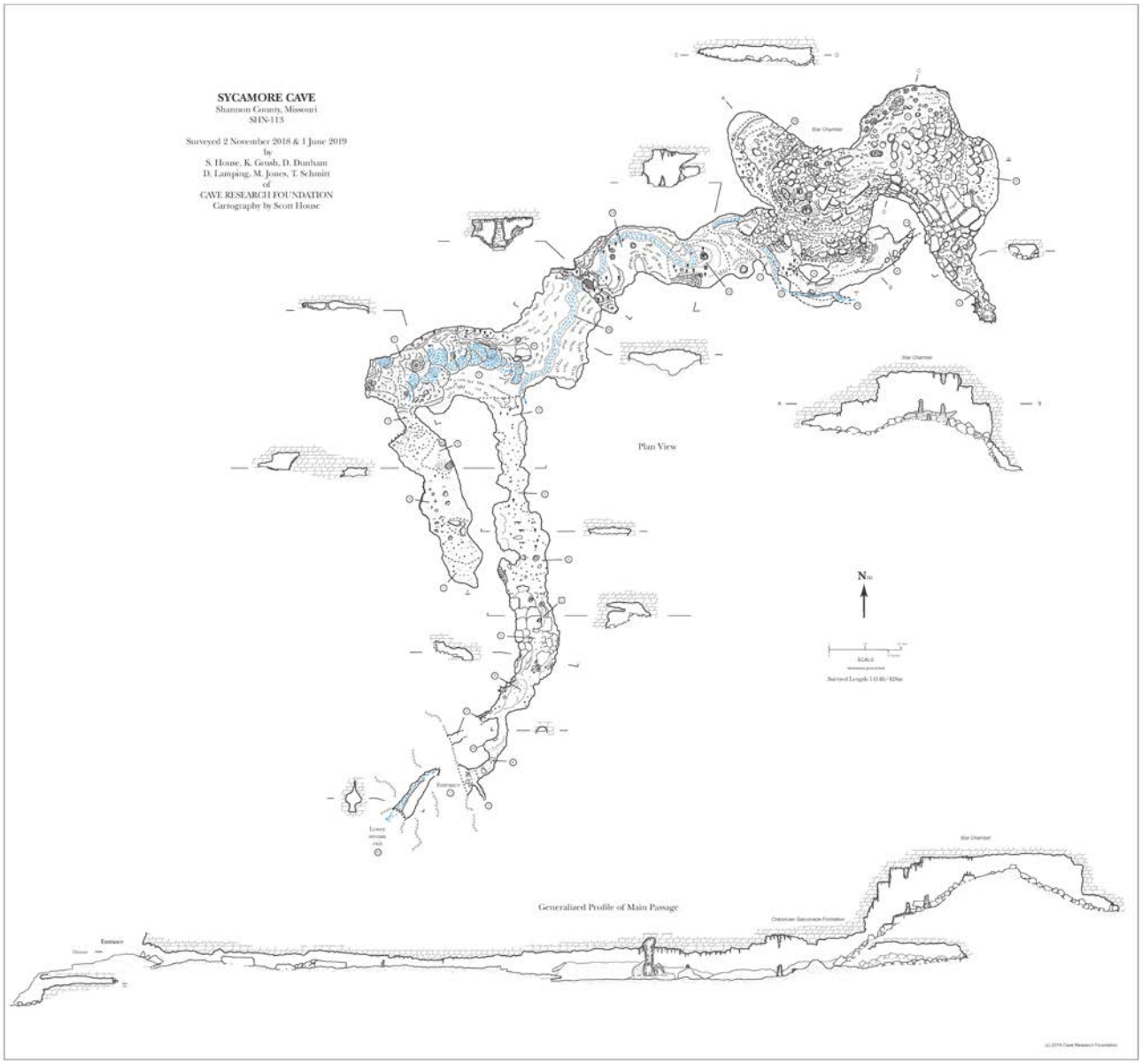
Bug search in Branson Cave. *Ron Colatskie*

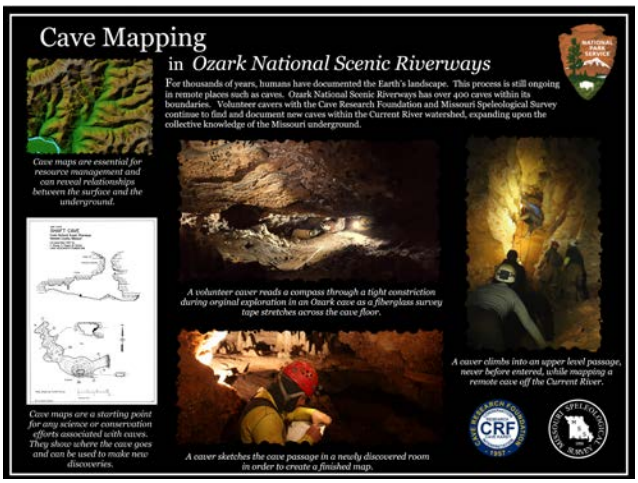
Courthouse Cave. *Scott House*

Chad McCain on the lip. *Chad McCain*

difficult issue for surveying wet caves. New maps were produced of a number of park caves including Bay Branch Arch Cave and Swiss Cheese Cave. The map of McCubbin Hollow Cave was finished after some years of effort.

Sycamore Cave. *Ken Grush*





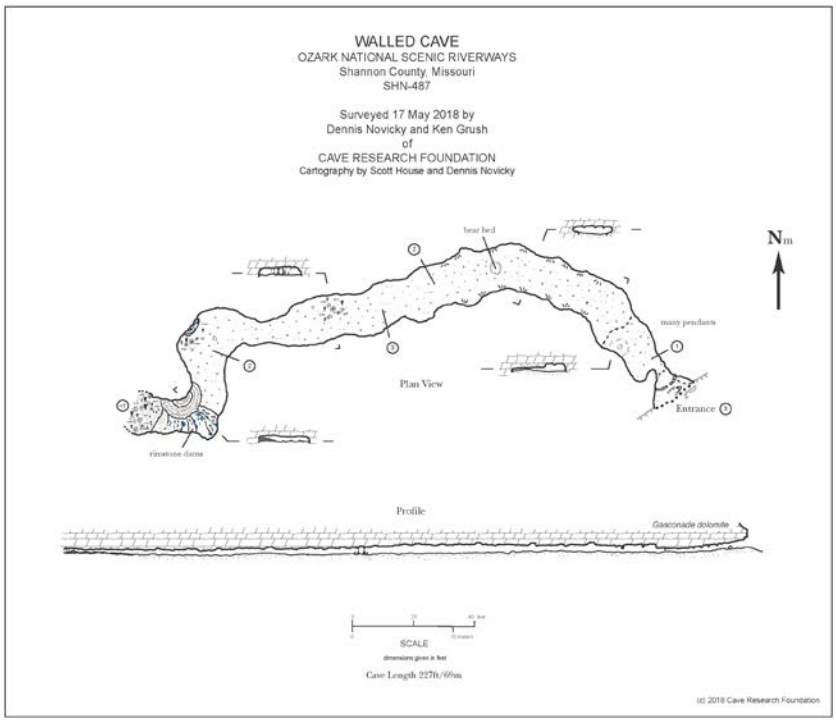
Cave Mapping Poster.

Cave Life Poster.

Sycamore Cave, an interesting and important cave located just outside the boundary on a park partner's land was surveyed and inventoried. New surveys were done in the Right Hand Fork of Round Spring Cavern in order to create a detailed geologic profile of the cave.

Public use (all caves are administratively closed due to WNS) was monitored, and any violations, mostly of a cultural nature, are promptly reported to the law enforcement rangers.

Cave gate and lock maintenance was done on every gated cave in the park. Over these two years, this included repairing one breach. Otherwise, all locks were checked and oiled. Other cave management problems are reviewed and prioritized; working with natural resource and law enforcement staff, these can be addressed quickly.



New facilities are at the U.S. Forest Service field station at Winona which is also jointly used by NPS. All CRF gating material was moved into a large shed, part of a historic warehouse, and the gear is all organized and inventoried. A new covered trailer was purchased for gating. Two new canoes were acquired by CRF and stored at the facility as well. A cave office was established and work was done by CRF to make this a more usable facility.

CRF education efforts at the park included presentations, cave tours, two new posters on cave life and surveying, and participation in school days. The posters were produced by Dan Lamping and are designed for use at visitor centers and in classrooms.

Mark Twain National Forest 2018–2019

Mick Sutton

The Mark Twain National Forest (MTFN) continued to be a major focus of CRF Ozark Operations, with nearly 180 field trips taking place over the period. About 40% of those trips were in support of the Butler Hollow Project on the Cassville sub-district in Barry County. This project originated with a need to gate five sites which had seen mining activity during a localized "radium mining" obsession in the early to mid-20th century but also included 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. The sub-district is a forested landscape of steep hills and deep valleys and includes the Piney Creek Wilderness.

Dillon Freiburger points out facies change. *Mark Jones*

Dennis Novicky and Kirsta Bartel at Cooks Cave. *Mark Jones*

The gating was completed under the direction of Jim Cooley with the help of MTNF staff and CRF and Americorps volunteer labor. Butler Hollow Mine Cave was a difficult construction project; an artificial adit entrance (horizontal entrance) required a relatively simple gate, but the upper natural pit entrance needed a picket fence type barrier constructed on steep terrain. Nearby Sugar Silver Cave was fitted with a small gate. The cave seemed an unlikely candidate for a mining operation, consisting of a relatively short and low stream crawl, but sure enough, blasting wire extended throughout to a small dome where a lot of clay had been removed. Over in Radium Hollow, one of the two artificial pit entrances to Radium Cave received a cupola-style gate, completing the gating for that cave.

As gating was wrapping up, Butler Hollow Mine Cave was resurveyed under the direction of Matt Beeson to replace an older map which omitted some passages and had interpretation problems. The additional passages proved to be fairly short but technically demanding. Twenty additional new caves elsewhere on the sub-district were documented and 30 cave maps were completed. One of the new caves, Mosquito Squadron Pit, proved especially interesting—this is a fairly deep pit (for Missouri) with its entrance near the bottom of the Butler Creek drainage—it's an intermittent spring and is flooded much of the time. The cave evidently represents a transitional stage in the gradual abandonment of a phreatic rise tube. This situation occurs in at least two other caves in Missouri,

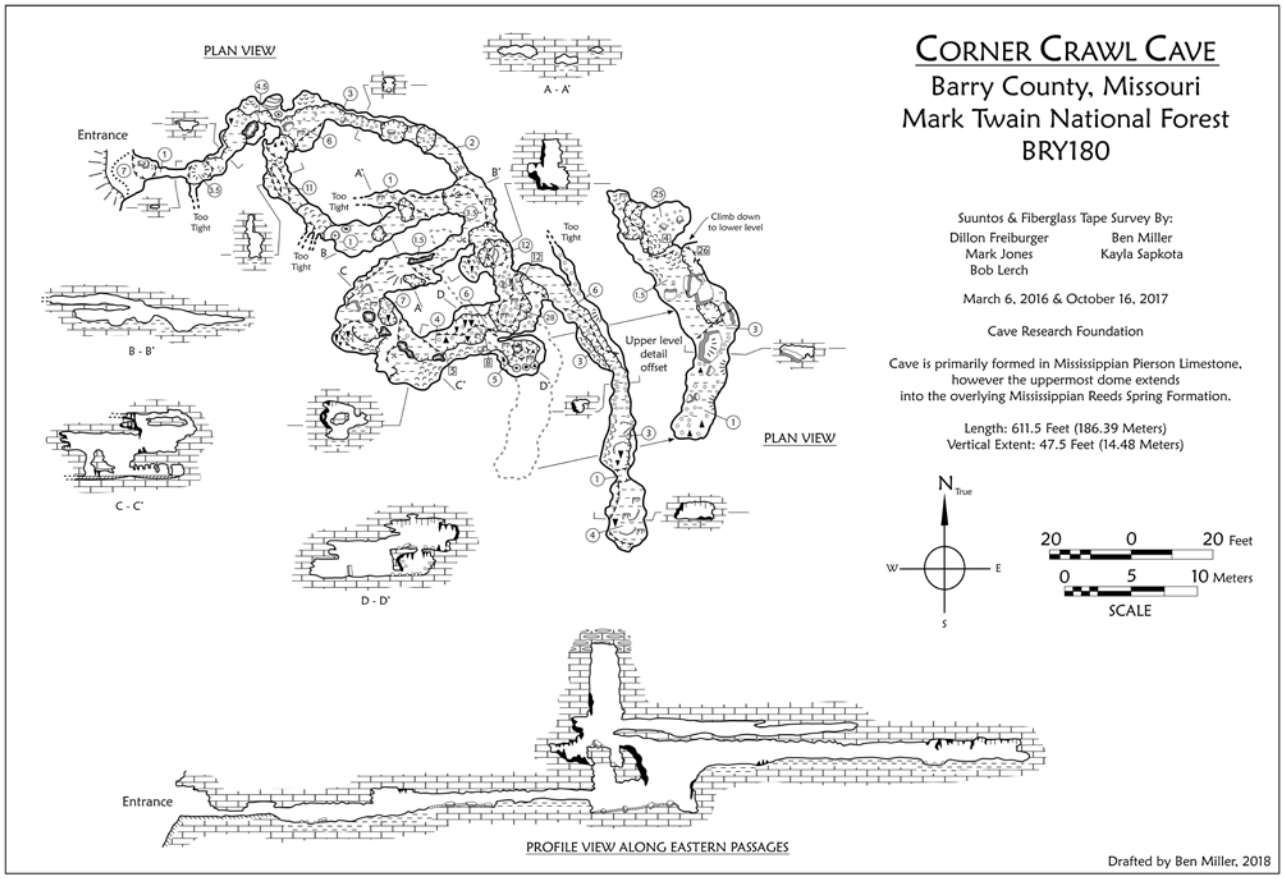
but is rare and unusual. The cave also had a unique biological feature—a five-legged grotto salamander! This surprising observation was published by its discoverer, Dillon Freiburger (Freiburger & Miller, *Herpetological Review*, September 2019).

Biological observations were made on most trips, resulting in more than 350 records added to the cave biology database. Observations included the continuing decline of cave bats, especially eastern pipistrelles and northern bats, the latter conspicuous by their absence. Two new sites were documented for *Stygobromus* amphipods and one for the troglobiotic millipede *Causeyella dendropus*.

American bears are showing up again in Ozarks caves, and two new records were created in MTNF caves. One new site was mapped, while at another cave, a routine monitoring trip uncovered three bears, one of whom (mom) sported a radio collar.

Five legged grotto salamander. *Dillon Freiburger*

The Butler Hollow project wrapped up in mid-2019, resulting in documentation of caves and karst on the



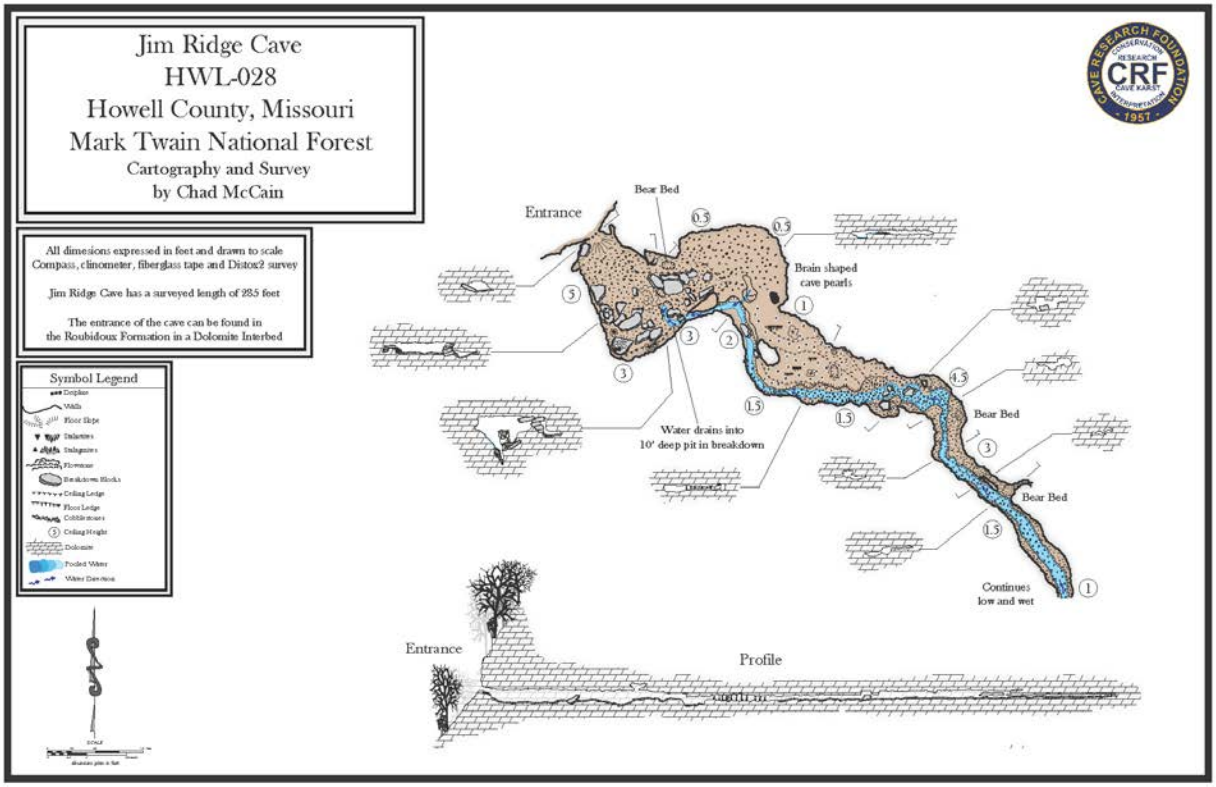
Matt Beeson at a spring cave. *Scott House*

Sue Hagan at Brock Cave entrance. *Mick Sutton*

Data work in a rental cabin. *Scott House*

Cassville sub-district being the most thorough of any area on the Mark Twain NF.

Meanwhile, the rest of the Forest was not neglected. A large amount of monitoring, inventory, and gating projects occurred throughout, resulting in 12 newly recorded small caves. Most of these were mapped, which together with maps of known caves resulted in 50 cave maps completed. Existing maps of several caves, notably Rattlesnake Cave in Christian County, were expanded and updated. The deteriorating gate on Cooks Cave in Reynolds County, a



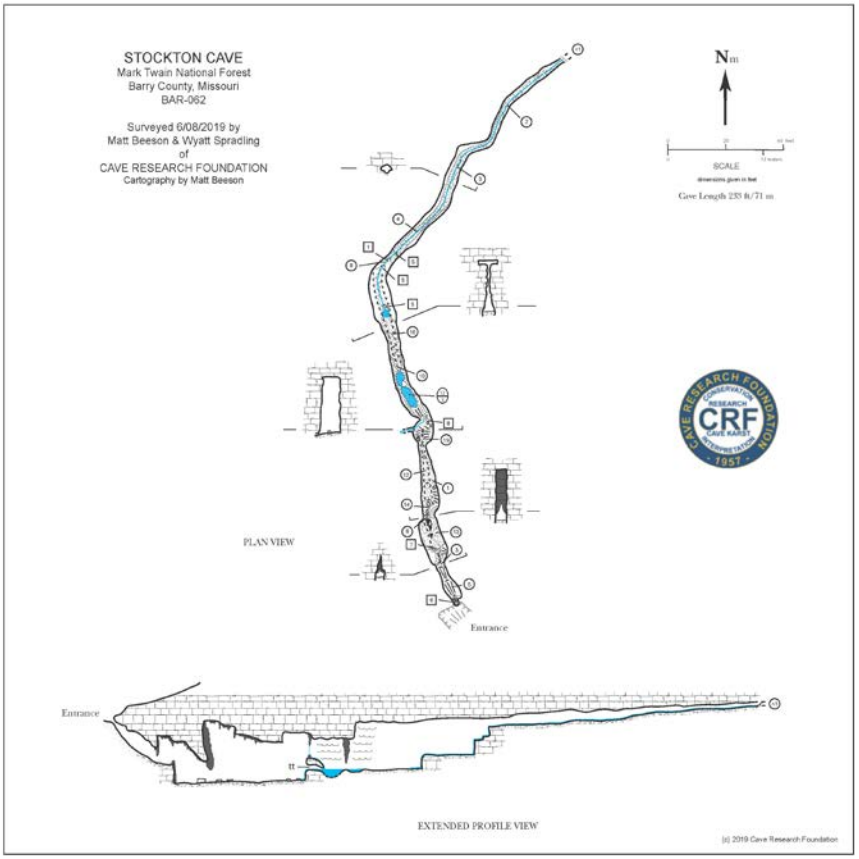
Bear in 2018 by Missouri Dept of Conservation game camera.

A new bear bed, claw marks, and CRF surveyor. *Jon Beard*

gray bat maternity cave, was repaired and Estes Cave in Washington County was assessed for an upcoming gating project. Archeological investigations were carried out at this and several other sites in collaboration with CAIRN (Cave Archaeology Investigation and Research Network). Finds included some potentially aboriginal petroglyphs in a cave on the Eleven Point District. Cave clean-up and restoration took place at several caves, notably Cowdry Cave in Christian County. One unusual project was the documentation of a series of sinkholes which have recently begun actively expanding, with one of them cutting into and closing a Forest road. The sinkholes are either directly above or in close proximity to active and recently abandoned mine workings on the Viburnum trend, which may or may not be related to the unusual sinkhole activity.

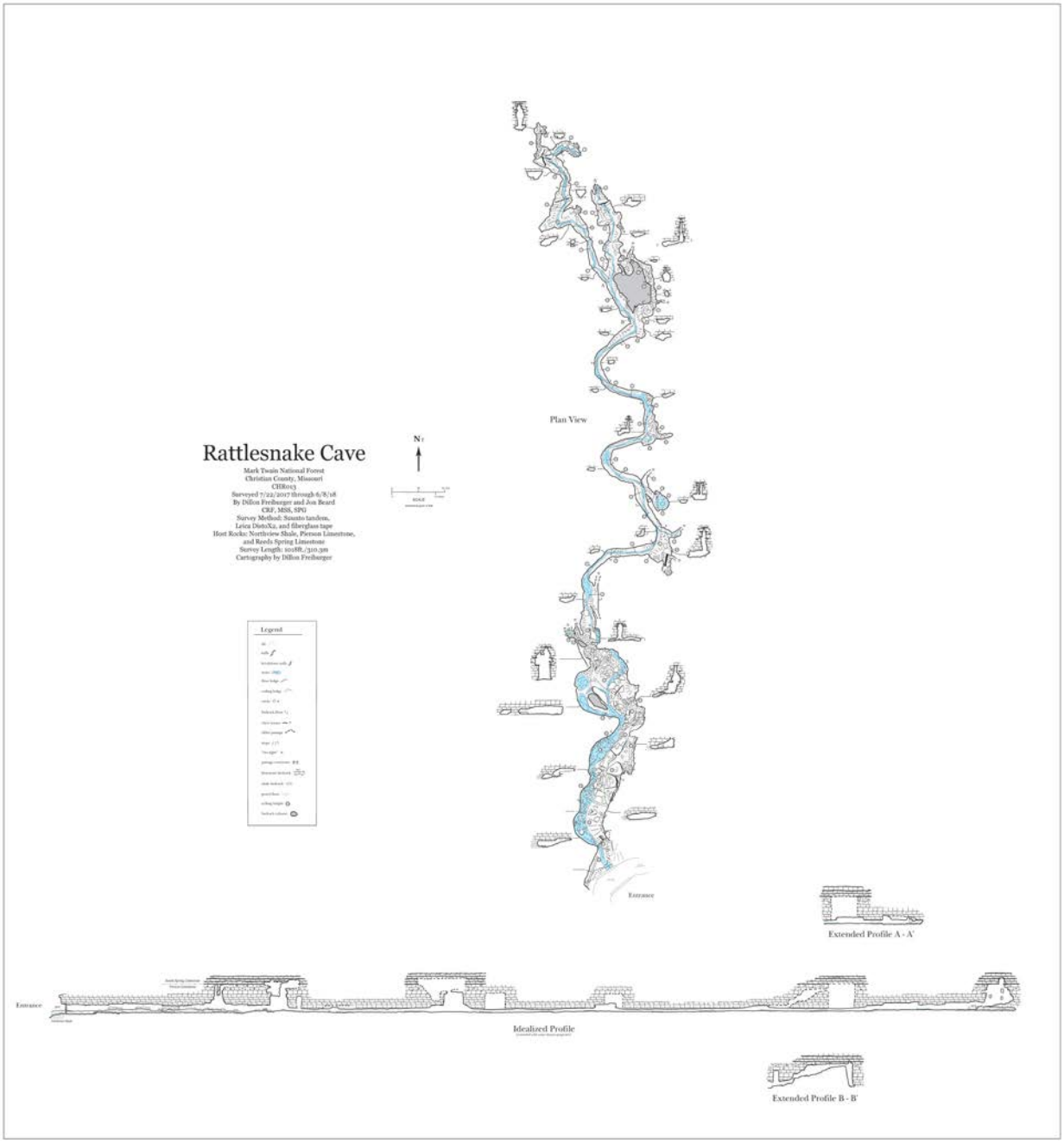
Bat records throughout the Forest continued to show declines in WNS-susceptible species—for example there was only one observation of a Northern Bat throughout the whole period. Doing much better in Missouri are black bear populations. One known bear den cave in Christian County was documented, and a new very active den was discovered in a small cave in Oregon County. MTNF personnel also encountered a bear in a cave with known recent bear activity. In the invertebrate world, specimens of an interesting stygobiotic isopod were collected from Cooks Cave for possible genetic analysis—this creature is tiny for a cave isopod, maturing at only 2–3 mm, and it is unclear whether it belongs to the genus *Caecidotea*, shared by all other Missouri stygobiotic isopods.

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



Mick Sutton in Corner Crawl Cave. *Mark Jones*

Long tailed or dark-sided salamander. *Mark Jones*



U.S. Fish and Wildlife Service

Scott House

CRF Ozarks and the Missouri Speleological Survey cooperate with the federal agency that oversees the recovery of endangered species (USF&WS). We do this by occasionally reviewing projects or impact statements. Data is provided to the service that helps it mitigate the effects of takings of habitat. CRF also participated in the biennial census at the Sodalis Nature Preserve in Hannibal, Missouri. This preserve is the result of a mitigation effort with funds channeled through the Conservancy Fund. The preserve mostly consists of the bulk of an underground limestone mine, the Lime Kiln Mine. CRF surveyed the mine over a period of several years and members have since acted as guides and trip leaders for (usually) four person crews that identify and count the bats within the mine. The most recent count in early 2019 included something over 170,000 Indiana bats (*Myotis sodalis);* the mine is by far the largest hibernaculum for the species.USF&WS personnel have participated in several trips, including a monitoring trip to a Priority One gray bat cave within the boundaries of Ozark National Scenic Riverways.

Scott House led a field trip to Perry County for the benefit of USF&WS biologists. The purpose of the trip was to orient them to the karst of Perry County. Stops were made throughout the county, looking at the karst areas, specific caves, and examples of cave gates and other measures taken to save the inputs into the cave systems. Berome Moore Cave was entered, led by Don Dunham, and briefly examined. While there, the biologists were able to identify two of the endangered grotto sculpin (*Cottus specus*), found only in Perry County caves.

Vona Kucynska in an Ozark cave. *Scott House*

Bat count in Sodalis Preserve. *Scott House*

Biologists consult the CRF map. *Mark Jones*

Missouri Department of Conservation

Dan Lamping

2018

In 2018, under permits provided to the Missouri Speleological Survey (MSS), 18 trips were taken to Missouri Department of Conservation (MDC) caves or in association with MDC supported projects by cavers with the MSS and Cave Research Foundation. The trips were taken through a permit system with the MDC given the blanket state closure on MDC owned caves. The process entails permit applications being submitted at the beginning of the year by MSS / CRF. MDC biologists then evaluate, and approve or decline the objectives. Once approved, the permits are good for the year and only apply to the specifically, pre-approved objectives.

Work in 2018 led to an addition of more than 100 faunal records into the Missouri Cave Database. Caves were visited in Camden, Laclede, Dallas, Shannon, Crawford, and Texas counties. Over 550 field hours were volunteered and over 84 person days.

Highlights for the year include Jon Beard doing monitoring work with MDC biologists at Mary Lawson, Turnback, and Saltpeter caves. Dennis Novicky and Brenda Goodnight surveyed Whiskey Cave in a new proposed purchase area in Shannon County. Jim Ruedin led a monitoring trip to caves in the Huzzah Wildlife area, where a team began the resurvey of Bear Cave, a project still ongoing. Gary Johnson led monitoring trips to Ladder Cave and Murphey Cave and a mapping trip to Vanderman Cave, all in Hickory County. Jim Cooley continued work by finishing the maps for Kings Onyx Cave (Camden Co.) and Two Legged Cave (Shannon Co.) and led survey into Rock Pool Cave in Shannon County. Jim Ruedin also led monitoring trips to Larkin Ford Cave and Forester Cave in Shannon County, as well as organized a large ridgewalk with Meramec Valley Grotto to the Gist Ranch property in Texas County to search for reported caves which we either have bad locations on or are non-existent. Scott House and Ken Grush took MDC bat biologists to Douglas Hollow Cave in Shannon County. Lastly, Dan Lamping led a mapping trip into Crawford County's Love Cave to resume survey after a hiatus of over a decade. The trip was primarily to make cartographic improvements but also led to new survey.

Love Cave. *Derik Holtmann*

Douglas Hollow Cave. *Scott House*

2019

In 2019 there were 34 individual trips taken to Missouri Department of Conservation (MDC) caves or in association

Joe Sikorski in Love Cave. *Derik Holtmann*

with MDC supported projects by cavers with the Missouri Speleological Survey (MSS) and Cave Research Foundation. Work in 2019 led to an addition of 84 faunal records into the Missouri Cave Database. Nearly 1,300 person-hours were catalogued working on MDC or MDC supported projects.

In January, cavers with CRF, along with MDC bat biologists, did a bat census trip to Powder Mill Creek Cave, along with Bluff and Little Bluff Caves, owned by NPS. The following day bat census trip was taken to Bat Cave, Shannon County.

In February, cavers with CRF served as guides in the annual bat census trip to Lime Kiln Mine.

Cavers with CRF completed the mapping of Saloon Cave along the Meramec River in March. This trip was done in conjunction with MDC bat biologists who did a bat census during the trip. Also, in February, Ken Grush, with the assistance of Tyler Skaggs, went to Gist Ranch to track down Rattlesnake Cave and others.

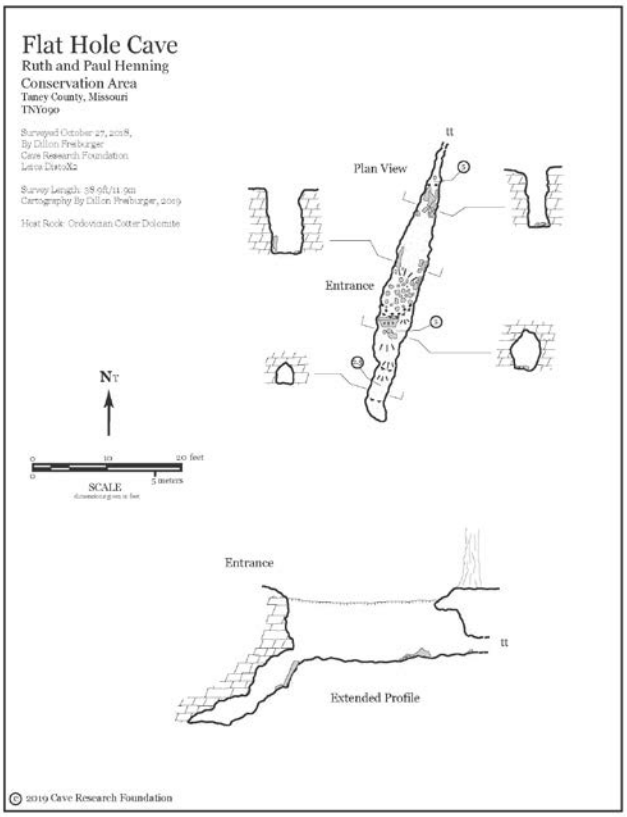
In April, Ken Grush and Tyler Skaggs returned to Gist Ranch to begin survey of Rattlesnake Cave on Gist Ranch.

In May, Joe Light, along with members of CAIRN (Cave Archaeology Investigation Research Network) went to Doss Cave in the Meramec valley to do archaeological investigation and general monitoring.

Love Cave. *Derik Holtmann*

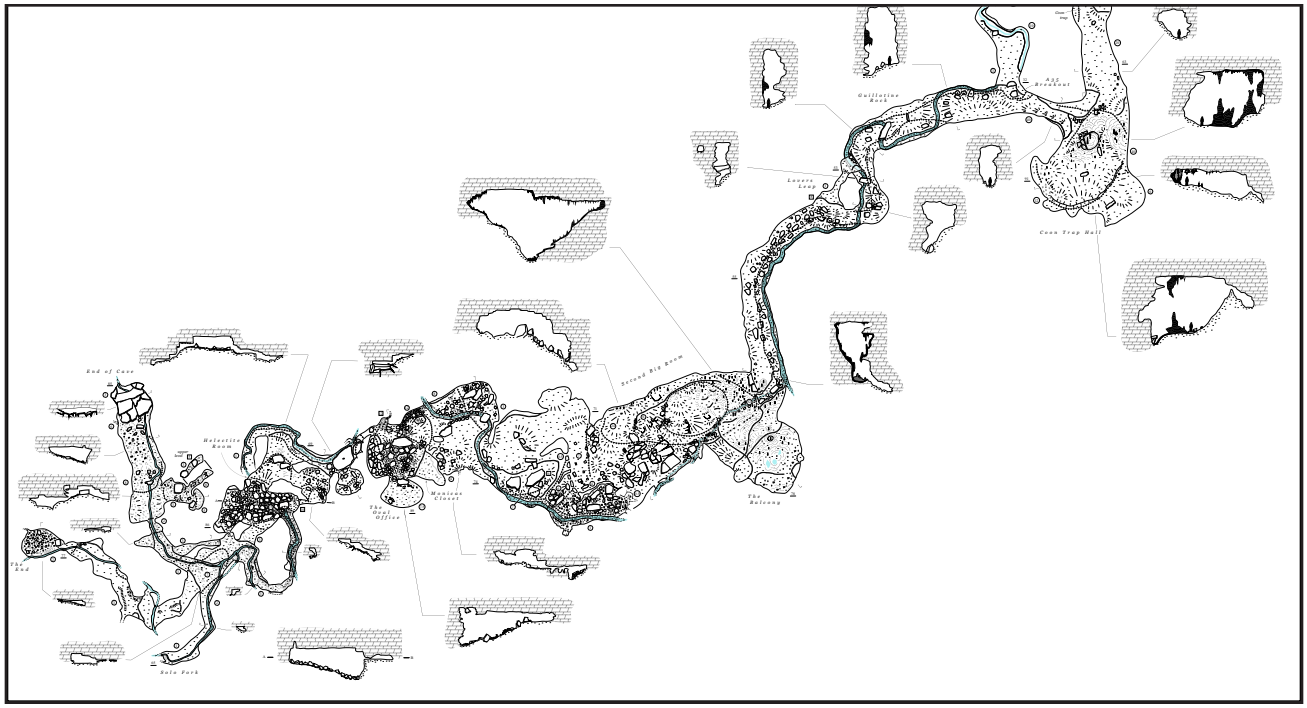
Love Cave. *Derik Holtmann*

Love Cave. *Derik Holtmann*



In June, Jim Cooley led a trip to Fiery Fork Cave to survey the main trunk passage of Onyx Mine Cave. Also, Joe Light led a monitoring trip with members of CAIRN to Little Scott Cave.

In July, Ken Grush returned to Rattlesnake Cave to field check the map that he's been working on. Also in July, Scott



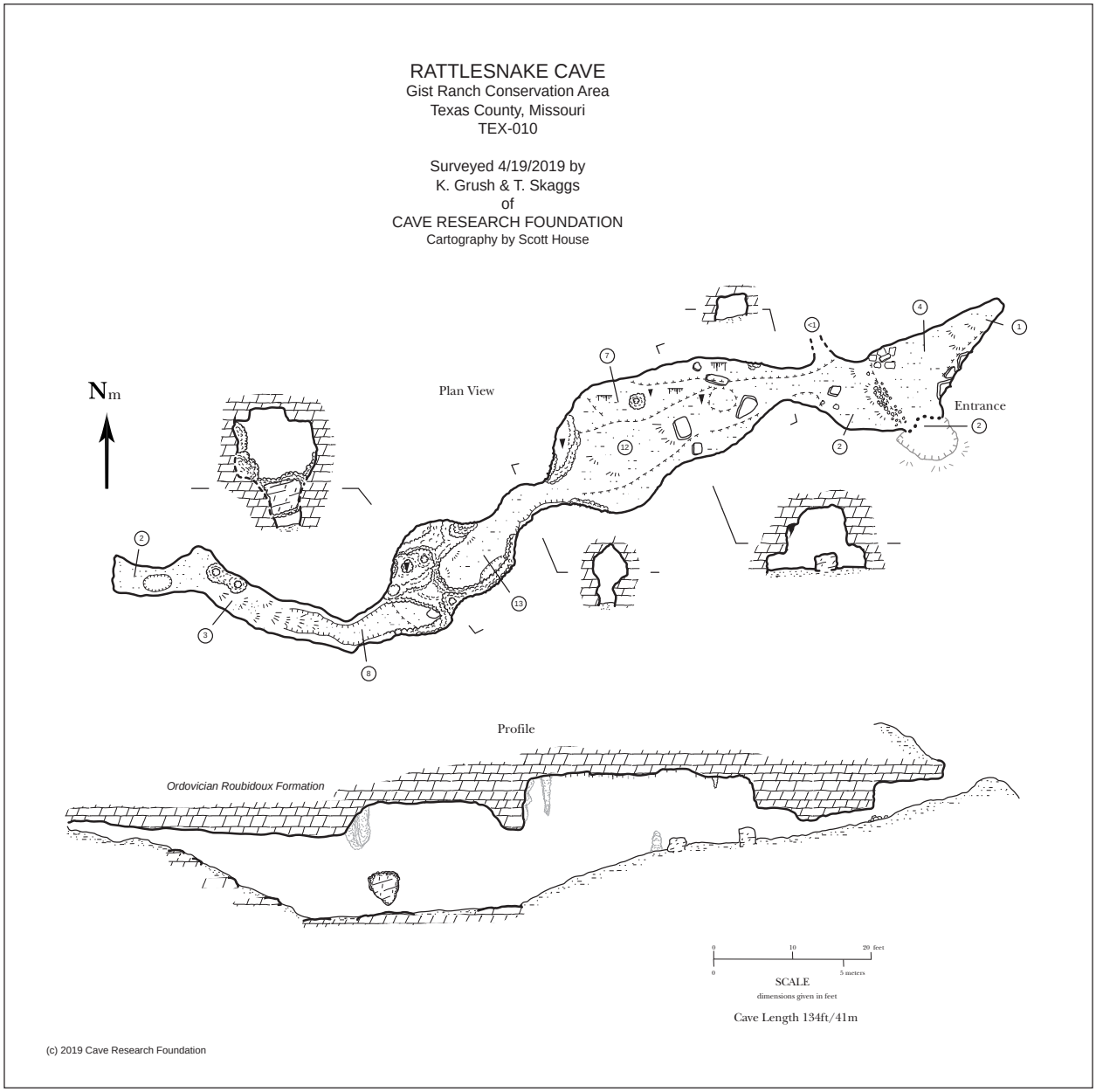
A detail from the Love Cave map. Cartography by Tom Panian and Dan Lamping.

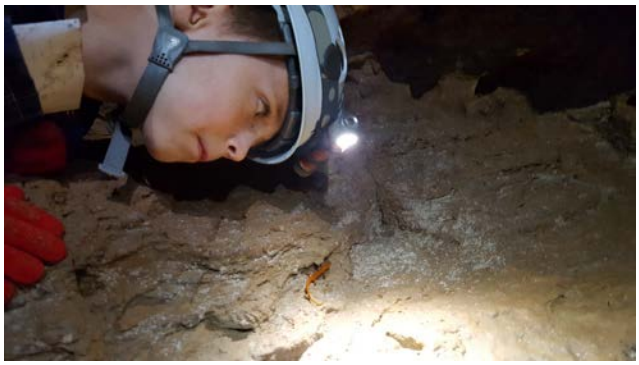
Peter Cave entrance. *Derik Holtmann*

House and Mick Sutton led MDC educators' workshop on a monitoring trip to caves in the Pulltite area.

In September, Matt Beeson began to lead the survey of Mary Lawson Cave in Laclede County. There were two trips in September, one at the beginning of the month and one at the end. A very significant gray bat population was present. Additionally, a survey trip was taken in Vandermann Cave in Hickory County. This was likely the final survey trip into the cave, though an additional trip may be needed in the future to field check the final map. Also, in late September, preparations began for the gating of Cobb Cave, a privately owned cave in Christian County. The gating was led by CRF caver Jim Cooley with the support of MDC and USFWS.

In October, crews continued working on and completed the Cobb Cave gating. This project accounted for the bulk of the person-hours for 2019. Additionally, a final trip, for the year was taken into Mary Lawson Cave. A total of 2,882

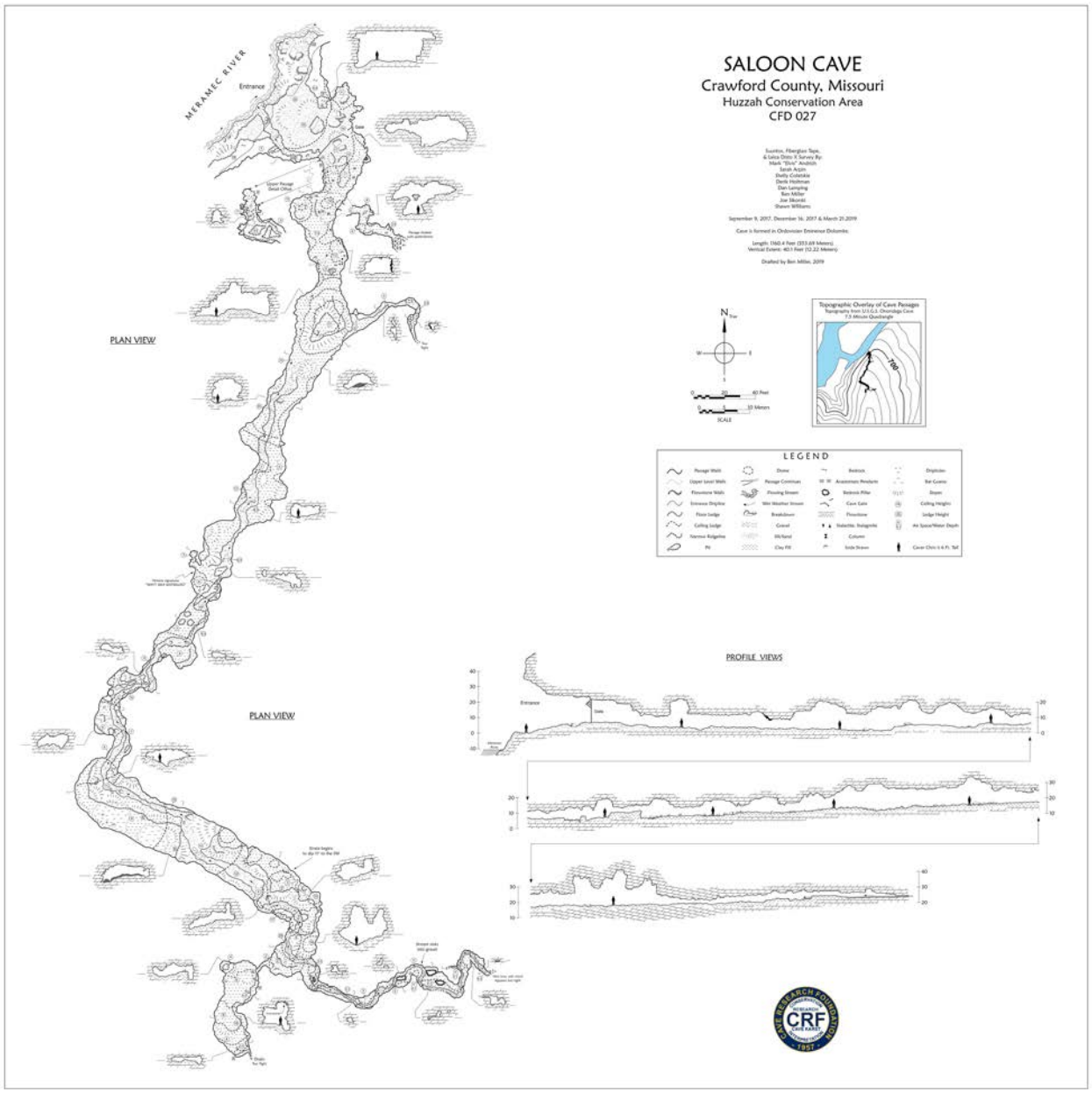




Henry Lamping at Lone Hill Onyx Cave. *Dan Lamping*

feet was mapped between the three trips in September and October before access was restricted due to bat hibernation. Joe Light led a monitoring trip to Lone Hill Onyx Cave in the Meramec Valley. A few tricolored bats were observed along with a small population of scattered Grays. Additionally, many Long-tail salamanders were counted. Most interestingly, the gate to the cave did not have a lock on it. Aside from the Cobb Cave gating, Jim Cooley also led to Onyx Mine Cave at Fiery Forks CA to survey work for the map. Dennis Novicky and Brenda Goodnight surveyed Three Layer Cave in Shannon County.

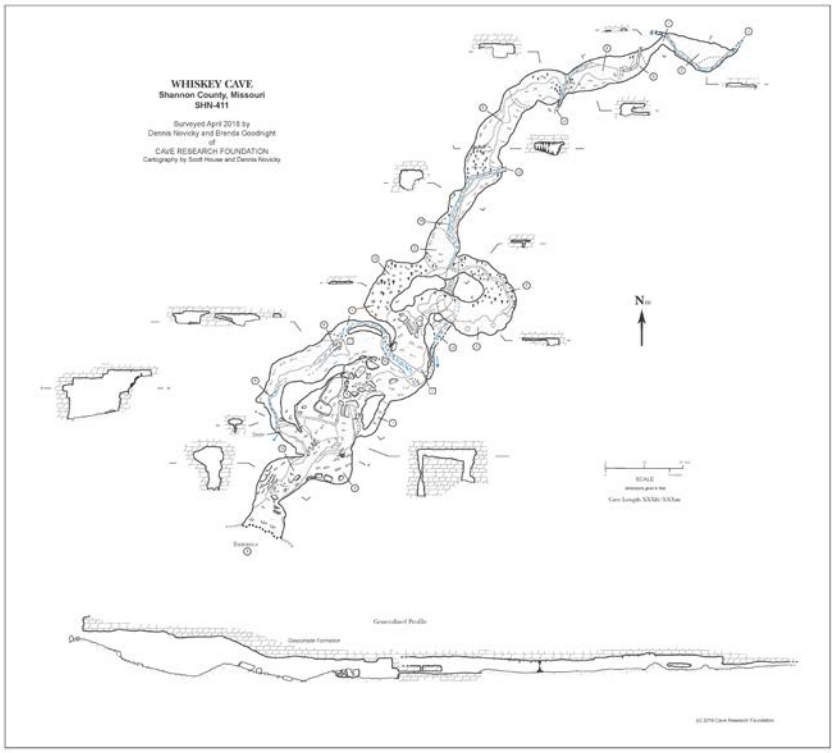
In December, Jim Cooley and Julie Cottrell monitored



Matt and Bud Beeson at Mary Lawson Cave. *Mike Beeson*

NPS caves in the Alley Spring area. They also monitored MDC's Pinnacle Bluff and Sunset Bluff Caves. That same weekend CRF and MVG crews located and surveyed Dry Pit Cave in Angeline CA. Wet Pit was sought after but could not be found. Additionally, Jim Ruedin led a group from MVG to the Pipestem Hollow area in Angeline CA and monitored Pipestem Spring Cave, Pipestem Cave, Gaping Cave, Peter Cave, and Woodrat Cave. Cave life was documented and the caves seem little disturbed. Lastly, on that same weekend, cavers stopped to check on the Powder Mill Creek Cave gate and lubricated the lock as part of general maintenance. A few days later, Scott House and Don Dunham went with MDC personnel and USFWS to tour around caves in the Perryville area. Also, in December, a CRF crew returned to the Love Cave in Huzzah CA to continue mapping. Several cartographic objectives were completed; however, additional passage was found, which has not yet been surveyed. The new passage will certainly push the cave's length to over one mile. Considerable progress has been made on the map of this significant cave since access has been granted.

Henry Lamping at Lone Hill Onyx Cave. *Dan Lamping*



L-A-D Foundation Cave Project

Dan Lamping

Dual Falls Cave, found by Tony Schmitt. Craig Williams looks for cultural remains, while Joe Sikorski takes a drink and Jeff "Spike" Crews looks on, outside. *Dan Lamping*

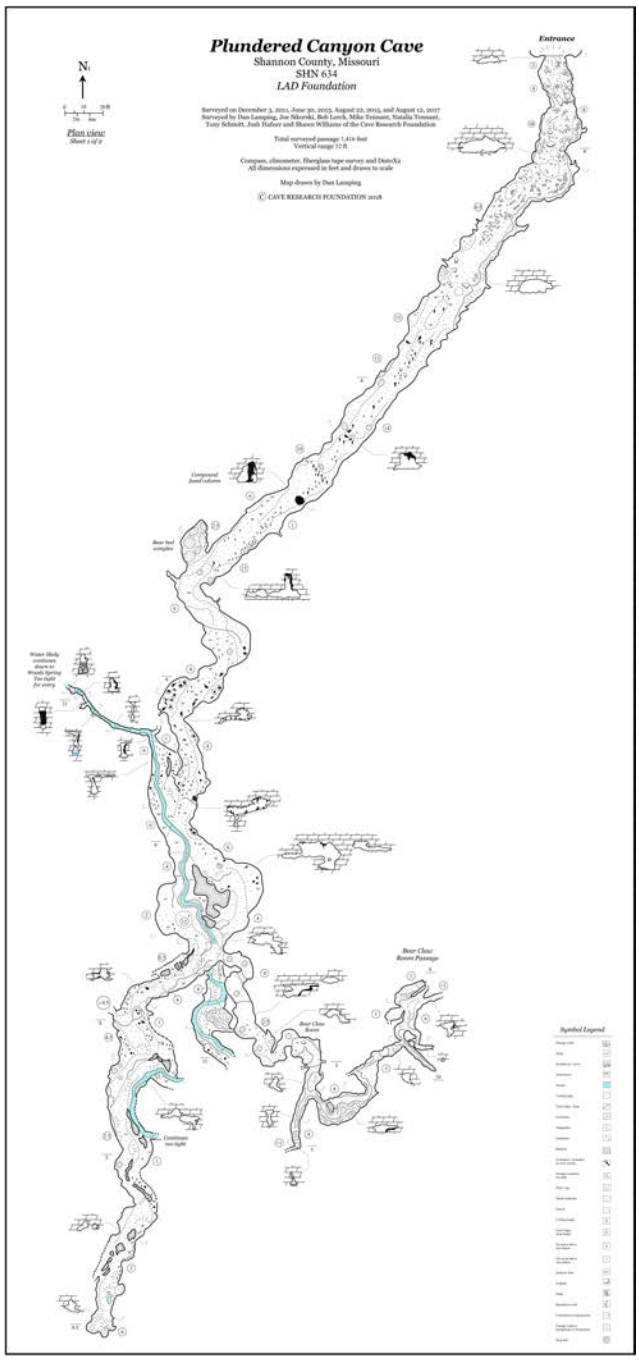
LAD Foundation owns a variety of karst and other lands throughout Missouri. The bulk of its lands are held by its wholly owned subsidiary, Pioneer Forest. LAD owns approximately 170 caves. Some of these are on lands leased (for a nominal amount) to the Missouri Departments of Conservation and Natural Resources (the latter includes state parks). Cave cooperators include the Missouri Speleological Survey, Meramec Valley Grotto, Cave Research Foundation, and the National Park Service.

2018 was a dismal year for field work in the backcountry of the Ozarks. However, the map of Plundered Canyon Cave was completed. This is a historic cave, only recently rediscovered, that generations of people visited and generally did not treat well. It may well be that some of the speleothem breakage was due to natural causes. Elsewhere, a number of LAD caves occurring within the boundaries of Ozark National Scenic Riverways were monitored.

In January 2019, on a bat monitoring trip with Missouri Department of Conservation (MDC) and Cave Research Foundation (CRF), it was observed that both the Cookstove Cave and Holmes Hollow Cave gates had been breached.

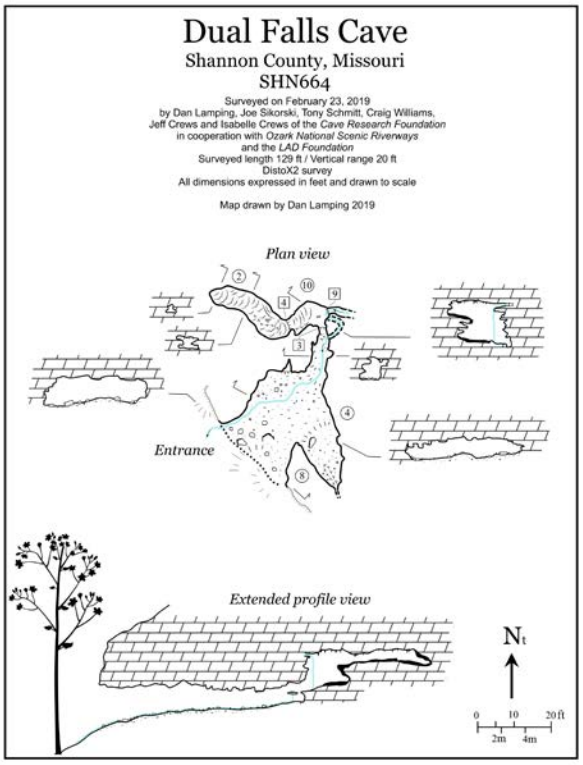
In February, another bat monitoring trip was made to Big and Little Bear Caves, also with MDC and CRF. Additionally, in February, a trip was made to the Chalk Bluff area to map a cave which had been found shortly after the Chalk Bluff graffiti clean-up in 2015. A crew mapped Dual Falls Cave in what appears to be a mislabeled toponym of "Island Hollow" on the 7.5' minute quad, but may actually be Bee Hollow. The cave, while pretty, was only 105 ft long. While in the area, another cave new to the MSS cave files was found on ONSR property, which was mapped and named Wet Shelter. Two large spring complexes were also found on this trip.

In March, a group of CRF cavers and members of the Meramec Valley Grotto (MVG) camped at Himont Tower. The purpose of the trip was to search the area just south of the tower, both Cave Hollow and Jims Creek to find a large cave which was reported to members of MVG a few years ago. The large group thoroughly scoured the area but did not find the reported cave. However, Laxton Cave was relocated. The cave is identified on the topographic map but had eluded cavers who had searched for it in the past. There is a highly picturesque spring located outside of the cave. Additionally on this trip, Frustration Cave, a very small feature, was visited and a rather large spring complex was found off Jims Creek that may potentially lead to a cave. A return trip is planned to continue searching for the



Spring outside of Laxton Cave. *Josh Hafner*

Tony Schmitt inside Laxton Cave. *Josh Hafner*



reportedly large cave in the area as well as to further investigate the spring in Jims Creek and to survey Laxton Cave.

In June, the gates to both Cookstove and Holmes Hollow were repaired by a CRF crew with the logistical support of a LAD crew. Both gates required welding to repair. Reinforcements in the form of expanded metal and supporting brackets were placed at the base of the two gates to prohibit future attempts to get under the gate. A single monitoring trip was also taken to Merritt Rock Cave in June.

In September, a trip was taken with LAD personnel to look at possibilities for signage in Perry County, Missouri. LAD karst lands north of Perryville were visited.

In December a trip was taken to Medlock Cave to monitor winter bat populations and measure summer gray bat guano. The gray bat population appeared to be doing well. Additionally, several Indiana bats were observed. Lastly, the gate repair at Holmes Hollow was checked and appeared to be undisturbed.

Lastly, CRF was asked to write a brief overview of cave resources on LAD lands. This overview included general management recommendations for studying and protecting caves and karst resources.

Dennis Novicky welds on the Cookstove Cave gate repair. *Mark Jones*

Krista Bartel welding on Cookstove gate repair. *Mark Jones*

Perry County, Missouri, Projects

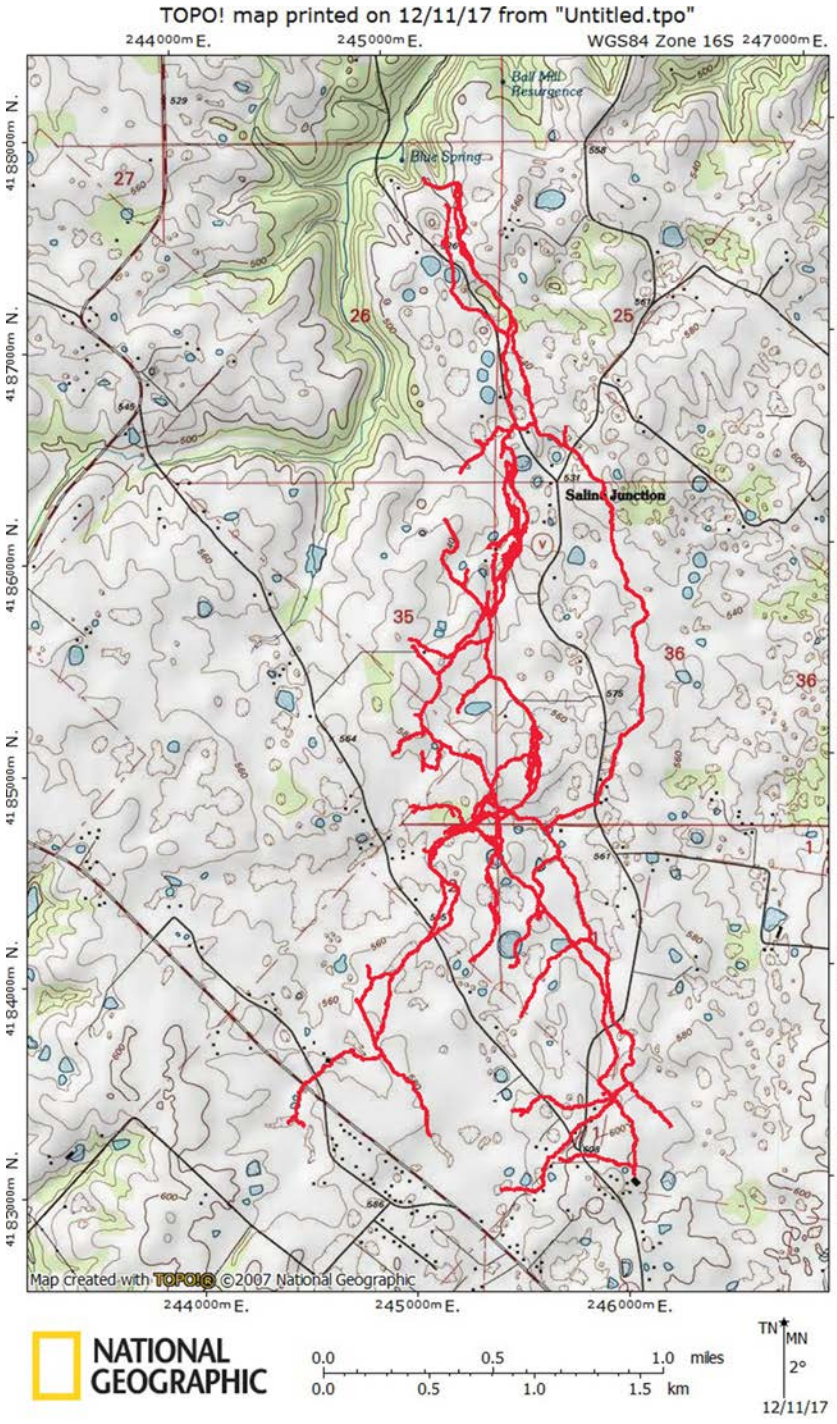
Ken Grush and Scott House

Perry County, Missouri maintains its "premier" status as the first in cave count and mapped footage in the state. Two major re-mapping projects continue. Crevice Cave is the longest in the state at 30.83 miles. Alex Litsch has picked up the cartographer role as long-serving Paul Hauck steps back from this position. Hauck had at least 2 trips in 2018, and Litsch had at least 2 in 2019. Hauck (2020) sent his final version of the map in both black and white and color versions. The city now manages the entrance of Crevice Cave, which was re-gated by CRF in 2017. Currently, Hauck is checking up on leads throughout Perry County working in part with Richard Young. Young is also working with others to improve location quality and photography throughout the county.

Chad McCain continues mapping in Berome Moore Cave, the state's second longest cave system at 22.12 miles. In the great Sinkhole de Mayo expedition of 2019, over 4700 feet of survey were collected on one weekend, "with 11 survey teams, 3 on Friday, and 8 on Saturday." The list of survey members is the "Who's Who of Missouri Caving."

The City of Perryville project, which includes the footprints of both caves has slowed somewhat with the many cavers focused on these re-mapping projects. Work does continue though, so when a couple of miles in one cave on one day is just a bit much, there are over 80 caves under the city that could benefit from a first map or a re-map. Biological investigations have shown that the federally-endangered grotto sculpin is alive and apparently well beneath the streets of the city.

A signage program will interpret Perry County's karst for visitors and residents. The signs are planned to be



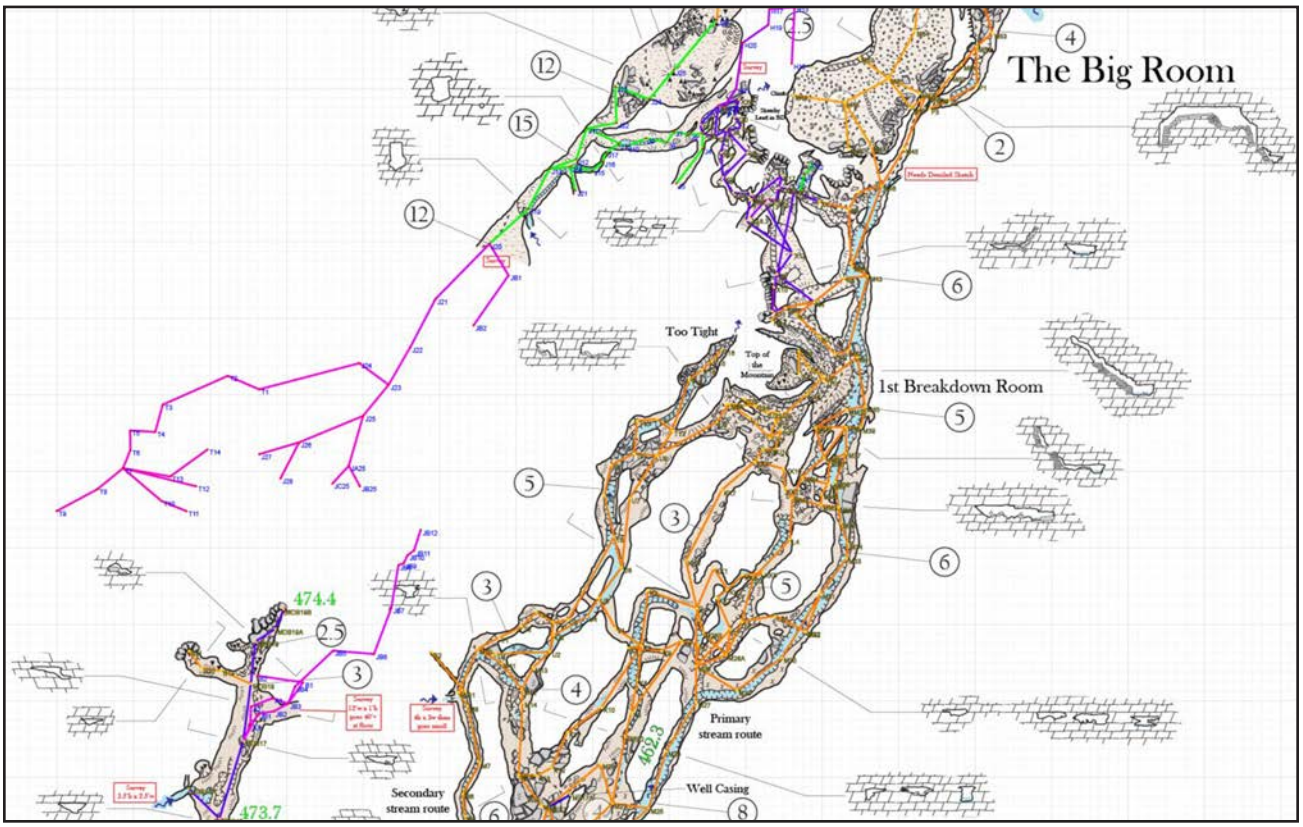
Line map of Berome Moore.

Biologists look for grotto sculpin in Berome Moore Cave.
Scott House

placed in public spaces, such as city parks and natural areas. CRF is working with a variety of caving organizations, other non-government organizations, the City of Perryville, and other agencies to get this done.

Planaria in Berome Moore. *Mark Jones*

Cave Life Prototype.



A detail from the working map of Berome Moore. Cartography by Chad McCain.

Ozark Cave Gating Efforts 2018–2019

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, mined caves and dangerous sinkholes for public safety, continued apace in 2018. That year, we completed the last four gates, or related structures, in the multi-year Butler Hollow project, an effort that resulted in the closing of 14 horizontal mine adits, vertical mine shafts, entrances to mined caves, and a dangerous sinkhole. In April, we attacked the eponymous Butler Hollow Cave, which presented two challenges. The first was a horizontal mined adit into the cave that was crumbling and in clear danger of collapse. The second was a gaping sinkhole rimmed with unconsolidated conglomerate (perhaps a contradiction in terms?), whose very steep slope was immediately adjacent to an equestrian trail. Any horse that slipped would slide down the side of a steep scree slope and then plunge sixty feet into the mined cave, taking its rider right along with it. A U.S. Forest Service bulldozer was required to open a trail down a 30+ degree grade, and also to place generators at a different point above the adit, which still could be reached only by CRF's 200-foot-long specialized electrical cables. The adit gate was constructed in a single day—record time!—by Jay Bridgewater, a CRF member and professional welder from Kansas City, supported by a dedicated Americorps crew of four young men who worked like banshees, and several CRF volunteers. This incredible effort allowed us to just barely beat an on-coming storm front, whose rainfall would have trapped all our gear and materials on the hillside for several days until the ground dried out. As it was, the bulldozer got stuck on the dry hillside several times anyway, while extracting equipment and materials after project completion. Meanwhile, post holes were dug by hand around the sinkhole opening in the unconsolidated conglomerate. After completing this project, Bridgewater teamed up with Joe Williams, another experienced CRF gate welder, to construct a second gate at Sugar Silver Cave, a mined cave that had been blasted open early in the 20th century in pursuit of the mythical Spanish silver stash.

In September 2018, we returned to another mined cave, Radium Cave, where we had already built a cupola over a vertical shaft and gated the horizontal natural cave entrance in 2015. (No radium was ever found in these caves.) The original plan had been to gate two mine shafts, but that plan was modified when one of the shafts collapsed,

Butler Hollow Cave. *Kirsten Alvey-Mudd*

obviating the need for a cupola enclosure. Well, in the intervening three years, the mine shaft further collapsed, and opened back up, requiring us to return and build the second cupola enclosure.

Immediately after this project, the gating team traveled to Noel, Missouri, where we gated Flutestone Cave, a privately owned cave on the property of Bluff Dweller's Cave, a major show cave attraction. Gating this cave was required to stop increasingly severe vandalism. Then, in November, we returned to erect our final Butler Hollow masterpiece, a fence gate around that yawning sinkhole, while assiduously avoiding sliding down that slope and falling in ourselves. U.S. Forest Service help was essential to drop a large, dying tree poised threateningly on a narrow edge of the sinkhole. After much discussion and calculation, this massive (and hollow) bole was very gingerly toppled by a crew of expert Forest Service technicians, who had been brought in from out of state solely for this purpose. The Forest Service also provided a bobcat to move the materials and equipment a mile down the ridge to the job site. The project was completed in the rain, including a brief period of freezing rain.

In December of 2018, CRF members repaired a gate on a major gray bat maternal colony on the Salem District of Mark Twain National Forest. The gate was an early model that had not held up to flood debris piling up on its flyover infrastructure. With considerable planning and help from MTNF personnel (moving the steel and boat) the work was accomplished in a single day.

Fence gate on a Forest Service cave. *Jim Cooley*

Work on a cupola gate on Radium Cave. *Jim Cooley*

Flyover chute on Cobb Cave. *Jim Cooley*

Gate work in 2019 began in late March, with the gating of two cave entrances on another privately owned (and currently closed) show cave property, the Old Spanish Cave attraction, near Reed's Spring, Missouri. Cathedral Cave and Waterfall Cave are actually two entrances to the same highly decorated cave, several hundred yards apart. This private owner was also increasingly concerned about persistent and worsening vandalism and gate breaching at his (closed) show cave, and wanted to protect his other assets. Immediately after concluding this project, we repaired two gates on the Mark Twain National Forest that had been breached, one at Butler Hollow Mine (by a welding torch) and one at Onyx Cave, Barry County, (by hacksaw and leverage).

In June of 2019, CRF folks fixed two gates on LAD Foundation lands. Both had been dug under. The gates were reinforced with additional protection to prevent digging and removal of screens to prevent that. The team was aided by staff from Pioneer Forest, the LAD subsidiary that owns the caves. One of the two caves is a major Indiana bat hibernaculum. Field work on both gates was accomplished in a single day.

In September of 2019, CRF built two gates for the U.S. Army Corps of Engineers, at Beaver Creek Caves #1 and #2 near Kissee Mills, Missouri. One of these gates was 30 feet inside the cave, just beyond a sloping, 20-foot belly crawl, which had been the site of a spelunker entrapment and rescue. This entrapment misadventure, and the ensuing wide publicity, got these caves declared a public nuisance by the Corps, which resulted in their closure.

Our final project for 2019 was a 50-foot-wide, ten-foot-tall chute gate erected at Cobb Cave in Christian County. This privately owned cave is the site of a major gray bat maternity colony, an endangered species. Unfortunately, it receives significant trespassing due to being well known in the rapidly urbanizing neighborhood of Nixa, Missouri, effectively a suburb of the third largest city in the state. Illegal visitation is compounded by the cave being adjacent to the James River, a popular float venue. Creative and diverse funding for this large project came from a variety of sources, including the landowner, CRF, the Missouri Department of Conservation, the U.S. Fish and Wildlife Service, Missouri Bat Census (a conservation-oriented 501c3 non-governmental entity), and the Springfield Plateau Grotto, a chapter of the NSS. The executive director of Missouri Bat Census, Kirsten Alvey-Mudd, who was a chef in a former life, provided three meals a day for eight days to feed the large crew required to assemble this gate. The Cobb Cave project required $10,000 worth of steel and 43 different volunteers contributing 125 person-days of labor.

During the 2018–2019 period, CRF teams also conducted on-site consultations. When appropriate, we designed bat-friendly cave gates and prepared construction proposals and plans for a variety of public and private cave owners and land management agencies. These entities included the Mark Twain National Forest, Ozark National Scenic Riverways, the city of Kansas City, Missouri and the city of Eureka Springs, Arkansas. These projects have not yet been funded.

Through the cooperation of the National Park Service and Mark Twain National Forest, a central facility for containing gating materials and tools was established at Winona, Missouri, at the Winona Ranger Station.

Missouri Department of Transportation

McDonald County I-49 Project

Matt Beeson

Aaron Thompson at Cave No More. *Matt Beeson*

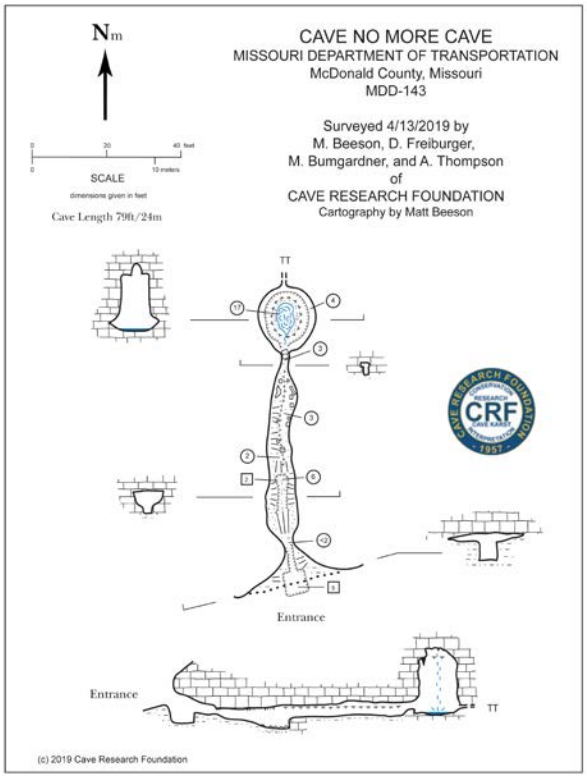
Early in April 2019, the Missouri Department of Transportation requested that the Cave Research Foundation investigate several caves found during compliance and design work on the Interstate 49 route in McDonald County, Missouri. Matt Beeson, Dillon Freiburger, Matt Bumgardner, and Aaron Thompson took on the challenge of quick field work, drafting, and report writing which were all accomplished by the end of the month. One reported location was found not to be a cave; of the three others, two would not be destroyed by highway construction, but one would be.

Cave No More Cave (MDD-143)

This was a small cave formed primarily in the Pierson Limestone. The entrance is 24 feet wide by 3 feet high. Just outside of the entrance is a 5' by 5' pit dug by contract archaeologists. Also a 2' deep trench was dug to enlarge the crawl into the entrance. Past this crawl the cave widens into passage roughly 6' by 6' before transitioning up into 20 more feet of crawl. Beyond the crawl the cave opened into a nice 18' tall Pierson Dome. There are a few formations at the ceiling. The Reeds Spring, Pierson, Northview Shale, and Compton Formations are all visible in the dome. This cave falls within the new I-49 road corridor and was to be destroyed by the construction of the highway.

Waterfall Ledge Shelter Cave (MDD-144)

The cave begins as a beautiful shelter some 53 feet wide and 11 feet high. The ceiling quickly descends, and one can enter the small cave part of it on hands and knees, crawling about 20 feet to a junction where the cave goes both left and right. Both ways are low belly crawls; the passage to the left has a ceiling joint that allows one to crawl to the back on their side. In about 30 feet a small stream passage enters on the left and the stream seeps down into the gravel. The stream passage is very low. On the right side of that passage, it terminates with some flowstone. The passage to the right is very low and wide. After about 30 feet, the floor has some large slabs of rock and with a ceiling height of 8–10 inches; it is too low to continue. Looking up ahead about 20 feet, it is obvious that there is a dome up there, but it cannot be reached.



Green Briar Refuge Cave (MDD-145)

The wide entrance quickly narrows down to a 4 foot wide by 2 foot tall passage. Once through that spot, the floor drops, and generally the ceiling height is about 4 foot for the rest of the cave. A large flat breakdown rock is on the right side of the passage sloping toward the middle of the passage. After about 35 feet, the cave makes an abrupt turn left and continues for another 45 feet. Almost to the end on the right side of the passage is a channel slot in the floor about 3 feet deep and about 8 inches wide with about 8 inches of water standing in it. It's evidently a pool or stream of water below but cannot be entered by humans. The cave ends a few feet beyond where the floor fill sloping up to meet the ceiling. There is one small flowstone on the left side of the passage just before the end.

Missouri State Parks

Missouri Department of Natural Resources

Ken Grush and Scott House

Jim Sherrell scrubs away graffiti in Echo Bluff State Park.

Although CRF has permits to work with the Missouri Department of Conservation (MDC), the Department of Natural Resources (DNR) permits separately for the state parks. Individual park naturalists also maintain a measure of discretion to allow visitation at the caves within their park jurisdiction. At least 17 trips were recorded during this time frame.

In May of 2018, Jon Beard helped state parks staff evaluate a small cave at Battle of Carthage State Historic Site.

In 2018, Ben Miller and Bob Lerch initiated a several-year program of dye-tracing to delineate the recharge area of Roaring River Spring, located in its namesake state park in southwest Missouri.

In the summer of 2018, CRF members and friends put on a living history demonstration at Current River State Park. This recreated a 1960s river float camp, complete with canvas tents and retro gear. One of the impressions was of an early National Park Service geologist studying caves along the river.

CRF helped sponsor the Missouri Speleological Survey meeting at Current River State Park (CRSP) in September of 2018. In addition to monitoring area caves, there was an extensive biological survey and cave restoration effort in nearby Echo Bluff State Park which netted 13 new faunal records. At CRSP, cavers put up displays related to bat conservation, survey, and gear.

In September 2019, Mick Sutton helped lead a several-day cave biology institute at Rock Bridge Memorial State Park. The Devils Icebox system is some miles in length and biologically rich. Jeff Crews is leading an effort to remap the Icebox (see separate report).

A cave mapping and inventory workshop at Roaring River State Park, led by Jon Beard and Shelly Colatskie added 17 faunal records and trained a group of naturalists.

Missouri Cavers Meet at Current River State Park

Scott House

Cavers from the Missouri Speleological Survey and Missouri Caves and Karst Conservancy met at the old Alton Club, now Current River State Park, for a weekend of resource work and fellowship. The event was hosted by Missouri State Parks and sponsored by Cave Research Foundation and the Ozark National Scenic Riverways. Over 40 cavers made it at one time or another despite the best efforts of tropical storm Gordon which dumped many inches of rain almost everywhere except the park. While side streams rose, the major rivers of the park did not; this allowed activities to go forward. Trip reports are included in the Ozarks Operations report, but crews did survey, monitoring, bio-inventory, and restoration.

Brave participants camped out while the rest of us hunkered down in the historic dorms that form part of this incredible site. For more information on the park go to: https://mostateparks.com/park/current-river-state-park.

Cavers chow down at Current River State Park. *Scott House*

Devils Icebox Remapping Effort

Jeff Crews

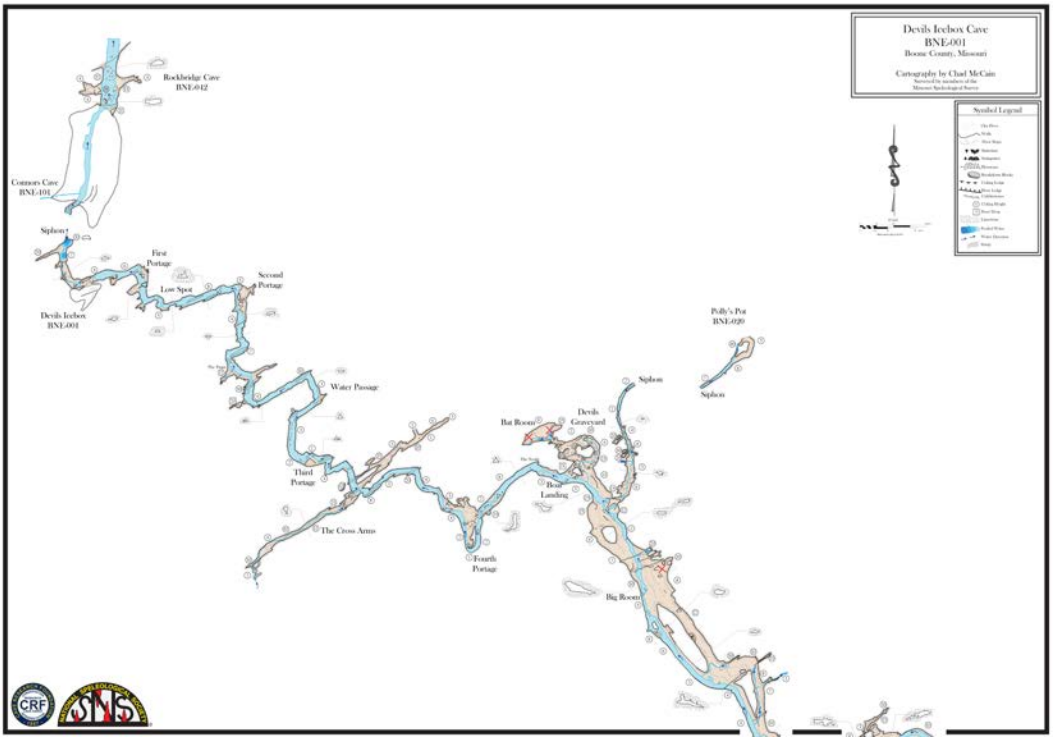
An effort to produce up-to-date maps of the Devils Icebox at Rockbridge Memorial State Park was started in 2019. The Dieke maps are currently the most comprehensive published maps. These maps include surveys primarily from 1959 to 1960 and contain significantly more detail and cave passages than the 1956 Johnson maps. They contain an adequate level of detail and were cutting edge at the time. The park has no desire to replace, or resurvey these maps, just update them.

In 2009, a sump dive by members of the Ozark Cave Divers Alliance discovered over a thousand feet of new cave passage and prompted the need for a comprehensive updated map. In actuality, there had been many discoveries and piecemeal surveys of the additional passages since the Dieke's last trip in 1960. With multiple failed efforts to continue mapping of the cave, it was apparent the project needed original survey data to form the backbone of the dataset. George Dieke graciously mailed his original survey books to Rolla, and they are now kept in the Missouri Cave Files at the Missouri Geological Survey, cooperatively managed by the Missouri Speleological Survey.

George's data has been entered into Walls, and new sheet boundaries were determined. The first sheet has been redrafted, primarily by Chad McCain, to match the line plot. On the second sheet and beyond, there were some missing survey data, mapping included on the Dieke map, that was not tied in and other clean up jobs that needed completed. Other later surveyed passages for which either the sketches or survey data has not been made available include: The R&B Passage, Beyond the Siphon, The Lurking Fear, and possibly others.

The 2019 survey effort has included 2117.8 feet of survey in nine different books completed on six trips into the cave. Objectives completed included connecting the Dieke surveys to the 1967 Vineyard survey, replacement of the missing Dieke survey, connected surveys by Hauck, House, and Baker, started survey of the Northeast Passage, surveyed leads in Water Passage, surveyed the Belfry and Boxworks heights. Total incorporated survey is 6.11 miles and 596 survey stations.

This has been a collaborative effort under a State Park's research permit with cooperators of the Missouri Speleological Survey, the Cave Research Foundation, and volunteers and staff at Rockbridge Memorial State Park.



Onyx Cave Survey Project

Howell County, Missouri

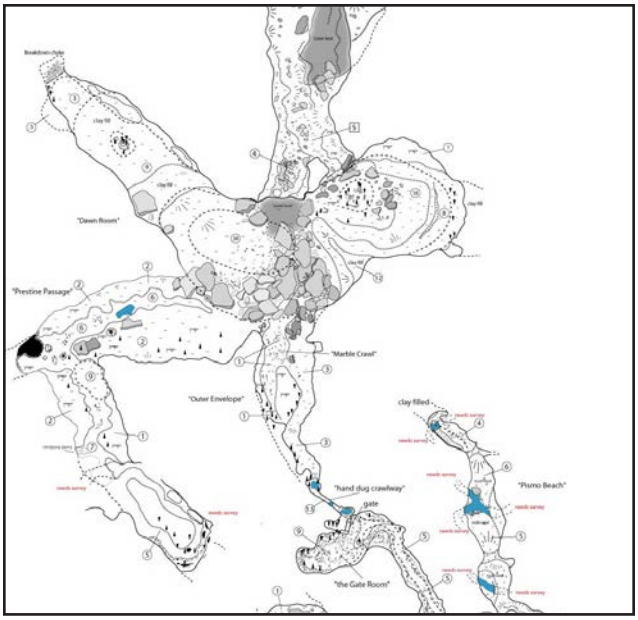
Scott House and Mark Brooks

Austin Brooks sketching. *Mark Brooks*

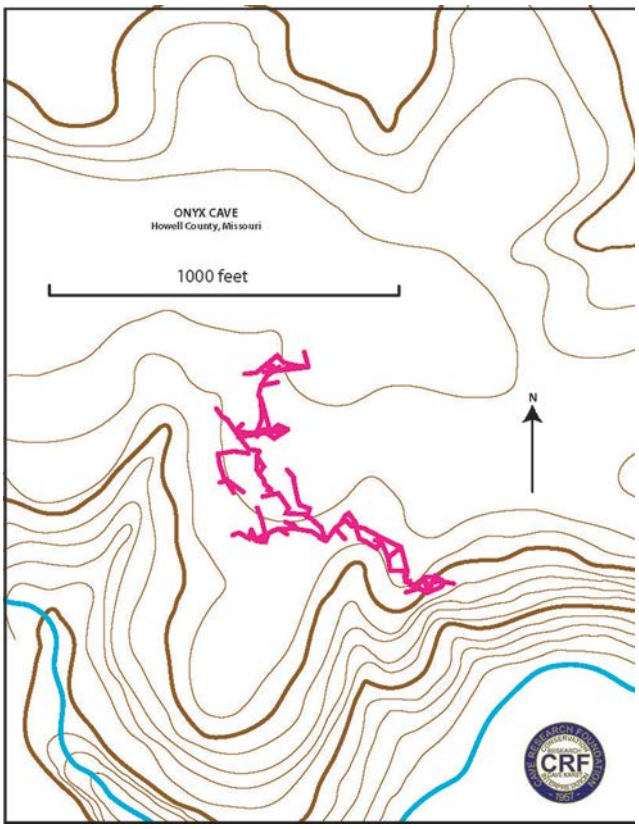
Onyx Cave, Howell County, Missouri is a spectacular and interesting cave on private property. Years ago, Mark Brooks and others began mapping it. That effort was never formally published, and Brooks decided to update and redo the map with more modern methodologies. Over the past few years, he and a small group of helpers have mapped over 3700 feet of well-decorated cave. This is a high upland cave, relatively rare in the southern Missouri Ozarks, developed in the Ordovician Roubidoux formation. The cave is home to a number of species, including one of the few caves in the county that harbor the grotto salamander.

The project continues with Mark doing data reduction and cartography.

Onyx Cave. *Mark Brooks*



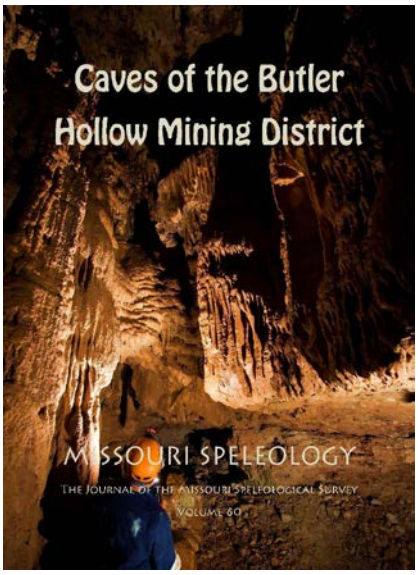
A detail from the Onyx Cave map. Cartography by Mark Brooks.

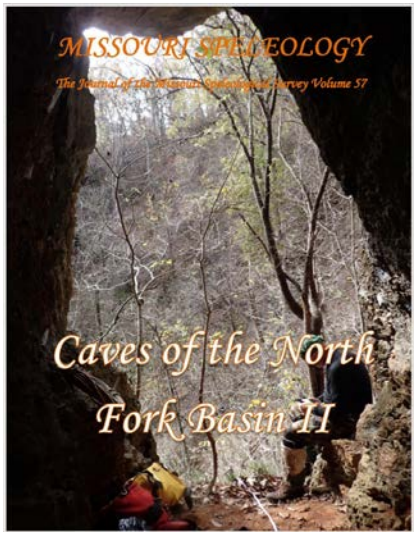


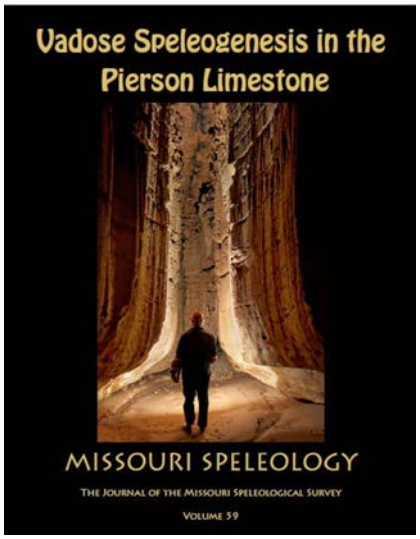
CRF and Missouri Speleology

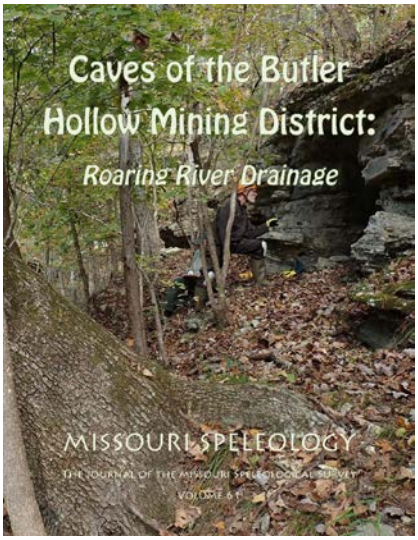
Scott House

Missouri Speleology is the journal of the Missouri Speleological Survey. In recent years, Cave Research Foundation has supported the journal by providing much new material. This also provides CRF with an easy publishing outlet to fulfill our goal of disseminating information in a variety of formats. CRF fellow Don Dunham is the editor and layout master. In 2018–2019, CRF helped publish four issues featuring work funded by federal agencies. These included two reports on the Mark Twain National Forest Butler Hollow project, one on a continuation of the Forest Service caves along the North Fork River, and a fourth featuring CRF Fellow Jon Beard's long-term and masterful study of the speleo-genesis of the Pierson Formation of southwest Missouri. Issues can be purchased through mospeleo.org/store.









The Missouri Cave Database

Ken Grush

The Missouri Cave Database (MCD) continues to live and grow. Many CRF members and other cooperators have given much to the database, since the last Annual Report of 2016–2017. Comparing 2019 (end of year) metrics to those previously reported: we have 3,277 Use Monitoring forms, a 20% increase; the 5,789 map count shows an 8% increase; 20,100 reports show a 31% bump; and 35,009 faunal records display a 12% jump. At end of 2019, we reported 7,475 caves. As of May 2020, we record over 7,500 caves.

A few comments might be helpful. The monitoring forms are an easy, five-minute process to explain the health of a cave and changes or impact made by visitation. They are largely to report on the caves that CRF has agreements to monitor for the National Forest or Park and state agencies. The caves that have maps are much fewer than the total maps because many caves have multiple maps. A round number of mapped caves would be 4,100 caves, which is more than half of the known caves in the state. Faunal records contain information on a single species on a given cave trip; one trip could generate 30 entries and has!

The reports were skipped above, so the author could explain a little more about reports. Sometime in the 1990s, the hardcopy cave reports, centrally stored in Rolla, were copied for distribution to at least two satellite locations in Missouri. Around 2012, some 20,000 files were scanned from the St. Louis satellite collection of hardcopy cave reports. Hence, two projects began. One project was the digital archive, while the other was a transcription process to capture the form and content of the original cave reports into the MCD. The transcriptions in the MCD can be readily searched by key words to research any topic. In fairness, many reports were previously transcribed and were entered as pieces into various parts of the MCD including directions, descriptions, hydrology, biology, etc. So, the new transcripts preserve the context of the whole report and fill in any gaps in reporting that may have been overlooked.

Regarding the "digital archive" for a moment, since the MCD includes a significant companion component. Where the MCD is fairly portable at less than 1 Gb of data, the archives are much larger at almost 1 Tb, with almost 460K files. The setup for the archives includes the Cave Archives, Map Archives, and Source Archives (recently renamed from the Newsletter Archive). Cave Archives are organized by county with each cave getting a folder. Within each cave, three "specific" sub-folders are for reports, for maps and cartography, and for photos. Map Archives are county folders of "jpg" format maps. The format has a historical precedent established by the state, but now other formats (pdf, ai, xar, etc.) are also preserved in both the map and cave archives. Source archives provide copies of all other material that provide input for the MCD. Material includes all available scans of related reports, newspaper clippings, text/word documents, PowerPoints, PDFs, photos, articles, grotto newsletters, some booklets, etc. There is lots of duplication among the three archives. All cave maps are in both Cave and Map Archives. Each report for a cave has a source, but, for example, the whole newsletter source doesn't get duplicated in the Cave Archive.

Much work remains to be done. Reports on five of the larger counties (by cave count) still need transcription. About 160 caves and leads were identified in 2018, and 58 in 2019. New data comes in all the time. Thanks to all our cooperators and volunteers.

Tumbling Creek Cave Project

Ozark Underground Laboratory

Scott House

In May of 2019, CRF and the Missouri Speleological Survey (MSS) initiated a new cartographic survey of Tumbling Creek Cave in Taney County, Missouri. The cave is the centerpiece of the Ozark Underground Laboratory, made famous by years of work by Tom Aley, aided and assisted by his wife Cathy and employees. In recent years, the Ozark Underground Lab Foundation was created to provide a continuous and lasting platform for the preservation of the cave and the important work that goes on there.

The cave is approximately 2 miles long and was previously mapped over some years by Don Rimbach, Ken Thomson, and others. The map lacked detail and vertical control, however, and to create a new, more useful product with GIS layers, cavers in Missouri undertook the effort to resurvey it.

Jon Beard restoring speleothems in Tumbling Creek Cave.
Mark Jones

Scott House and Jon Beard sketch in Tumbling Creek Cave.
Mark Jones

A several day trip in May of 2019, in conjunction with the MSS spring meeting, saw four survey parties in the cave. The main route was surveyed from the artificial shaft entrance to the Breakdown Room and main stream then on to the Big Room. From the Big Room, a large section of the East Passage plus Hibernation Hall were surveyed by two crews. A final trip cleaned the trails, in the wake of muddy surveyors.

In August, another survey trip finished the Breakdown Room area. Cave restoration, in the form of reattaching speleothems, was also done on this expedition.

A November expedition combined survey with restoration and trips to nearby Mark Twain National Forest lands. Two restoration trips began the week. This was followed by six survey parties over several days. The surveyors finished the East Passage and then turned their attention to

Dan Lamping at Natural Entrance of Tumbling Creek Creek.

the Main Stream. This flows to the natural entrance (historic Bear Cave) which has an immense chute gate for gray bats. Surveying downstream from the Breakdown Room and upstream from Bear Cave, the entire Main Stream was completed.

Thus far, 6900 feet have been surveyed with a vertical range of 107 feet. ArcGIS files have been completed and the map drafting (by Dan Lamping) is in process. Much is left to survey, including the Northwest Passage (accessible only by rope) and the upstream Main Stream from the Big Room.

The project is enabled by staying at the rustic field facilities of Ozark Underground Lab (OUL). These consist of three buildings provided for guests of OUL. One contains a kitchen and mess hall, another is a new bathhouse, and the third building has a large bunk room, and a classroom suitable for computer and file usage. Residences of the Aleys and other workers are elsewhere on the property, along with the three buildings of the Lab proper.

Three Forks Caves Project

Oklahoma

Mark Jones

2018

Several trips were made by the CRF to the Oklahoma Ozarks to Three Forks Cave and associated caves during the year. Clayton and Cynthia Russell, the landowners of Three Forks Cave, also serve as caretakers of the adjoining NSS Don R. Russell Cave Preserve. Mark Jones, Dennis Novicky, and Clayton Russell were the primary cavers with assistance from Jenn Ellis, Brenda Goodnight, Jimmy Gore, Mike Nelson, Austin Novicky, Don Payne, Cynthia Russell, and Rita Worden. The year's survey focused on Three Forks Cave with several smaller caves being inventoried when convenient. Several successful expeditions were recorded with the highlights in Three Forks Cave being the survey beyond the Guad (a guano, mud water slurry), connecting Bearcrawl Cave to the Cactus Passage, discovering a promising virgin lead, and knocking off numerous secondary passages. Other caves inventoried included Don Cave, Sand Cave, and Linda Bearpaw Cave. The caves of Gittin Down Mountain were rife with cave fauna which included the largest known hibernating Ozark Big-Eared Bat site, a significant gray bat maternity colony, a healthy pipistrelle population, a woodrat community, several salamander species, along with oodles of orb weavers, camel crickets, and amphipods.

Survey totals for 2018

- Three Forks Cave—2,705 feet, 10,478 feet total with even more yet waiting.

Dennis Novicky pushes a lead in Three Forks Cave.

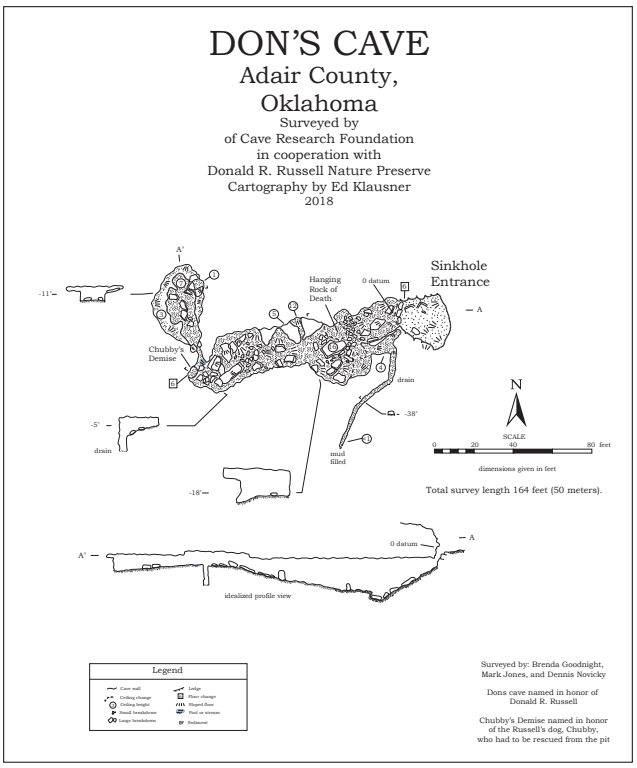
Mark Jones

- Linda Bearpaw Cave—445 feet with plenty of cave remaining.
- Don Cave—266 feet, completed.
- Sand Cave—348 feet with more to do.

Ozark big-eared bat within the NSS Donald R. Russell Cave Preserve. *Mark Jones*

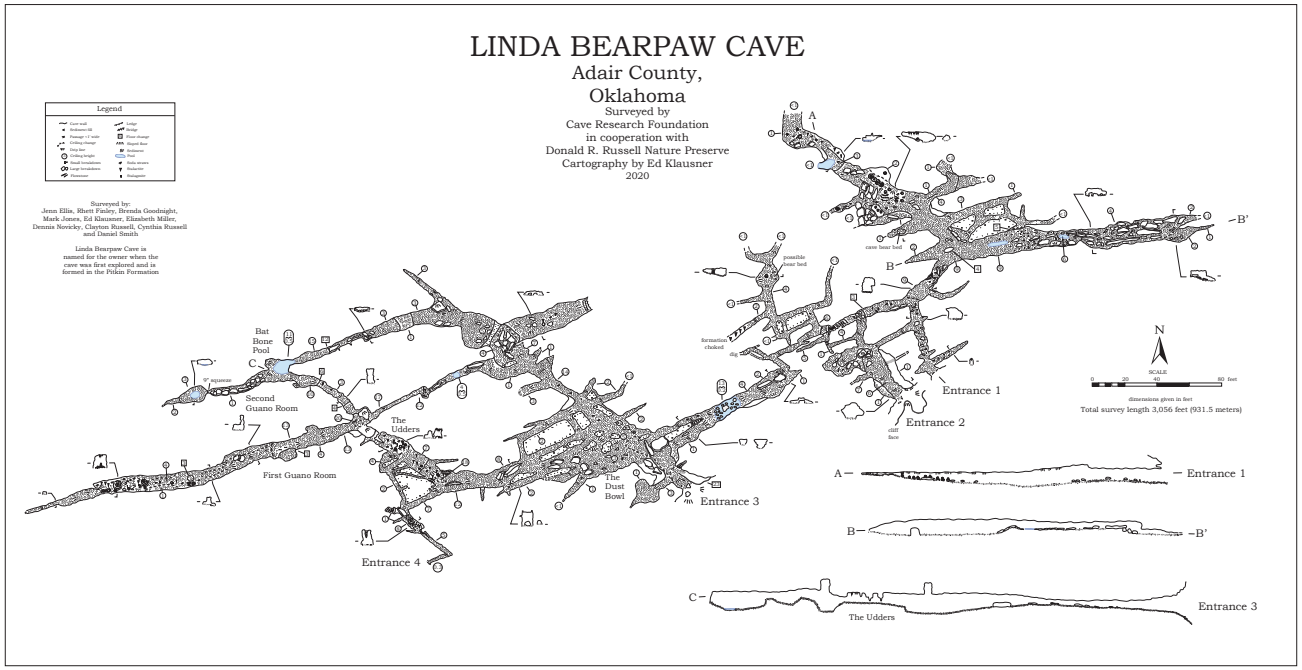
2019

Continuing the success of 2019, the survey of caves in the Oklahoma Ozarks racked up impressive footage. Mark Jones, Dennis Novicky, and Clayton Russell continued to lead the charge in surveying the caves of Gittin Down Mountain. Other cavers included Claty Barnett, Jon Beard, Jenn Ellis, Rhett Finley, Brenda Goodnight, Britt Hardwick, Ed Klausner, Hannah Lieffring, Elizabeth Miller, Nicole Ridlen, Cynthia Russell, Kayla Sapkota, Pradeep Sapkota, Daniel Smith, Aaron Thompson, and Brandon Van Dalsem. Major accomplishments for the year included the completion of the Sand Cave survey, a significant portion of Linda Bearpaw Cave being surveyed, an Ozark Big-Eared bat inventory at Gittin Down Mountain Cave, and the never-ending survey of Three Forks Cave. The cave critter population continues to be consistent with 2018. Many thanks are owed to Clayton and Cynthia Russell for their hospitality and enthusiasm.



Survey totals for 2019

- Three Forks Cave—1,525 feet, 12,003 feet total thus far and not stopping.
- Linda Bearpaw Cave—2,597 feet with a couple unpromising leads remaining.
- Sand Cave—382 feet, completed, total length 730 feet.



Sequoia / Kings Canyon National Park

Jennifer Hopper and Fofo Gonzalez

Operations Managers

2018 Annual Report

General Observations

- Two new projects were started this year: 1) Barbara Wortham is Principle Investigator (PI) for a paleoclimate study, using stalagmites to determine likely precipitation and temperature variation over the last 20,000 years. She is currently establishing a baseline drip rate and current precipitation in the area near Lilburn Cave. 2) Carol Vesely is PI for a cave inventory project which is being developed in Lilburn Cave but may carry over to multiple caves in the SEKI area and give access and provide data for many years.
- The drought in California eased up after 2016, which allowed us to spend a larger amount of time underground caving (up 57%), versus collecting and carrying water to the research station.
- 2017 saw a higher level of volunteer hours (up 48%), and a larger amount of JV participation. In addition, the number of executed trips versus planned trips increased in 2017. The number of person-days donated almost doubled from 2016.
- The exploration project in Lilburn Cave is ongoing with a 57% increase in the cave length surveyed over 2016.
- The cave specialist position for the park remains vacant. We have a good relationship with the Branch Chief of Physical Sciences, who now directly oversees the CRF partnership with the park.

Cave Management

- We continue to abide by strict 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 expedition leader is responsible for choosing whether or not to test JVs in vertical skills on site before entering the cave.
- We established online platforms including an email distribution group, social media, and Google Drive for expeditious data sharing with key park personnel and JVs. Investigator and trip reports, as well as other data collected, are uploaded after expeditions. This assures the continuity and data preservation with leadership changes.

Cave Data Management

- The Chief Cartographer, Dr. Jed Mosenfelder, updated the cave atlas with the latest survey information as of 2017. Hard copies of the atlas were printed for the park, and the data was made available to all project PIs and JVs.
- We provided a laptop at the fieldhouse which enables trip report preparation, sharing, and storage.
- In consultation with the park, we established a protocol regarding photographs made by professional photographers participating in the project. This was prompted by a situation that arose on one of the expeditions, in which photos taken during the expedition were later found to be for sale online.

Cartography Project (Jed Mosenfelder, PhD)

- The total length of passages surveyed in 2016 was 210 feet, the majority of it in new passage. In 2017, 490 feet were surveyed, also mostly new passage.
- A future goal in the cartography project is to expand the group of individuals working on the cave map. In years with a large amount of survey data to process having a single person responsible for all updates on the cave map proved inefficient due to the magnitude of the responsibility and the limited time that is normally available for any single person to work on it.

Other Projects

Structural Geology and Lilburn Cave (Marek Cichanski, PhD)

- This project evaluates the role of structural deformation on the karst and its surrounding non-carbonate rocks. Dr. Cichanski performed geologic mapping in the cave in June and September and created 6 geology quads, which are stored on a shared online platform.

Passage Restoration at Lilburn Cave (Bill Frantz)

- 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 had more water in the canyon in 2017 than 2016, which was more conducive to restoration activities in the cave. Bill is always looking for areas to restore and is open to suggestions from JVs.

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.
- The focus of this project area will shift to cave inventory for the near future.
- Another 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 likely extend for many years.

Hurricane Crawl Survey (Carol Vesely)

- Hurricane Crawl, a pristine and delicate marble cave, was first explored about 30 years ago. Sections of the survey are not up to standard, and there are still promising leads to be surveyed. However, Carol Vesely's energies are currently devoted to testing the developing inventory software, and training JVs on its use. In the future, Carol will work with Joel Despain to submit a research proposal to continue surveying Hurricane Crawl.

Cave Inventory (Carol Vesely)

- We have developed a cave inventory app, based on an Android operating system for portability and ease of deployment. Currently we are on the third version of the second full redesign, with ongoing alpha and beta testing. The focus is making the software nimble and as self-explanatory and logical as possible. We have calculated that 537 volunteer hours have been dedicated so far to developing the software program and training presentation.
- We are assembling three full sets of cave inventory kits, which will consist of a tablet in a rugged, shockproof and waterproof protective case, a pencil and paper cave inventory backup system and a carrying case.
- We will discuss with Carol Vesely expanding the cave inventory to other areas of the national park, and given that cave inventory is a topic that has attracted the attention of multiple national parks, we could even help other parks set up their own cave inventory initiatives, thanks to the ease of implementation of the Android based app.

Slide Creek / Eleven Range Overlook (David Angel)

- Joel Despain proposed this area for a CRF project. The access is difficult, and requires ropes to descend into the canyon. Once there, the terrain is difficult to move through with poison oak and uneven ground without trails. Although some caves have been located in the area in past years, 2017 attempts to relocate the caves were not successful.
- After the disappointing trip in which the GPS data for the known caves and karst features was not accurate and nothing was found, David requested a future trip which would include someone who had been into the caves before (Joel Despain). Once the base data of the known features has been established, further trips will be planned.

Ursa Minor (Joel Despain)

- This project focuses 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.
- This is an ongoing active project with alternating work trips and restoration trips to preserve the pristine nature of the cave.

Other Possible Projects

- **Monitoring of Stage at Big Spring (Jennifer Hopper).** We are continuing field tests of the data loggers and Bluetooth data collection systems (after a few issues), 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).** Per the park's suggestion, we are researching instrumentation with a smaller footprint than the prototype tested. We have secured funding for the purchase, which we expect soon.

All these studies already have some history or need to be evaluated and further analysis done before starting.

Educational and Cooperative Efforts

- John Tinsley has organized brown bag lunch sessions at the park.
- Several PIs and JVs will participate in a November 2018 science event called "50 Years of Research" at Sequoia National Park) including Babs Wortham, John Tinsley, and Joel Despain. Presentations will include research updates, a poster about the Lilburn project, and a touch table. For the 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.
- Future projects may include educational posters regarding karst areas and the importance of caves and the surrounding flora and fauna.

Plans for the Future

- We continue to work with park representatives, inviting park employees to participate as JVs on the project.
- We have expanded our scope to other areas in SEKI besides Lilburn Cave and Mineral King. There are several areas in the park that have not been a focus of research, and a number of caves other than Lilburn have potential for projects, including possible unexplored leads. The expansion of the Cave Inventory project will allow for one avenue of research outside the traditional areas of focus.

2019 Annual Report

General Observations

- Two primary projects are in their second year: 1) Paleoclimate study (Barbara Wortham, PI), using stalagmites to determine likely precipitation and temperature variation over the last 20,000 years. 2) Cave inventory project (Carol Vesely, PI), developed in Lilburn Cave, but may carry over to multiple caves in the SEKI area and give access and provide data for many years.
- Increased needs for inventory data for the Cartography project and water collection samples in support of the Hydrology and Geochemistry project, led to a 50% increase in the number of expeditions in 2018 vs 2017 (18 vs 12).
- Rain levels were higher in 2018 than 2017, which allowed us to spend a larger amount of time underground caving (up 21%), versus collecting and carrying drinking and wash water to the research station. In 2018, we began tracking water collection hours to separate this task from other station maintenance.
- 2018 saw an increase in volunteer hours (up 40%) to 5,374. The number of person-days donated increased 26% from 2017 to 202.
- The exploration project in Lilburn Cave is ongoing; however, there was a 37% drop in the cave length surveyed over 2017 (307 ft vs 490 ft).
- The cave specialist position for the park remains vacant. We have a good relationship with the Branch Chief of Physical Sciences, who now directly oversees the CRF partnership with the park. However, she is retiring at the end of 2019, and the CRF may have a stronger role in cave management in the park. A meeting of key stakeholders is planned before the end of 2019.

Cave Management

- We continue to abide by strict 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 expedition leader is responsible for choosing whether or not to test JVs in vertical skills on site before entering the cave.
- We maintain online platforms including an email distribution group, social media, and Google Drive for expeditious data sharing with key park personnel and JVs. Investigators' reports and trip reports, as well as other data collected, are uploaded after expeditions. This assures the continuity and data preservation with leadership changes.

Cave Data Management

- The Chief Cartographer, Dr. Jed Mosenfelder, updated the cave atlas with the latest survey information as of 2018, for a total of 91 quads. The data was made available on Google Drive, with a backup on Dropbox and multiple personal computers, as well as with the park.
- We maintain a laptop at the fieldhouse which enables trip report preparation, sharing, and storage.
- In consultation with the park, we established a protocol regarding photographs made by professional

photographers participating in the project. This was prompted by a situation that arose on one of the expeditions in 2017, in which photos taken during the expedition were later found to be for sale online. The park has determined that a $150 permit will allow photography in special access areas such as Lilburn Cave, during previously scheduled trips. New photography-only trips will not be granted permission.

Hydrology and Geochemistry: Paleoclimate Project (Barbara Wortham, PhD candidate)

- Understanding the future of our climate depends on building records of how our climate has changed in the past. Records of paleoclimate can be built from stalagmite archives found in cave environments.
- A stalagmite sample was analyzed for U-Th to date its formation. In addition, thin sections of the stalagmite pieces have been analyzed for trace elements. This analysis may show how El Niño Southern Oscillation impacts the southern Sierra Nevada. In addition, the stalagmite is being tested as a possible record of past fire activity. Thin sections will be used for oxygen and carbon isotope analysis, to determine variability in precipitation and vegetation.
- Ongoing monitoring of the cave environment includes cave water pH, and stable isotopes, pCO_2, temperature, and humidity. This data is collected during trips to Lilburn. The goal of this monitoring work is to understand how 1) the surface water that is likely primarily derived from snowmelt is influencing the dripwater in Lilburn, and 2) how temperature and precipitation variability impact dripwater, physically and chemically. From this we can better interpret our results from the Lilburn stalagmite.

Cartography Project (Jed Mosenfelder, PhD)

- The total length of passages surveyed in 2018 was 307 feet, 17 feet being resurvey. Total cave length as of January 2019 is 22.17 miles, putting Lilburn at #29 on the list of long caves in the US.
- A future goal in the cartography project is to expand the group of individuals working on the cave map. In years with a large amount of survey data to process, having a single person responsible for all updates on the cave map proved inefficient due to the magnitude of the responsibility and the limited time that is normally available for any single person to work on it.

Cave Inventory (Carol Vesely)

- Working under the cartography permit, we are developing a cave inventory collection system. We have developed a cave inventory app, based on an Android operating system for portability and ease of deployment. Ongoing alpha and beta testing and data collection are in process. The focus is making the software nimble, self-explanatory, and logical as possible. As of 2018, 15 JVs have been trained in cave inventory. All new passage and 60 existing stations have been inventoried. As more JVs become familiar with the system, we expect the rate of inventory to increase.
- We have assembled three full sets of cave inventory kits, which consist of a tablet in a rugged, shockproof and waterproof protective case, a pencil and paper cave inventory backup system, and a custom zippered carrying bag.
- In the future, we would like Carol Vesely to expand the cave inventory to other areas of the national park, and given that cave inventory is a topic that has attracted the attention of multiple national parks, we could even help other parks set up their own cave inventory initiatives, thanks to the ease of implementation of the Android based app.

Other Projects

Structural Geology and Lilburn Cave (Marek Cichanski, PhD)

- This project evaluates the role of structural deformation on the karst and its surrounding non-carbonate rocks. In 2017, Dr. Cichanski performed geologic mapping in the cave and created 6 geology quads, which are stored on a shared online platform. In 2018 Marek was not able to attend any trips due to a combination of work and health issues. He expects to be able to resume his trips in 2019–2020. For 2019, Marek has merged his structural geology project into the Cartography project.

Passage Restoration at Lilburn Cave (Bill Frantz)

- In 2017, 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 had more water in the canyon in 2018 than 2017, and some areas in the cave were washed completely clean of sediment that had been in place for years. In October 2019, Bill and Peri moved to New Hampshire, so we will be seeking assistance to continue this project as needed.

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.
- Meteorological station in Farewell Gap, Mineral King—The California Water Resources division would like to move the meteorological station from Farewell Gap to the White Chief area. We plan to help the NPS by ridgewalking the area to look for cave resources, to prevent damage to those sensitive environments.
- 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 likely extend for multiple years.
- The focus of this project area will likely shift to cave inventory for the near future.

Ursa Minor (Joel Despain)

- This project focuses 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.
- An August 2018 trip focused on cartography with 6 JVs participating. This is an ongoing active project, with alternating work trips and restoration trips to preserve the pristine nature of the cave.

Hurricane Crawl Survey (Carol Vesely)

- Hurricane Crawl, a pristine and delicate marble cave, was first explored about 30 years ago. Sections of the survey are not up to standard, and there are still promising leads to be surveyed. However, Carol Vesely's energies are currently devoted to testing the developing inventory software and training JVs on its use. In the future, Carol will work with Joel Despain to submit a research proposal to continue surveying Hurricane Crawl.

Slide Creek/Eleven Range Overlook (David Angel)

- Joel Despain proposed this area for a CRF project several years ago. The access is difficult, and requires ropes to descend into the canyon. Once there, the terrain is difficult to move through with poison oak and uneven ground without trails. Although some caves have been located in the area in past years, 2017 attempts to relocate the caves were not successful, and GPS data for the known caves and karst features was determined to be inaccurate. David requested a future trip which would include someone who had been into the caves before (Joel Despain). Once the base data of the known features has been established, further trips will be planned.

Other Possible Projects

- **Unsurveyed Caves.** The park has notified us of approximately 4 caves in a road construction area. One to two may be significant, and we have discussed possible future survey trips.
- **Monitoring of Stage at Big Spring (Jennifer Hopper).** We are continuing field tests of the data loggers and Bluetooth data collection systems (after a few issues), since we are using equipment designed and created specifically for this project. This proposal is undergoing a park-mandated tribal/historic review, and we hope to have an update in early 2020. This project would support the Hydrology and Geochemistry 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).** Per the park's suggestion, we have purchased instrumentation with a smaller footprint than the original prototype. This research will support the Hydrology and Geochemistry project.

Educational and Cooperative Efforts

- John Tinsley has organized brown bag lunch sessions at the park.
- Several PIs and JVs participated in a November 14–15, 2018 celebration of research and fire management called "50 Years of Research" at Sequoia National Park. Babs Wortham, Joel Despain, and John Tinsley presented research updates and history of the Lilburn project, and supported a touch table. For the touch table, multiple donations were made by CRF members and California grottos, of items related to caving (and specifically, caving in Lilburn) 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. Research posters are on display at the visitor center.
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CRF Projects in the Southwest Region

Janice Tucker

Operations Manager

2018

CRF fielded several projects in the SWR in 2018, all of them at Carlsbad Caverns National Park. William Tucker was the lead organizer for all of the r,estoration projects. Several CRF members led survey/resurvey trips in April of 2018. Volunteer hours donated to the park from CRF projects in this time frame amounted to 789.5 hours. What follows is a synopsis of CRF's efforts. Individual investigators will have more detailed reports.

William Tucker led three restoration projects; May 26–27, June 9–13, July 21–25, and November 10–11. There were 8 CRF volunteers in May who worked on two pools in the Big Room. During the June trip, 4 CRF volunteers did restoration work at the Breast of Venus, the Dome Room, the bridges of Lower Cave, finished work on the Ghost Pool, and removed coins and other objects from pools along the visitor trails. Finally, in July five days were spent restoring the Celery Stalk pool with 7 CRF volunteers helping. The two-day November trip included 4 CRF volunteers restoring pools near National Geographic Pit.

Ed Klausner, Dave West, Dwight Livingston, and John Lyles had a joint expedition in April 2018. Ed Klausner continued working in Lower Cave, and 405.8 feet of survey was completed, eliminating 27 leads. Dave West continued working in the multiple levels of the Music Room. 575.4 feet of new survey was added on three levels, and a major cross section was done through Devil's Mound, Devil's Den, the Music Room, and the tour trail in the Main Corridor. John Lyles resurveyed the passage from Glacier Bay to the Rift in Lechugulla Cave. Dwight Livingston worked on the Mystery Room for three days while helping with other projects the remaining days of the joint expedition. 451.8 feet of survey was added. Derek Bristol had an expedition at the end of 2017, beginning of 2018. 1872.5 feet of survey was added to the Guadalupe Room, New Mexico Room and just north of the Kings Palace.

A bull-shaped helictite in the Mystery Room. *Tony Canike*

2019

CRF participated in four survey projects and three restoration trips in Carlsbad Caverns in 2019. Detailed reports follow.

Ed Klausner and Dave West were cartographers for projects in Lower Cave and the Music Room in February–March, Dwight Livingston was cartographer for the Mystery Room project in April, and Derek Bristol was cartographer for New Mexico Room, Guadalupe Room, Chocolate High, and Left Hand Tunnel in July and December. Dwight Livingston's expedition netted 1499.7 feet of survey, Derek Bristol's 8283, Dave West's 1733.55, and Ed Klausner's 641.9 for a total of 12,157.85 feet of survey.

William Tucker led restoration trips in June, September and November. His restoration trips resulted in 468 hours of volunteer time within the Cave.

Restoration Work at Carlsbad Cavern

William Tucker

2018

On Memorial Day weekend 2018, eight CRF volunteers worked on two pools in the Big Room at Carlsbad Caverns. The pools are identified as: the pool near Rail #327 and the pool near Rail #416.

Originally the plan was to work on the pool at Rail #327 and the pool known as the Ghost Pool which is at Rail #413. The best laid plans of mice and cavers almost never work out that way. We had used all of our buckets at the pool at Rail #327, and we did not have the time to begin the Ghost Pool. Instead, a smaller pool in bad need of attention near it was selected since it was of a size that could be accomplished. We made good on this new commitment.

The pool at Rail #327 is going to be spectacular once the water has completely settled. This was a priority pool on the list of projects that were identified in September of 2017. It has been accomplished. The smaller pool was also dramatically improved and it was in much need of attention.

Volunteers were: Lee Ann Dean, Mary Ann Bradshaw, Kelly Holladay, Janice Tucker, Kolt Blackmon, Tammy Tucker, Bill Weston, and William Tucker with 146 volunteer hours provided.

During the week of June 9–13, 2018, a small group of CRF volunteers set out to perform a variety of cave restoration projects in Carlsbad Caverns, mostly around the Big Room. By the end of the week, we had performed a significant restoration at the Breast of Venus, cleaned mud from the of trail in the Dome Room, cleaned the bridges in Lower Cave to protect the cave pearls, removed a large number of coins and other debris from pools near the visitor trails, and performed a complete restoration on a small pool known as the Ghost Pool.

At the Breast of Venus formation, the difference was dramatic. The formation was covered in a thin layer of lint; there were visible boot scuff marks on the namesake stalagmite; and there was a significant amount of trail debris including coins and tossed stones in the bottom of the pool basins under the bell canopy skirt of the stalagmite. After restoration, the lint was been removed, the scuff marks were cleaned away and, the trail debris, coins and other out-of-place material had been removed. This notable formation had a brighter appearance.

At the Ghost Pool, it was nothing short of a transformation. Before, the pool bottom was completely covered in trail debris with a dark coating of decomposed lint. None

William Tucker

Smaller pool after returning the water. *William Tucker*

Working on the smaller pool, November 2018. *William Tucker*

of the subaqueous popcorn nodules were even visible. The bumps on the bottom that were visible were tossed or out-of-place stones and did not belong. There was also an easily seen and recognized blob of spit tobacco on the end of the pool nearest the trail. Within the debris in the pool basin were a large number of wads of used gum and a significant number of coins and other miscellaneous bits of flotsam. After restoration, the water was clean and clear, the popcorn pool bottom could be easily seen from the visitor trail, and the pool looked very close to what it should look like were this an undisturbed cave.

A large number of coins were removed from various pools near the visitor trails, especially from the one immediately behind the sign that asks visitors not to throw coins in the pools at Devils Spring. In Lower Cave, the nylon bridges were cleaned so that the tracked mud on them would not reach the point of spilling over into the cave pearls. That is the purpose of the bridges. Other bits of detritus were also removed from near the visitor trails as it was noticed.

In all, it was a very successful week. It was very beneficial to the cave, the visitors we encountered, and certainly the participants themselves.

Volunteers: Kathryn Vernon, Lee Ann Dean, Tammy Tucker, and William Tucker donated 158 volunteer hours of effort.

From July 21–25, a third restoration expedition set out to restore the pool near the Celery Stalk as it was badly in need of attention. It was overgrown with algae and had obvious foreign material in the bottom. It was an eyesore. We had attempted to do this project in June, but a lack of volunteers forced us to postpone it. In July, we decided to tackle this very challenging project.

During the five days, we pumped all of the water from the pool into temporary reservoirs that we constructed in nearby dry pool basins. We gross cleaned and removed the foreign material including a great number of coins, we fine cleaned and treated for algae, we fine cleaned again and retreated for algae and finally, we returned the water to the basin.

A surprising amount of foreign material was removed from the pool. The results were spectacular and were as good as can be expected. The pool should get even better with a little time. Time will allow it to settle and time will allow it to refill to make up for the water that was lost in the restoration process.

Volunteers: Karen Perry, Kristy Sullivan, Jim Raley, Alex Moorkamp, Joseph Gavigon, Tammy Tucker, and William Tucker for a total of 206 volunteer hours.

Thanks are due to all of the Park employees, especially those of the Cave Resources Office who worked with us on the various projects, especially the Ghost Pool project.

William Tucker

2019

Geographic Pit

On Friday, June 14, four experienced CRF volunteers began a project to restore a large, heavily impacted pool located on the other side of the trail from National Geographic Pit. This pool is badly contaminated with a lot of trail debris in the form of out-of-place rocks. They obviously tumbled from the trail and were never retrieved. Gum, coins, and other detritus are visible and who knows what we will find by the time we are done. This pool has never been restored and is in close proximity to the trail.

The goal for the day was to remove all of the water and to store it temporarily so that the pool basin could be restored. We set up four vinyl swimming pools (Figure 1) at various locations and pumped the water into those pools. We had to be a little creative in locating the swimming pools as ideal sites were nowhere to be found. In the end, it worked.

By the end of the day, we had removed the water and did a quick rinse of the basin. We planned to begin the detailed cleaning the following day. Immediately after emptying the pool, a quick examination found a broken bottle under the large rock in the center. We removed the shards of it. The bottom was intact and numbers and symbols were visible on it, so, it was taken to cultural resources for assessment.

The volunteers who worked on Friday included: Lee Ann Dean, Jimmie Worrell, Tammy Tucker, and William Tucker. A total of 30 person hours of volunteer effort were involved in Friday's activities. The many visitors we encountered were appreciative of our efforts. They asked a lot of questions, and we did our best to answer them.

Large Pool across the Trail from National Geographic Pit

On Saturday, June 15, we began the process of cleaning and restoring the pool basin. Most of the problem in this particular pool basin was trail construction debris that had somehow ended up in the pool. The debris was mostly medium sized rocks like those used in the wall construction and some loose sediments that had cascaded from the trail. Of course, we also found coins, gum, plastics, and other material that did not belong, but the trail construction debris was the majority of the material and it cleaned up very quickly.

We took the sediments and rocks from the bottom of the pool and used them to hide the cables on the opposite side of the trail. This made good use of these out-of-place items.

The cleaning went very quickly and by lunch time, it was obvious that we were going to be ready to return most of the water by later in the afternoon. So, at lunch, one member went to retrieve what was needed to return the water (pump, filter, additional buckets, etc.). Tammy and Janice had picked particularly bad tracked sediments on the shelves above the pool and continued to work on these for a while. The rest worked to setup the pump. Both were obvious places where sediments had been tracked into the popcorn. Once they were satisfied with their work, we proceeded to return the water by pumping it through the filter (to catch any lint) back into the now restored basin. By 4 p.m., all of the clean water had been returned. We left about 10 or so five-gallon buckets of water that still needed to settle. We planned to return that water in a few days. After filling the pool, we packed up and exited the cave to clean and store the gear.

The volunteers who worked on Saturday included: Lee Ann Dean, Jimmie Worrell, Janice Tucker, Timothy Charlton, Annabella Charlton, Tammy Tucker, and William Tucker. A total of 63 person hours of volunteer effort was involved in Saturday's activities.

Figure 1. Vinyl swimming pools to temporarily store pool water. *William Tucker*

Figure 2. Cleaning formations. *William Tucker*

Celery Stalk Pool and Lower Cave, June 16

We started the day at Celery Stalk Pool. Previously Tammy and I had noticed some anaerobic activity going on in the deepest part of that pool. This is probably due to sugars from gum or candy and other carbons being eaten by anaerobic bacteria. It is unmistakably black in color. The usual solution is to stir the water which oxygenates it and kills off the activity. We chose to test that theory at Celery Stalk Pool.

We used the sump pump with a short piece of hose to agitate that area in the hopes of oxygenating it to kill off the black bloom. We are hopeful that the black bloom will continue to disappear.

That task did not take long. The next task we wanted to accomplish was to go into Lower Cave to clean the bridges. There was a tour in Lower Cave, so we had a little time to kill. Near Celery Stalk, a large amount of lint was noticed right next to the trail, so we decided to spend a little while picking lint while we waited on the Lower Cave tour (Figure 2). In only about an hour, a significant amount of lint was collected. When the tour exited Lower Cave, we entered to clean the bridges.

We worked for about three hours to scrape, sweep, brush and sponge the bridges clean. The goal is to prevent the dirt from being washed into the cave pearls.

The volunteers who worked on Sunday included: Lee Ann Dean, Jimmie Worrell, Janice Tucker, Timothy Charlton, Annabella Charlton, Tammy Tucker, and William Tucker. A total of 49 person hours of volunteer effort was involved in these activities.

Figure 3. Cleaning out pools. *William Tucker*

Big Room and Lower Cave

On Monday, June 17, five CRF volunteers including: Jimmie Worrell, Lee Ann Dean, Angelina Guerra, Tammy Tucker, and William Tucker, walked the entire visitor trail looking for trash, coins or anything that did not belong paying particular attention to pools (Figure 3).

Several bags of trash were picked up and removed. Larger items included: two hats, a styrofoam cup, several park maps, and others. The most disgusting thing, and we found a lot of it, was spit tobacco blobs.

We noted a few graffiti marks and photographed them for documentation purposes. A total of 42.5 person hours of volunteer effort was involved in these activities.

Big Room, June 18

The goal for June 18 was to return the last bit of settled water to the large pool near National Geographic Pit. Of course, that wasn't enough of a goal, so we decided to start on a smaller project: a badly impacted pool at rail #207. Five CRF volunteers including Jimmie Worrell, Lee Ann Dean, Angelina Guerra, Tammy Tucker, and William Tucker worked on these two projects on Tuesday.

We knew we were unlikely to finish the pool at rail #207, but it would not hurt a thing to leave it partially completed. That is what we did.

We removed most of the foreign material and then put the small amount of water back. It is not finished and we plan to work on it again in the future. We should be in a good position to finish this project in one or two days.

As to the large pool near National Geographic Pit, we finished returning all of the settled water. We also spent several hours doing some fine, dry brushing in some obvious tracked areas near the light and between the two pools. In the end, the results are very good.

Big Room, August 31

On Saturday, August 31, a group of five volunteers worked on a large pool basin near rail #522. The volunteers included Phyllis Boneau, Mary Ann Bradshaw, Kelly Holladay, Kolt Blackmon, and William Tucker. The effort was led by William Tucker who spent 50 person hours cleaning.

This site had been scoped out on previous trips into the cave and looked to be a very good project. The pool basin was heavily impacted by trail sediments, out of place rocks, and trail construction debris. When the site was scoped in June, it was dry. On this trip, there was a small amount of water in the bottom.

This site turned out to be much more of a project than we imagined. We thought we were going to find a relatively small amount of trail sediments in the bottom of the basin. Instead, we found much more sediment than we thought. It became obvious that sediments were dumped at this site sometime in the past. We found a layer of trail sediments on the calcite pool bottom that averaged about six inches thick. Coins, bits of broken glass and other bits of debris were found under the sediments right next to the calcite bottom; so it was obvious the sediments were added. There was too much for tracked and washed in to account for the accumulation.

We worked to remove the majority of the debris. Twelve buckets of sediments, each about half full, were removed. Broken speleothems and other cave related rocks were set aside to naturalize back into the area once we are finished. About 10 gallons of water was set aside to settle to be returned on the next day.

Big Room, August 31

Megan Reeland and Lila Jones were led by Tammy Tucker to work on the pool from the previous day. Two people removed the clearest water using a small container and a turkey baster. This was set aside in a five-gallon bucket. Next we "rough cleaned" the pool basin using the remaining water (which had been stirred up and therefore contained some sediments). We finally sponged the water and sediments out of the pool basin and put that water into

Figure 4. Sediment removal from a pool. *William Tucker*

separate buckets to settle. With the basin empty of water, we used spoons, picks, and brushes to remove sediment from the pool bottom. The cleaning was completed. We were able to return the first bucket of very clear water. The remaining two buckets of settling water were left until the next day (September 1) and then the clear water on top was carefully put back into the basin. The partial bucket of sediments was taken to the quarry.

Area restored: Pool #207—4 square feet, 30 person hours.

Big Room, September 1

The following day, September 1, we continued work on a badly impacted pool basin near rail number 522. Five volunteers worked on Sunday for a total of 52.5 person hours. The volunteers included Tammy Tucker, Megan Reel, Lila Jones, Kolt Blackmon, and William Tucker. The effort was led by William Tucker with advice from Tammy Tucker.

We continued to remove sediments from the site (Figure 4). 6 More buckets, each about half full, of sediments were removed. By the afternoon, we were able to begin the arduous task of fine cleaning the pool basin. We made good progress in the effort but were unable to finish.

More work will need to be done here to complete the project. We are planning to concentrate on this site on future trips until it is complete.

52.5 person hours were spent on restoration work.

Big Room, November 9

A group of five volunteers worked on a large pool basin near rail #522 on November 9. The volunteers included Jimmie Worrell, Lila Jones, Lee Ann Dean, Tammy Tucker, and William Tucker. The effort was led by William Tucker. We had begun work on this site in August of 2019. The goal for this trip was to make more progress. We hoped to complete all of the dry cleanup work. The pool basin was heavily impacted by trail sediments, out of place rocks and trail construction debris. Upon arrival at the site, a large tobacco blob was clearly visible. It was not there on the last trip.

Figure 5. Lila Jones using a dental pick to loosen embedded sediments. *William Tucker*

We began at the top and worked downward. The technique was to loosen the embedded sediments from the between the popcorn nodules of the pool basin using dental picks (Figure 5). The fluffed sediments were then collected using dustpans and wisk brooms and put into buckets. Using this technique, we collected four five-gallon buckets of out-of-place sediments. This included a large amount of concrete and other very foreign material, but most of it was trail sediments which had been tracked or washed into the basin. Most of it was obviously from the old dirt trail. We succeeded at cleanup of most of the upper portion of the basin. This included two landing pads where the tracked sediments were the thickest and most tightly embedded in the popcorn.

42.5 person hours of volunteer effort was expended on this effort.

Big Room, November 10

A group of seven volunteers continued work on a large pool basin near rail #522. The volunteers included Jimmie Worrell, Lila Jones, Lee Ann Dean, Kelly Holladay, Mary Ann Bradshaw, Tammy Tucker, and William Tucker. The effort was led by William Tucker.

We continued the effort from November 9. We worked to loosen the sediments with dental picks and sweep and collect the loosened material into buckets. Six five-gallon buckets of sediments were collected during 73.5 person hours of volunteer effort.

New Mexico Room, Guadalupe Room, Chocolate High, Left Hand Tunnel, and Big Room Sections of Carlsbad Cavern

Derek Bristol

2017–18

Objectives for a late 2017 early 2018 expedition were divided among multiple areas of the cave with two days spent in the Guadalupe Room, one day spent in the New Mexico Room, and one day spent just north of the King's Palace. The results of the expedition included 1,872.5 feet of total survey; 1865.6 feet of new survey, and 6.9 feet of redundant survey. The expedition added 0.35 miles to the length of Carlsbad Cavern, which now stands at 33.26 miles.

There were a number of objectives for working in these areas including producing updated and high quality section maps, fixing a handful of loop closure errors, and pushing several remaining leads. During the last expedition, over the Thanksgiving holiday, two climbing leads were scouted in the Guadalupe Room that appeared to have potential. These were both ascended using technical aid climbing techniques (Figure 1). A relatively new strategy that employs concrete screw anchors was used to make these ascents. The screw anchors are very fast to place, adequately strong for aid climbing, only require a 1/4" diameter by 1.5" deep hole, and are entirely removable.

The result of using this technique was that the climbs were completed safely, reasonably quickly, and no hardware was left behind on the climbs. Additionally, the holes are so small and so little rock flour was generated, that the impact from the ascents was essentially invisible. While one of the climbs went to a large but blind alcove, the other went to a very well decorated fissure with passage that continues. The first of the climbs were de-rigged, but the other was rigged with stainless steel hardware and equipped for a return trip that will need to be made with full clean gear. In addition to the climbs, several other survey goals were accomplished, including a surveyed connection between the Balcony and Mezzanine in a boneyard area east of the New Mexico Room, and the survey of Sand Passage on the west side of the New Mexico Room (Figure 2). The nearly 2,000 feet of survey accomplished during this short expedition helped get the section maps much closer to completion. While many leads remain, a good mix of new and resurvey was accomplished.

Figure 1. Aid climb in the Guadalupe Room. *Kevin Manley*

On day one, Derek, Kevin, and Eric entered the cave via the Natural Entrance and traveled out to the Guadalupe Room via the normal route and went to the center of the upper part of the room near station GC14 where a hole in the ceiling had previously been scouted. A short effort was made to toss a baseball with an attached cord over a chockstone in the ceiling lead, but the distance was too far for this tactic to succeed. The team then went to the wall to the west of GC14 and began a traditional aid climb using removable gear including 1/4-inch screw anchors and traditional chocks and cams. The route goes up the wall, out a short roof, and across a ceiling ledge to reach an alcove where an intermediate belay anchor was set. From there a short free climb led to the room in the ceiling. This appeared

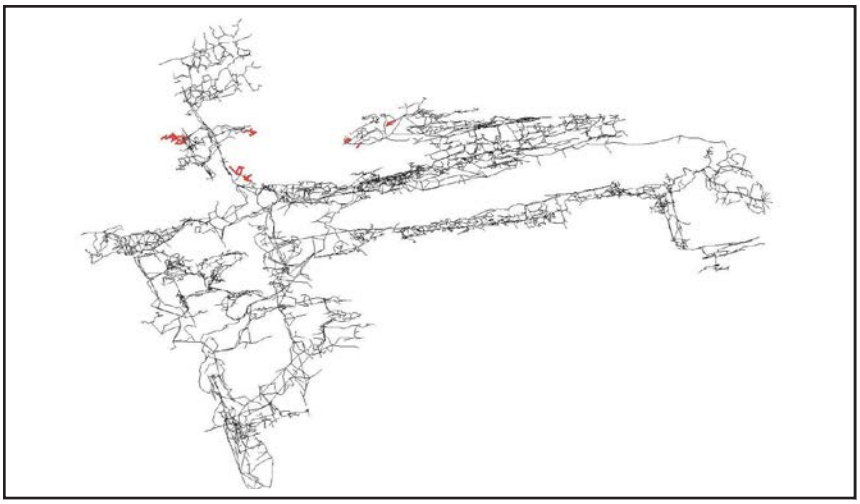


Figure 2. Newly surveyed section in red.

to be blind with one possible lead up a formation-choked fissure, but time was short so the decision was made to come back in two days to survey. A two-bolt anchor and a rebelay bolt were set and a 95-foot rope was rigged.

The next day, Derek, Kevin, and Eric entered the cave via the natural entrance and went to King's Palace and followed the main passage out to the New Mexico Room. They first went to the Balcony to look for and survey the expected connection up to the Mezzanine and the CM survey. The team used NMA31 as a tie-in, but unfortunately the lead list that was brought had been generated in November, and didn't have the most recent survey from the Thanksgiving expedition, and the stations of NMA32–44 had already been used. The new survey stations of NMA32–47 were entered as NMA32'–47', and the flags will need to be corrected on the next trip to that area. The boneyard area east of NMA31 was surveyed to a room that appeared to be terminal but a very tight ascending tube was found with the older RUM survey tags that was followed and led to the connection to the CM survey above. There were a number of additional leads in the tie-in area that were left for a future trip. The team then traveled out to the old "Sand Passage" at the NW corner of the New Mexico Room, where a new NMC survey was begun by tying into NMB1. The entire sand passage was surveyed except for a climbing lead at the NW end that can be done with a rope toss and maybe 40 feet of static rope. A boneyard fissure along the west side of the sand passage where it connects back into the New Mexico Room was also surveyed but does a short loop back into the room.

On day three, Derek, Kevin, Eric, and Nicole entered the cave via the Natural Entrance and traveled out to the Guadalupe Room via the normal route and returned to the fixed rope hung two days earlier near station GC14. The team started surveying by tying into GC14 and shooting up into the room above. As suspected, the main room was confirmed to be a series of blind alcoves, but the tight formation fissure had an opening large enough to fit through. After surveying a short distance it was apparent that the formation lead continues, but it was also obviously extremely delicate and would require full clean gear to continue while mitigating impact. This new area was named Gossamer Loft (Figure 3) due to being very delicate. It was decided to leave it for a future expedition, so the survey was ended, and the team went to the other targeted climbing lead at the bottom of the room near GC30. This climb was scouted and a climb begun along the right side of an overhang. Screw anchors were used and later removed to ascend about 40 feet up to a hole in the wall. A static rope was fixed and the team surveyed up into the boneyard area. The entire area was surveyed in eight shots with several more holes dropping back into the room, but no other leads. Because there were no other leads the rope was pulled down after the last person rappelled. Since the team had climbing gear, the area was scouted until another potential climbing lead was found along the south wall above GC36. This was climbed using entirely free-climbing methods and natural anchors, but the alcove above was found to be blind. The lead was surveyed and the climb was descended by down-climbing, and no gear was left behind.

Figure 3. Surveying in Gossamer Loft. *Kevin Manley*

Figure 1. Surveying Gossamer Loft. *Sonia Meyer*

Figure 2. Pool formation in Gossamer Loft. *Sonia Meyer*

On the last day, Derek, Kevin, Eric, and Nicole entered the cave via the elevator and took a short tourist trip around the Big Room before heading out to King's Palace where they climbed the initial climb towards the New Mexico Room. At the top of the climb, at the base of the first ladder, is a large room that had not been fully surveyed during the last expedition in November 2017. This was surveyed to the northwest by using NMA3 as a tie-in and starting the NMD series. There are several large holes in the floor of this room that need to be surveyed but will require a rope to access. A small room to the north was surveyed to a termination. The team then surveyed an ascending fissure above NMA5 to a large ledge that overlooks King's Palace. The team then surveyed a pair of holes in the floor below NMA4 into a boneyard complex with several connections out into the King's Palace.

Team members included Derek Bristol (CO, expedition leader, sketcher, climber), Kevin Manley (CO, climber), Eric Weaver (NM), and Nicole Lewis (CO).

Thanks to Rod Horrocks, Ellen Trautner, and Erin Lynch in the Cave Resource Office for providing information, training, housing arrangements, and gear preparation. Without their support, none of this would have been possible.

July and November 2019

The primary goals for July started off being exploration of leads and fixing of bad loops in the Guadalupe Room and New Mexico Room. With the late approval of the aid climb of Liberty Dome in the Big Room, the limitation of only climbing when the tour trail had closed for the day, and with the difficulty and logistics of the climb, a total of three evenings were spent on this objective. The time was used to make the initial ascent, put in robust rigging, thoroughly check for leads, and conduct a detailed survey. Despite these late evening activities, one day was spent in the Guadalupe Room and another two days were spent surveying and fixing loops in the New Mexico Room. The major portion of the Liberty Dome climb was completed on the first night (July 4). It was hoped that any new discovery could be named "Independence Hall", but alas, no going leads were discovered. A second night was spent removing anchors used in the ascent and rigging rebelays for safe access, and a third night was used to thoroughly explore and survey the top of the dome. A register from 1976 was found but not the reported boneyard maze.

The Gossamer Loft area in the ceiling of the Guadalupe Room was revisited with full clean gear and the exploration and survey continued, but this well decorated area was very quickly finished with no remaining leads after about 150 feet of survey.

Teams visited lower-level areas on the southern end of the Guadalupe Room and discovered well-decorated rooms and passages with many leads remaining to be explored. Finally, time was spent in the New Mexico Room with the primary objective of fixing a series of six bad loops, but two of these are no longer accessible because ropes were pulled, and three of them suffer from issues related to mistakes made in relabeling, which will be very difficult to fix, and will require additional trips to the area. Still, steady progress is being made on improving the data and moving the cartography ahead.

Team members included Derek Bristol (CO, expedition leader, sketcher, climber), Steve Reames (CO), Marty Reames (CO), Aria Midice (NM, sketcher), Hunter Klein

Figure 3. Bat skeleton in flowstone in Gossamer Loft.
Sonia Meyer

(CO), Sonia Meyer (CA), David Brumbaugh (NM), Leah van Vranken (TX), and Tiffany Nardico (CA). Most of these cavers have done volunteer work in Carlsbad Caverns National Park in the past. This was the first expedition for Hunter and Tiffany. Everyone caved safely, with low impact, and remained focused on generating high quality survey data.

On the first day, Derek, Sonia, Marty, and Tiffany entered the cave via the Natural Entrance along with Aria, Steve and Leah. The two teams traveled together to the Guadalupe Room. At the rope that leads to Gossamer Loft, the teams split up. Derek went with Aria's team towards the Grand Ballroom and pointed out several leads that needed survey. He then returned to the Gossamer Loft rope where Tiffany, Marty, and Sonia were completing their ascent. Once everyone was at the top of the fixed rope, they took time to calibrate both of their Disto-Xs and then changed into clean gear and shoes for the transition onto the clean flowstone above GC14D. A new designation, GL, for Gossamer Loft, was begun, and the team surveyed to the southwest across a very delicate area that has a flowstone floor and many stalactites, soda straws, and helictites (Figures 1 and 2). A number of dead bats were observed encased in flowstone (Figure 3). Following a low spot in the ceiling, a room was encountered that is about 25 feet wide and 60 feet long with a floor that transitioned from flowstone to sediment. Marty crossed the sediment-floored area in socks to verify that the far side of the room did not contain continuing passage. The survey and sketch of this room was completed and the team then surveyed to the northeast through a very narrow opening between columns. Another small room was encountered, and Tiffany crossed the sediment-floored section to verify that this end of the passage also terminated. The survey was completed, and no leads were left. The team retreated to the rope, changed back into dirty gear, and descended back into the Guadalupe Room. The team traveled down to the lower portion of the Guadalupe Room to a fixed rope that's rigged and rappelled to a mid-level passage where they began a survey. The rope continues down an additional pit, which is the direction the survey was taken. At the bottom of this pit is a room with breakdown leads going to the north and east that were left for another day. The team followed a southwest trending passage that also descends rapidly, following the downward-dipping south wall of the Guadalupe Room into a series of boneyard passages (Figure 4). A crawl that doubles-back under the main passage and heads back northeast was surveyed to a termination. The team re-climbed the fixed rope and met back with Aria's team near the Gossamer Loft rope. A total of 308.6 total feet was surveyed in 20 shots using GL1–6 and GC40F–S. 303.8 feet was new survey, and 4.8 feet was redundant.

Aria, Leah, and Steve surveyed into a lead heading northwest using the survey designation GRG. The passage is complex and mazy with a mix of solutional passage and breakdown. The survey eventually dropped into a large room that has gypsum chandeliers reminiscent of Lechuguilla Cave. The area was named Lil' Lechuguilla, and 11 leads were left with much more work to be completed. The team returned to the top of the Guadalupe Room and met with the other team. A total of 321.9 total feet was surveyed in 23 shots. 298.5 feet was new survey, and 23.4 feet was redundant.On day two, Derek, Marty, and Hunter were a team and were joined by the second team consisting of Aria, Leah, Tiffany, Sonia, and Steve. The teams travelled together to the Chocolate Drop where they all changed to clean shoes and continued to the Ranger Room. The teams split up with Derek's team checking the ropes to the NY survey only to discover the ropes were removed. There are two bad loops in the NY survey and several leads but reaching these will require re-climbing the domes above the Ranger Room. The team then traveled down a flagged trail to reach the start of the Western Lower Maze and the

Figure 4. *Hunter Klein*

CF survey. The objective was to locate survey blunders in four loops along the west side of the New Mexico Room in this lower maze. After some route-finding, they located CF64, which is part of one of the bad loops. The team began a resurvey by just re-shooting from station to station since the original stations were easily recovered. All of the shots matched the old data until the final four shots of the loop, which had a station sequence of CF75–80–81–82–60, rather than the CF75–82–83–84 shown in the Compass data file. Correcting these fixes this one bad loop. They then traveled north in the Western Lower Maze and located CF150, which is part of a series of three interconnected bad loops that share some station sequences. Right away, it was apparent that several shots included additional mis-labeled stations. It seems apparent that the CF stations in this area were relabeled after they were originally surveyed, and the data in the Compass file was changed to reflect these new station names, but either the stations were entered into Compass incorrectly, or the wrong labels were replaced in the cave. Subsequent surveys then tied into these newly labeled stations, so fixing these problems is going to take much more time than originally thought. Time ran short to fix any more loops so the team traveled back to the New Mexico Room and met with the other team at the rope leading back to the Green Lake Room. A total of 197.9 total feet was surveyed in ten shots using CF60–82. 49.1 feet was new survey, and 148.8 feet was redundant.

Aria, Leah, Tiffany, Sonia, and Steve began to survey from the New Mexico Room into the Ranger Room. A webbing hand-line was fixed at the short climb-up required to get into the room. They surveyed only two long shots going south before reaching a drop that will require about 100 feet of rope. A total of 105.3 total feet was surveyed in 2 shots using NMB7–8. 105.3 feet was new survey.

After dinner Derek, Steve, Marty, Hunter, Sonia, and Tiffany returned to the southern end of the room above Bottomless Pit. Permission had been granted by the Cave Resource Office to re-climb Liberty Dome, which had originally been climbed by Tom Rohrer and Ron Kerbo in 1976. There were reports of possible leads that had been left at the top of the dome, and a new higher quality survey was needed. The railing was crossed near Mirror Lake, and the team followed a wide, flat ledge that crosses the south side of Bottomless Pit. Eventually this ledge narrows and ends at the east side of a large overhang that guards the upper portion of the dome. A previously scouted line that follows the left side of this overhang was chosen to begin the climb (Figures 5 and 6). This line is approximately 40–50 feet left of the original ascent, which takes a more direct but steeper route. The climbing gear was organized and a bottom anchor was established on a large gypsum block on the ledge. Sonia belayed as Derek led the first 40 feet using direct aid techniques up the slightly overhanging wall. A 10 mm × 60 m dynamic rope was used for the lead belay, and a 9 mm × 230 foot static rope was trailed and used to rappel and ascend for cleaning pitches. Most anchors were ¼ inch diameter by 1.75 inch long Hilti Kwik-HUS screws with 8 mm aluminum hangers and a quickdraw. These require a very small hole that is nearly invisible, and the screws can be easily removed. They require a rotary hammer to make the hole and impact driver with 7/16 inch socket to place,

Figure 5. *Hunter Klein*

Figure 6. Derek Bristol in Liberty Dome. *Sonia Meyer*

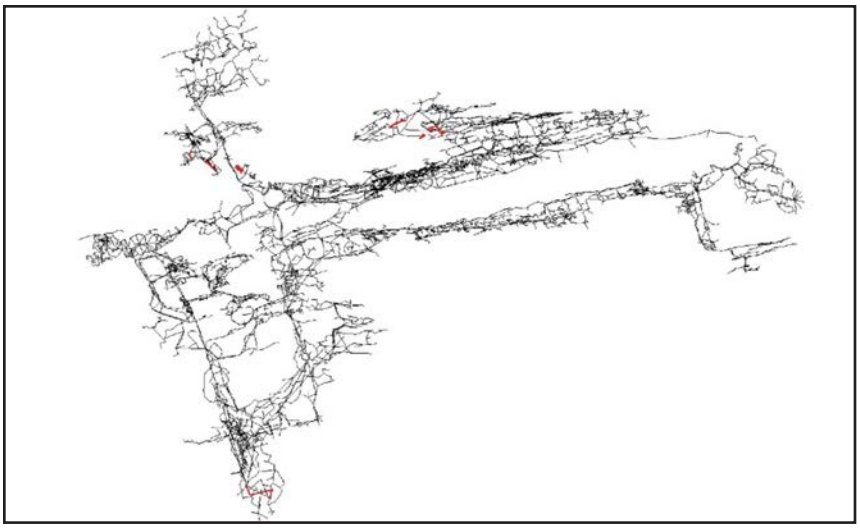


Figure 7.

but they are fast, low impact, and capable of holding a lead fall. On the first pitch every third or fourth anchor was a 3/8-inch by 3-inch stainless sleeve bolt for an additional safety margin; however, placing these requires changing the SDS bit in the rotary hammer and removing them is a fiddly process with a small pair of vice-grips. At the 40-foot level, a small roof is crossed to a shallow sloping ledge. From this point, the climbing route takes a sharp turn to the right and traverses this diagonally ascending ledge back towards the center of the dome. Due to the change in direction, and the availability of this sloping ledge, it was decided to set a belay anchor here to avoid rope drag later. A two-bolt anchor was set using the 3/8-inch sleeve bolts, and Derek rappeled back to the start of the climb on the ledge above Bottomless Pit. Because the pitch was overhanging, it could not be cleaned on rappel and required anchor removal while re-ascending the dynamic lead rope. All lead climbing anchors were removed except for one of the 3/8-inch stainless sleeve bolts that was about 25 feet off the ground. A significant amount of time was spent, but the bolt could not be removed, so the hanger and nut were removed and the stud hammered into the hole. Once the pitch was cleaned, the climbing gear was reorganized, and Sonia ascended the static rope to the two-bolt belay anchor and put Derek back on belay. Derek continued the climb by following the sloping ledge heading up and to the right using direct aid. After about six screw placements, a slightly lower-angled section of the wall allowed for about 50 feet of free-climbing to reach the middle of the dome. The final 40–50 feet of the pitch goes up a fairly vertical section of wall, and the original climbing route was intersected. The old 1/4-inch corroded steel bolts are evident. Direct aid was used again to climb the final vertical section of the wall to reach a lip and a lower angled slope above. About 10 feet up this slope, which was free-climbed, is a large breakdown block where a two-bolt anchor was set, and the two ropes were fixed. The slope continues above and is easy free-climbing to reach the ceiling level, but rope drag from the long previous pitch prevented going any higher. Derek rappelled and clipped the static rope through the lead climbing anchors and was able to return to the belay anchor with Sonia and they both rappelled to the ground. It was close to midnight and the team decided to return the following day to clean the upper pitch and complete the rigging.

The following day, Derek, Hunter, Steve, Marty, Sonia, and Tiffany returned to de-rig the long pitch and removed all the hardware used for the previous day's climb. Derek continued up and installed a permanent two-bolt anchor. A static rope was secured, and the lower two-bolt anchor removed. Derek and Sonia reascended the newly secured fixed rope and scouted the area for leads, but none were found. Survey of the area was left for the following night.

On the last night of the July expedition, there were again two teams surveying. Marty and Hunter continued to the New Mexico Room in an attempt to fix some bad loops in the NW corner of the Western Lower Maze. This proved difficult because several stations in the area appeared to be mislabeled. Additional analysis and a return visit will be required to sort out the problems. Derek, Sonia, Tiffany, Marty, Steve, Hunter, and David returned to Liberty Dome and surveyed it with two very long shots, and a number of splays (not included in the survey length) were used to improve accuracy. A total of 372.2 feet of survey was completed, 303.7 of it was new.

Figure 7 shows the plan view line plot of Carlsbad Cavern with the new survey in red.

A new team returned in November, consisting of Derek Bristol (CO, expedition leader, sketcher, climber), Steve Reames (CO), Marty Reames (CO), Aria Midice (NM, sketcher), Sonia Meyer (CA), Hazel Barton (OH, sketcher), Garrett Jorgensen (NM, sketcher), Kevin Manley (CO, sketcher), Jen Foote (NM), Amy Bern (CO), Carl Bern (CO, sketcher), Ben Smith (CO), and Kelli Housley (NM).

The primary goals for the November expedition were to continue working on surveying leads in the Guadalupe Room, New Mexico Room, and Chocolate High. In addition, several areas of the Guadalupe Room Complex were confusing and some resketch was needed.

The first day of survey had Derek, Sonia, Hazel, Kevin, and Jen going to the Mezzaanine in the New Mexico Room.

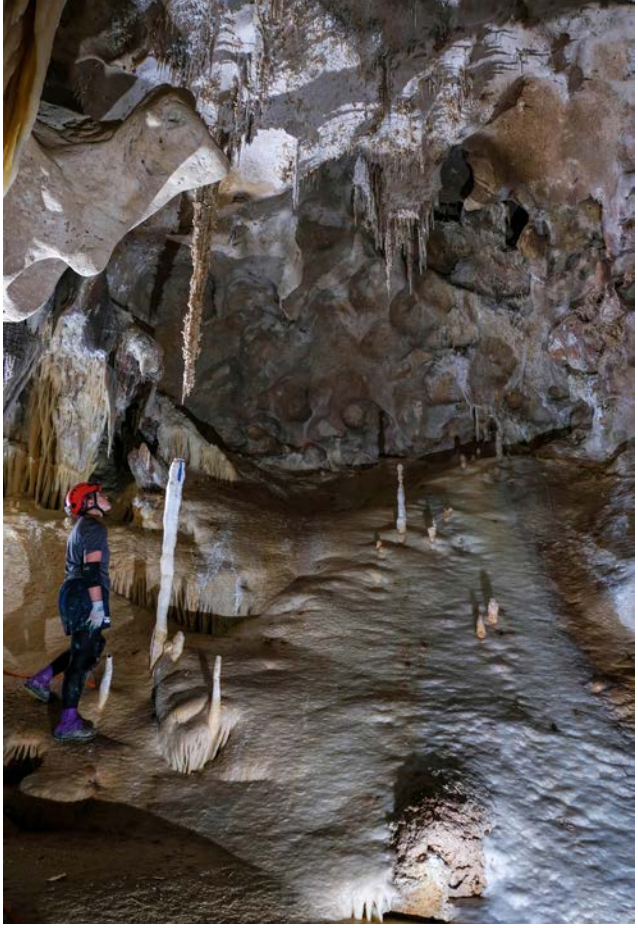


Figure 8. Aria Mildice in the Western Lower Maze.
Hazel Barton

Figure 9. Derek Bristol in Liberty Dome. *Hazel Barton*

Figure 10. Carl Bern in Liberty Dome. *Hazel Barton*

Hazel, Kevin, and Jen formed a team that checked leads and surveyed the pit connections down to the passage being surveyed by the second team. They finished all the boneyard leads near the bottom of the pit connection. Derek and Sonia surveyed part of the balcony leaving one small lead.

The following day, Derek, Hazel, Kevin, Jen, and Sonia split into two survey teams and picked off some of the leads in the Guadalupe Room Complex (Sand Passage and Los Cuates Room). One lead that Derek found was a meandering fissure that blows air but is covered with slippery mud. It may connect to Bat Cave

On the third day of the expedition (November 25), Derek, Sonia, and Hazel and went to a lead in Chocolate High via Chinille Basin. This lead was found to be an easy climb but without going passage. They surveyed what was there and then continued on to a low area to the north. The area is low and decorated and had been scooped but not surveyed. They surveyed 527.9 feet of new survey. Meanwhile, Kevin, Marty, and Steve went to the Ranger Room and rigged some webbing to make the climb safer. They surveyed into a room (Junior Ranger Room) to a drop at a fissure. They had no rope, so they stopped for the day after getting 124.6 feet of new survey.

Derek, Hazel, and Sonia formed one team for day four and went to the Sand Room on the west side of the New Mexico Room. They brought a 100-foot static rope to make a rope toss over a stalagmite on a ledge that is about 15 feet above the floor. Once ascended, they discovered that there was no going passage. They then surveyed down a small hole missed from the previous survey trip and this led to a window above the north wall of the New Mexico Room. Finally, they went to a passage that descends into the north end of Western Lower Maze (Figure 8) where they found no recoverable survey stations. Due to loop closure errors and inaccurate sketches, they started a complete new survey where they got 609.7 feet of survey.

A second team of Kevin, Steve, and Marty returned to the Ranger Room to the fissure, but this time they had rope to allow them to complete that survey.

November 27, the fifth day of the expedition, saw 853.2 feet of survey by Derek, Amy, Ben, and Garrett in the Western Lower Maze (west side of the New Mexico Room). Hazel, Aria, and Sonia also surveyed in the Western Lower Maze for a total of 381.4 feet of survey. Kevin, Marty, and Steve returned to the Ranger Room to a perched middle level. They found a pool and a back way into the Ranger Room while surveying 277 feet.

On day six, Derek, Ben, Garrett, Carl, Hazel, Kevin, Sonia, and Jen went to the top of Liberty Dome to scout for leads (Figures 9 and 10). They only found one that was six feet in length. They took a short video clip of a potential dig.

On November 29, day 7, Derek, Garrett, Hazel, and Sonia traveled to Left Hand Tunnel where Derek replaced the ropes and rigging at the north side of the room at BCH1. The team then surveyed into a tight fissure with good air flow. It got too narrow to continue after 5 survey stations. The team then went to the (Figure 11) Bell Cord Room climb, where the static rope had been removed. Sonia led with Derek belaying, and they reached the Bifrost Room that contained a high lead. They didn't have enough time to climb but left a static rope to the Bifrost Room for future survey. Kevin, Jen, Kelli, and Steve went to the Ranger Room and finished the survey and then continued surveying a fissure until a pair of pits. These were left as good leads. They also left a climbing lead after completing 229.5 feet of survey. Aria, Ben, Amy, and Marty surveyed to the Flower Gardens. After 443.6 feet of survey, they headed out for the day.

Finally, on November 30, Derek, Carl, Ben, and Aria went to Chocolate High to several leads that turned out to be either too tight or too fragile. Finally, they surveyed into a room with many leads and much to survey. After 763.3 feet of survey, they ran out of time. Hazel, Steve, and Marty returned to the Western Lower Maze where they surveyed to a pit and then around the pit, keeping to the same level. Some of the cave they surveyed seemed virgin. 474.7 feet were surveyed. Kevin, Jen, and Sonia went to the Chess Room and surveyed 270.9 feet before running out of time.

Figure 12 shows the survey (in red) accomplished during this expedition.

Figure 11. Sonia Meyer aid climbing in the Bell Cord Room, Derek Bristol belaying. *Hazel Barton*

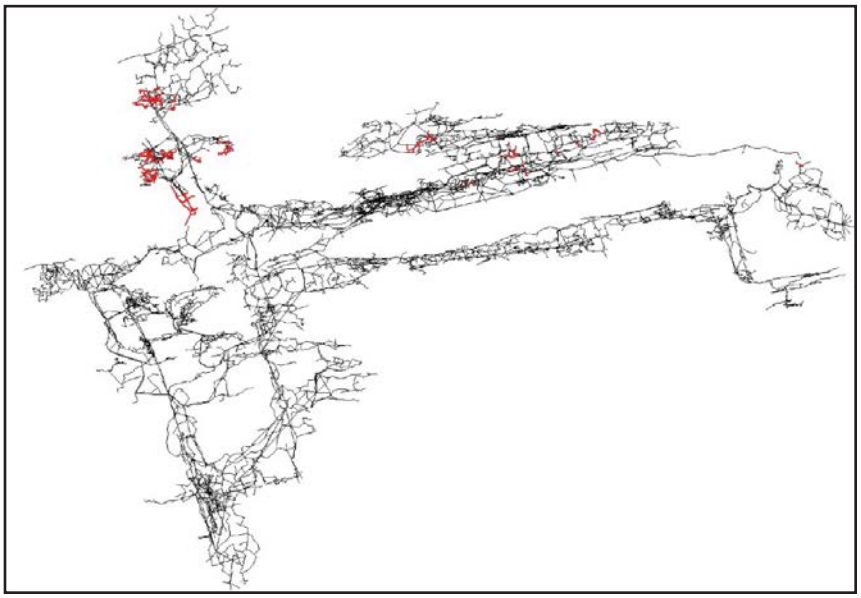


Figure 12.

Mystery Room Survey in Carlsbad Cavern

Dwight Livingston

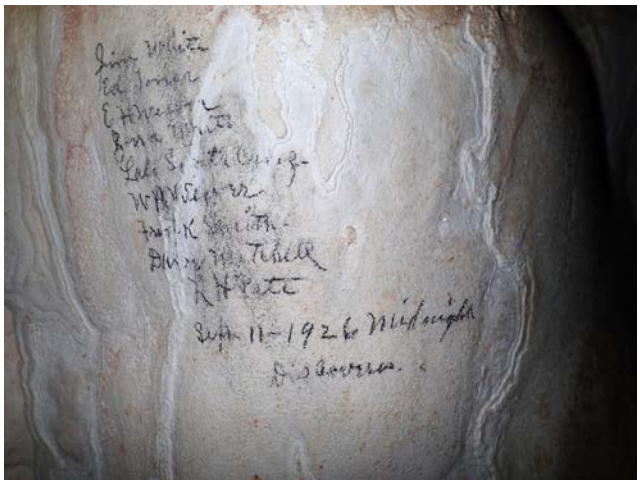
2018

The 2018 Mystery Room expedition took place in April, with survey trips made on the 8th, 10th, and 13th. Other expeditions—Carlsbad's Music Room and Lower Cave surveys, and Lechuguilla's Glacier Bay survey—shared personnel during that week. Roughly 450 feet of Mystery Room survey were added to the 8400 feet from 2007 to 2017. We connected to the Lower Cave survey, added a number of leads for resurvey, and sketched a great part of the western profile.

The Mystery Room is a section of Carlsbad Caverns. It connects to the western end of the Queens Chamber and to Lower Cave at a couple of places. For a more detailed description of the Mystery Room, see the 2017 expedition report.

Sunday morning we meet with Erin Lynch, Physical Science Technician at Carlsbad Caverns National Park. The meeting focused on John Lyles's Lechuguilla expedition, which Tim Bilezikian and I planned to join Monday and Wednesday.

Ghosts in the Mystery Room. *Mark Jones*



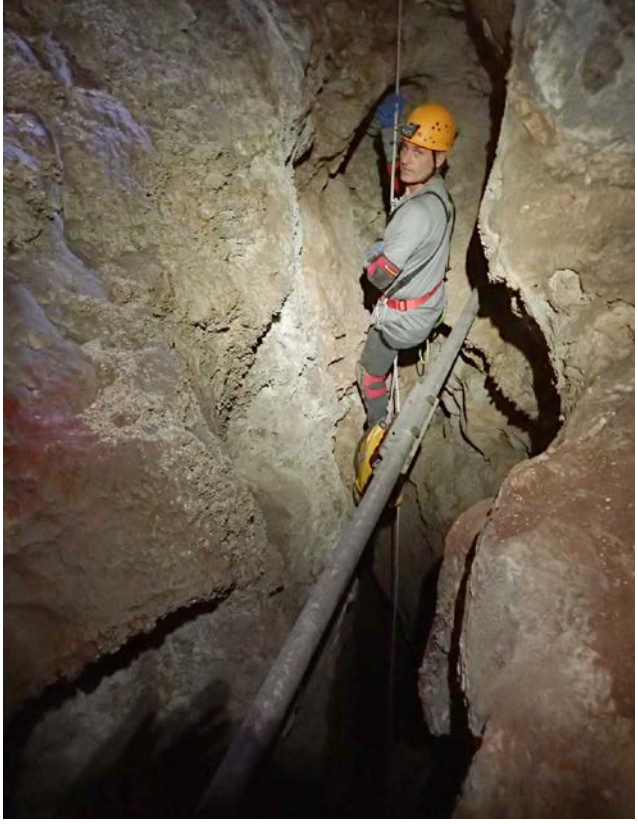
Jim White and others at H15B. *Mark Jones*

On Sunday, our first caving day, Tim, John, and I headed for the natural entrance (the elevators would not be available all week). We carried a couple of ropes, a 62- footer for the traverse, and a 120 for pit leads.

In the Queens Chamber, as usual, we hit a tour during their lights-out talk, though this time we managed to sit undetected on a bench by the trail until the tour started up again and threaded past. A woman near the back asked if she could take our picture. She did, and then with very little persuasion, she sat with us for another picture, a coil of rope on her shoulder, a helmet on her head, and a wonderful grin on her face.

We found the traverse up into the Mystery Room was already rigged. After the climbdown, we began our work, checking our working map (a 20-foot-to-the-inch scroll for both plan and profile) against the actual cave, looking for missing features. We identified plenty—the "Noel" high lead on the south wall, a deep slot that crosses the room past H6 and needs a rope, and just about the whole north wall, which wants a continuous survey and its own profile. At H11B, we decided we'd identified enough future work and started survey of a "deeper than 60ft pit" on the north wall. We rigged the 120 rope and completed about 180 feet of resurvey, what appeared to be the fourth survey into this charming little grotto.

Tuesday was our next Mystery Room trip. William Tucker joined Tim, John, and me on a trip where we hoped



Tim Bilezikian next to the pipe in the Cable Slot.

Dwight Livingston

to drop and survey the Cable Slot, find Mabels Room, and shoot a connecting shot down into the Mystery Room from a Mabels Room balcony. This proved wildly optimistic. Below Mabels Room, we placed old flagging tape on the head of a white stalagmite as a clear Disto target. We then rigged Cable Slot with the 120-foot rope, dropping in from the higher southern end. We considered moving the steel pipe that spans the slot (once used to hold power lines). It is not secure, and would make a mess if it fell, but it was easy to bypass on both rappel and climb. Given its iconic status, we decided to leave the pipe alone and survey past it.

Before that survey, I wasn't sure the slot even needed a rope, but indeed it does, dropping 70 feet between mostly aragonite-covered walls. We stopped to survey a small room about 45 feet down on the west side of the slot, and John pushed a little way eastward into boneyard leads, which we left for a future survey trip. At the bottom, we found a tall descending canyon that led us south, toward Lower Cave. The passage was said to cross over a deep pit, somewhere ahead, and perhaps it lay right before us, just past a couple of pitches. We had used up the 120-foot rope, so we tied the 62 footer onto the end and continued down the pitches. They turned out to be only modest drops, really just a sharp dip in the canyon passage floor. Farther south, where the passage floor climbed to a high point, we found station A7 (also known as XC8 and CFAD4), our connection to Lower Cave.

The other expeditions finished Thursday, and Friday morning most of the crew departed Carlsbad. Tim, Mark Jones, and I remained to do a last Mystery Room trip. I wanted to sketch the western end of the main profile using

William Tucker ready to drop the Cable Slot.

Dwight Livingston

Disto shots to get an accurate ceiling line. We saw more ledges in the ceiling near Mabels Room than I remembered seeing before, indications that a trip to Mabels Room may be a major effort. Mark took pictures of prominent columns and stalagmites, which I plan to use to detail the profile. We sketched down into the lower canyon, east to the pool at HA12, then back to the extreme west end of all Carlsbad Caverns at HA64, a nicely decorated room that ends with an unambiguous calcite choke. We exited early, leaving time to complete the expedition paperwork and get dinner in Whites City.

Much was accomplished this expedition, both in survey and planning future work.

Expedition Stats

Date	*Survey*	*Feet*
April 8, 2018	H11B–H11G	181.5
April 10, 2018	HB1–HB10	270.3
Total		**451.8**

2019

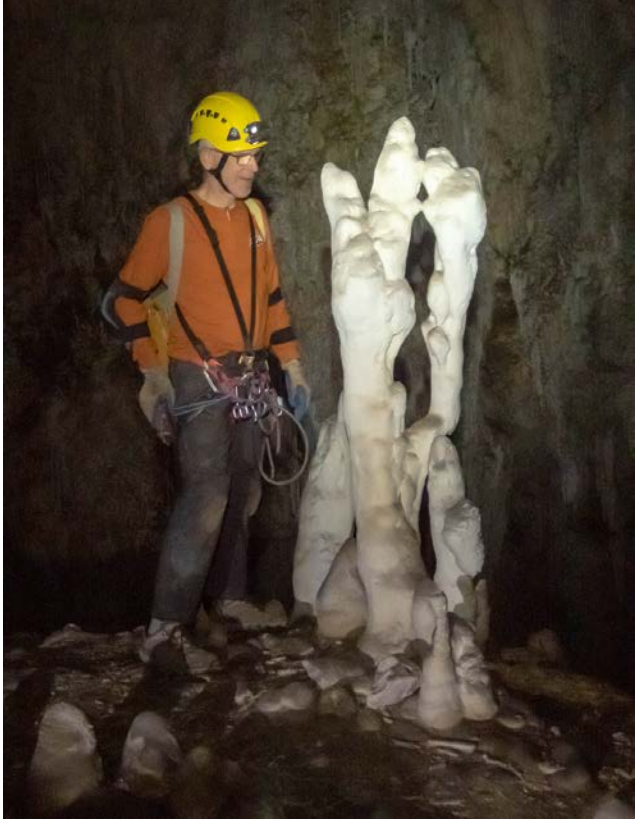
The 2019 Mystery Room expedition took place in April, with survey trips made on the 22nd, 24th, 25th, and 26th. We surveyed 1500 feet, of which 345 feet were new survey. A connecting shot was made to Mabels Room, and seven cross sections were measured and sketched.

The Mystery Room is a section of Carlsbad Caverns. It connects to the western end of the Queens Chamber and connects at two locations to Lower Cave. For a more detailed description of the Mystery Room, see the 2017 expedition report.

Tim Bilezikian John Lyles, Dave Socky, Tony Canike, and I supported both the Mystery Room and Glacier Bay (Lechugilla) projects. Due to new decontamination rules between caves, we brought dual sets of gear, kept them segregated and performed nightly wipe-downs of some hard-surface instruments. Disto calibration took up much of Sunday evening, using John's upgraded "Woodhenge" calibration course.

Monday morning, we met with Erin Lynch, Physical Science Technician at Carlsbad Caverns National Park,

Tony Canike showing the feed bag technique. *Dave Socky*



Dwight Livingston with crisscross stal. *Tony Canike*

for orientation, policy updates, and gear. Our two teams then left for the Mystery Room. No one used the natural entrance all week; instead, we took advantage of the new visitor elevators. We carried a 60- and a 120-foot rope, and again found the traverse off the Queens Chamber already rigged.

Dave, John, and Tony began a survey along the north wall and were immediately caught up in side leads and spent the day climbing and surveying spaces behind the north wall at H6, which lead them up onto balconies overlooking the main passage, as much as 60 feet above the floor where they started. The walls were filled with helictites and other speleothems, with plenty of bat bones, including a bat skeleton still hanging in place.

Meanwhile Tim and I studied the alcove at H2, where the DAT files show four "NOEL" stations placed up a short wall, which is steep, exposed, and decorated with popcorn and flowstone. Last year, I thought we might drape a rope behind stalagmites for protection, but after a close look, we felt there were too few stalagmites and that such a climb would be too destructive. We measured and sketched as best we could from H2, getting at least 70% defined, the rest to be assumed.

Wednesday, after a day at Lechuguilla, the expedition started at two new areas. Dwight, Tim, and Tony journeyed to Mabels Room, using a route through the Big Room and down into Lower Cave. Ed Klausner had sent me clear

Tim Bilezikian on the traverse above the Queens Chamber. *Dwight Livingston*

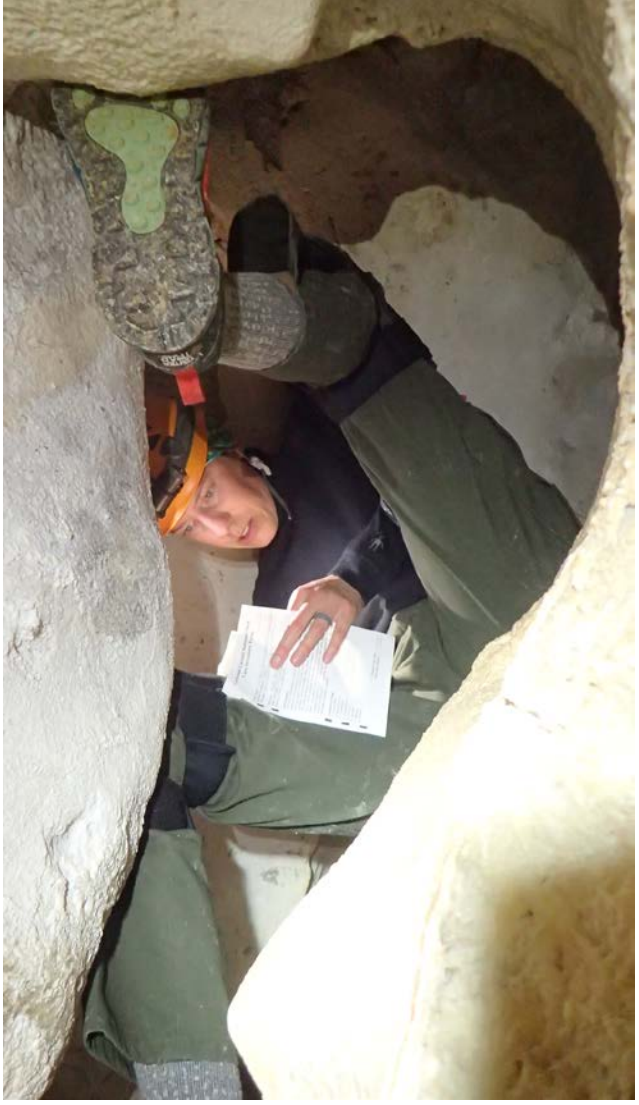
John Lyles pushing the Green Room lead. *Dave Socky*

instructions, which was fortunate, as I do not think I could have figured it out. Mabels Room is nicely decorated, worth a visit, and the window down to the Mystery Room is dramatic, a hole in the floor roughly 20 feet across, with a bedrock prow projecting eight feet toward the center. At its tip lay a small stone rapped in blue ribbon, station LB175, set there as the tie-in for Mystery Room. Last year, I'd set flagging tape on top of a stalagmite under the window, making an X for Ed's team to shoot. The flagging tape was old and stiff, and while we were elsewhere, it curled up and rolled away. This time we had used fresh tape tied around the ends, so we had a good target. We set a safety tether, made shots, and sketched. Across and above the hole are leads, possibly a route to other windows in the Mystery Room ceiling. A pulldown cord hangs from a hefty jug-handle, which might be employed to provide access to the hole above and perhaps across. It seems someone has been across. I would like to hear the story of that push, find any data from it, and maybe rig across the window next year. After sketching profiles, we retraced our route, ate at the Underground Lunchroom, shot a backsight to Mabels Room, and spent the rest of the afternoon setting stations and sketching to complete a Mabels Room cross section across the passage.

Meanwhile, Dave and John, joined by Jamie Moon and Katie Person, dropped Cable Pit and, halfway down, started surveying a new lead that John had noted last year, a boneyard passage across from the Telegraph Room. It took them through a hundred feet of passage, all apparently virgin cave, including the Green Room with its impressive blocks of montmorillonite and ending at a canyon drop that needs some rigging. Surveying the small and snaking passage took up most of the day, leaving only a little time for shooting photographs.

On Thursday, Tim and I returned to the slot at H6–7, finished our survey, and turned west to see how much of the north wall survey we might complete. We climbed up on some shelves (HE39) and surveyed the Mystery Pool room (HE40). The pool was noisy at times, quiet at others, turning on and off abruptly every few minutes.

On Friday, we again had two teams in the Mystery Room, one being Dave and Tony, who did an amazing amount of complex cross section sketching, a fine base for creating some "million dollar" cross sections in the Mystery Room map. Tim and I completed our survey of the north wall, which included some complex Disto work to create



Katie surveying in the Green Room lead. *Dave Socky*

plan-view sketches of ceiling windows located 80 feet overhead. The windows measure to be about 25 feet high, so one can easily imagine significant passage above the ceiling. In one place, at station H16C, we found a ceiling dome within one of the windows, which measured as high as 220 feet.

Again it seems one more expedition will complete the room. We expect to return next April.

Expedition Stats

Date	*Survey*	*Feet*
April 22, 2019	HD1–13	242.3
April 22, 2019	HE1–9	155.7
April 24, 2019	HE20–24	350.4
April 24, 2019	HBA1–11	102.5
April 25, 2019	HE30–41	253.2
April 26, 2019	HE42–44	395.6
Total		**1499.7**

Lower Cave of Carlsbad Cavern

Ed Klausner

2018

Before the start of the 2018 expedition at Carlsbad Caverns National Park, I had 75 leads plus a few re-sketches remaining in Lower Cave. I didn't expect much survey as leads have proven to be a few stations at most. As the lead list items dwindle, the difficulty of reaching the leads increases, and the number of leads knocked off per day decreases.

Karen Willmes labeling a station. *Ed Klausner*

Chris Beck climbing to a lead. *Mark Jones*

Dave West was working in the Music Room, Dwight Livingston in the Mystery Room, and John Lyles in Lechugilla Cave during this same expedition. Other surveyors (Elizabeth Miller, Karen Willmes, Mark Jones, Chris Beck, Jeannette Muller, William Tucker, and Tim Bilezikian) went with one of the cartographers depending on interest and ability.

The Central Boneyard of Lower Cave (Figure 1) contained many of the remaining leads and much of the expedition was spent in this area mopping up these small leads. A few proved too difficult to reach on what I thought was a good route, so time was also spent looking at the survey data to find an alternate route. In the end, we found alternate routes for all leads that we tried to reach, but not all the leads netted any survey.

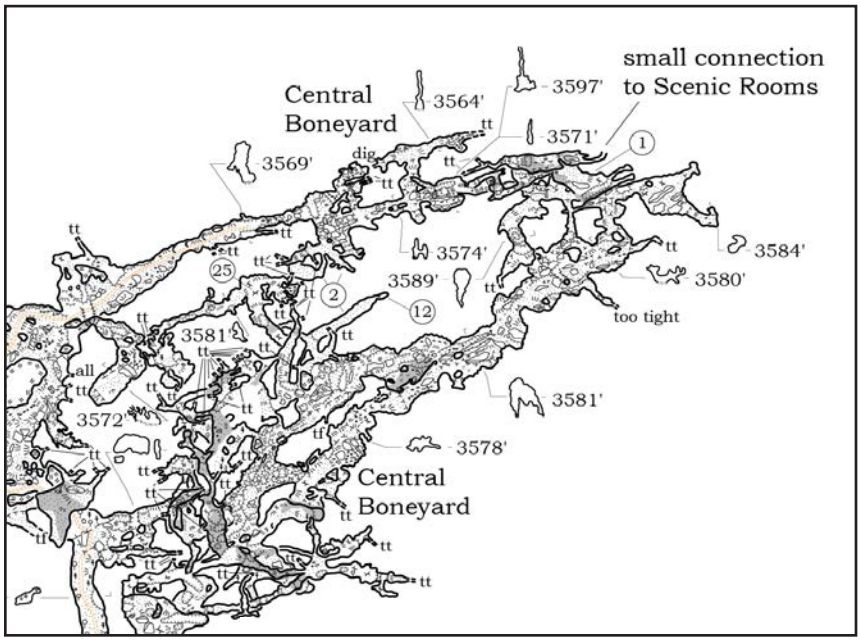


Figure 1.

One of the leads in the Central Boneyard led to the Scenic Chambers in the Main Corridor. It was one of those leads that was difficult to reach the way I had originally planned, but very easy, but long, by an alternate route.

Fortunately, there were some small surveyors (Karen Willmes and Elizabeth Miller) who were able to check some of the tight leads. A few of these leads went for two or three stations, and they are no longer on the lead list.

William Tucker, Elizabeth Miller, and Chris Beck with old flagging tape. *Ed Klausner*

One other area in which I had leads was Mabel's Room and on to Talcum Passage. We finished all the leads in this area and are now left with leads only in the area of the fixed ropes leading up to Mabel's Room.

We completed 27 leads and several re-sketches, and I was able to eliminate many additional leads once I understood that when a particular sketcher said the lead was too tight, it was indeed too tight. The total number of leads now is now down to only 23, which can hopefully be completed in one more expedition.

In addition to surveying, the park also asked us to replace some of the flagging tape on the long loop trail in Lower Cave because we'd been travelling back and forth along this trail getting to our objectives. We replaced about a dozen rolls of flagging tape and carried the brittle, older tape out with us.

2019

Dave West and I had a joint expedition to Carlsbad Cavern from February 25 to March 5, 2019. Dave was working on the Music Room, and he will report separately. We were joined by Elizabeth Miller, Karen Willmes, Chris Beck, Jeannette Muller, Mark Jones, and Paul McMullen. Survey teams were determined by interest and ability. We also wanted to make sure that Paul got to see lots of different parts of the cave as this was his first trip to Carlsbad Caverns.

I started the expedition with 23 leads remaining in Lower Cave. I had high hopes of finishing these leads and producing a final map. Note that this only includes leads that I can actually do. There is also a detailed list of "next generation" leads that are too delicate, too tight, requires drones, or requires digging. We did accomplish this goal and the map was produced a few weeks later.

For the first day, I needed climbers. Mark, Chris, and Paul joined me to survey some of the nine remaining leads along the route to Mabel's Room. The first was along the climb up to the fixed ropes. I was told this climb is the "Yellow Brick Road." At LB9D, there was a hole that was noted in the previous survey. We put in four shots and tied back to the tour trail. The lead that was along the tour trail was missed by that survey team.

The lead near the bottom of the fixed ropes was too small to fit through. Along the fixed ropes, there was a lead noted above the station (LB15). We could not safely reach this lead, but Chris climbed to the top of the fixed ropes and then worked his way through surveyed passage to a hole that was the same as this lead. We put in survey from a known station (LB82) to the hole (not surveyed and the passage not listed as a lead). We also continued past the window for three more stations.

The next lead was the boneyard off to the side of the top of the fixed ropes before the climb to Mabel's Room. At LB22, we put in two survey shots, the last was into a tube that was flagged off for bat bones. We found that LB17 was the other side of this small tube and we put in three shots that should line up with the survey done from LB22.

Finally, we put in four survey shots from LB20 and tied into LB35. We now had completed six of the nine leads in the area. The last three would have to wait for the next day.

Day two saw the same team return to the same area to finish the last three leads. The first was too exposed and had a steep slope, so it will find its way to the next generation lead list as a bolt or two would be needed.

Paul McMullen coming out of a lead. *Mark Jones*

Ed Klausner on book. *Paul McMullen*

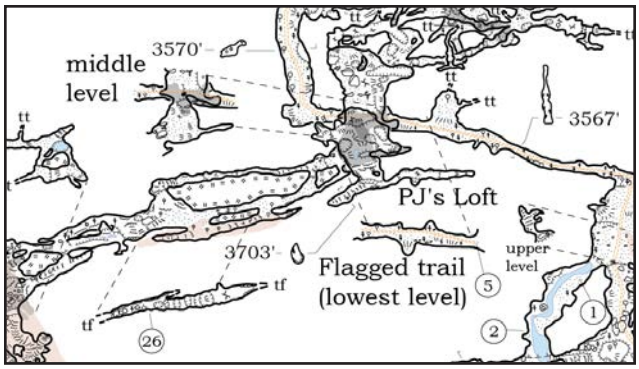


Figure 2. PJ's Loft.

We then found our way to the last two leads (LB139 and LB140). The route is through boneyard, and we were glad to have a line plot with us. The first led to six survey shots down two separate tubes. Finally, the lead at LB140 led to five survey shots before it got too small. Fortunately, Chris went around to where he thought the survey was going and saw Paul. He was at LB137 and looking through a small hole.

Finally, after finishing the LB survey, we dropped down to the tour trail and went to the overlook near Nicholson's Pit. Elizabeth, Chris, and William Tucker looked at this lead near the fixed ropes on a previous expedition and tied from LC156 to an old CFK survey. Unfortunately, we couldn't locate the CFK survey, so had to go back this expedition and put in two more shots until it got too tight to continue.

On day three, PJs Loft was our objective. There were 10 leads and we finished them all. Some were surveyed and some were put on the next generation lead list. We did find a new lead above LH67, about 12 feet up (3W × 8H) and we attempted to climb up to it. The rock was friable and we broke off what we thought was a good ledge. We left this for checking by a drone. Figure 2 shows PJs Loft and some of the surrounding area.

Three of the 10 leads were in passage that could be surveyed. On the first, we got 45.7 feet of survey (virgin passage), the second resulted in 86.9 feet of passage (also virgin) and the third 156.9 feet of passage (again, virgin). Near the end we found a tall canyon near LH59 that was about 50 feet up. We could not find a way up. Later that evening, I plotted the data and found it was below the Talcum Passage and the map showed pits there.

On day 4, which turned out to be the last day of the Lower Cave survey, Elizabeth, Karen, and Jeanette joined me in a trip to the LG survey near the Lower Cave tour trail. LG2 had a lead noted that required Aqua Socks. We brought them and put in two survey shots into a pristine alcove. Figure 3 shows some of the LG survey area.

The last lead was one that was marked as delicate, but I wanted to take a look at it. It's near the Stegosaurus. The route was small and delicate, and Karen and I were stopped when the passage got too small for us. Since it was marked as delicate, I don't feel too bad about not being able to check the last remaining lead.

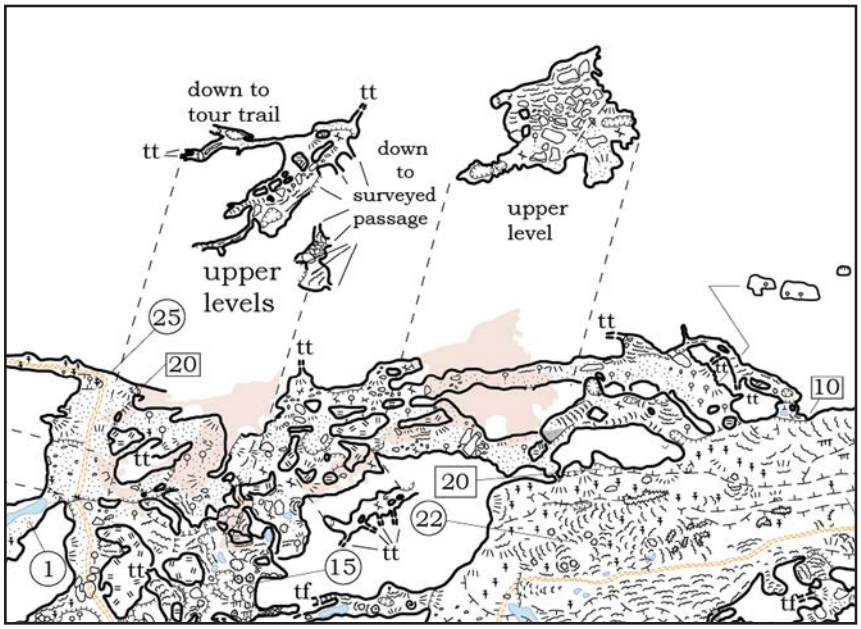


Figure 3. Some of the LG survey.

Music Room Expedition Report

Dave West

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

April 2018

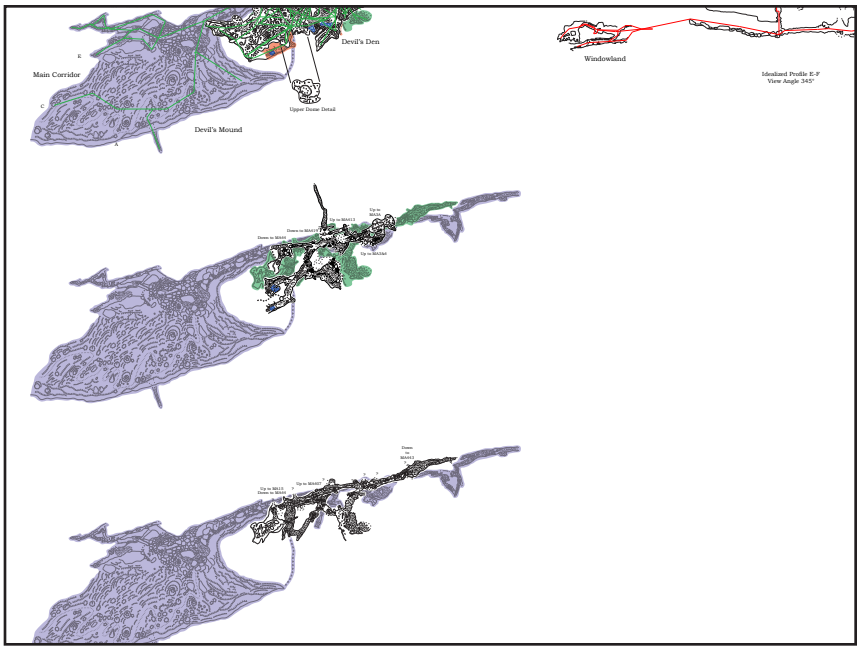
Building on last year's expedition, this year's plans were to complete as much of the Music Room level as possible and advance the other three levels to the extent possible. Participants included Karen Willmes, Jeanette Muller, William Tucker, Elizabeth Miller, Mark Jones, Ed Klausner, Chris Beck, Dwight Livingston, Tim Bilezikian, and myself.

On Saturday, April 7, Karen, Jeanette, William, and I proceeded to the beginning of the MA survey off the Main Corridor and validated the distances on MA1–5 while getting a profile along the ledge from MA2–5. We then moved on to MA8 to get a profile across the Music Room from there to MA24. Then after a lunch break, we went to MA10 and got a profile in boneyard from there along the MA414 letter series. With time remaining, we went to a lead Karen had observed at MA4A, a crawlway on a narrow ledge that was occupied by a large rock one needed to pass high above the trail in Main Corridor. It headed into the wall, and after four shots, it connected to another lead near MA4A. We ran out of time while sketching the last shot from MA904 back to MA900. When the ranger turned out the lights, we figured it was time to leave.

The following day Karen, Elizabeth, Mark, and I went to the previous day's last station at MA904 to finish up the sketch. We then ran a line to tie in to MA38, then surveyed two lower level routes into the Music Room before running out of time. There is more to do in this level. What previous surveys have identified as bedrock is actually a very large piece of breakdown. I saw occasional evidence of previous surveys, but they are not in the current database, so we had 189.35 feet of "new" survey and 55.85 feet of redundant survey for tie ins.

Sunday morning Jeanette, William, and I proceeded to MA9C and rigged a cable ladder and belay line down to a ledge with old light fixture remnants. I climbed down and verified that there is no lead at MA9D. We packed up and returned to MA909 to run a survey from it to MA906 for a profile. This took two shots, but it had me climbing around a bit to sort out what was going on. Then we proceeded to Devils Mound to sketch the shot from MA46–MA85 that nobody else had sketched. I began making corrections to the MA300 survey as well. We need to return to continue adding detail.

Monday's objective was to continue the profile from the Music Room to Devils Mound. I led Ed, Chris, and Jeannette to the Music Room provided with a 165-foot



A portion of the Music Room map by Dave West.

Tim Bilezikian checks leads in the Music Room. *Mark Jones*

tape, duct tape, a C-cell battery, and a walkie talkie. I then rejoined Karen, and we went down to the trail below the Music Room to monitor the tape as it was lowered. Where the tape hit the floor was noted and indicated the floor at that point was precisely 100 feet below the base of the rock on which MA24 resided. Unfortunately, this could not precisely line up with the profile line, but it gave us an indication of floor/ceiling at the location. The group reformed and proceeded to the top of Devils Mound. I led Ed and Chris to their objective, adding detail to the MA54–83 survey. After leaving Ed and Chris at the start of their objective, Elizabeth and I rejoined Karen and Jeanette. We obtained a number of shots to various points on the opposite wall, ceiling, and floor that helped identify the ceiling ledges in the profile, as well as the location of the floor below. The others finished up their re-sketch.

Our objective Wednesday was to finish the Music Room/Devils Mound/Devils Den Profile. After Elizabeth and I finished getting ceiling detail for the previous work, we departed from it to follow our general bearing of 50/230. As this took us past one of the undocumented "leads," we went ahead and surveyed it as well. After finishing up the profile in this direction, we headed back to the trail and set up a shot to the far side of Devils Den. We then took the final two necessary shots, sketched in the remaining detail, and called it a day.

I stayed on the surface Thursday to ensure everything I needed to supply the Park was ready to turn over before we left the following day. Dwight and Tim had been focusing on the Mystery Room survey, alternating with trips to Lechuguilla, and they also wanted to see the Music Room area. Mark led them to a lead he had poked into the previous year. They surveyed below MA3B8 and headed south to establish a perimeter to the area. This led to two balconies overlooking the Main Corridor. Continuing west and north, they connected to MA427. They also found and flagged an area of bat bones.

To summarize, remaining leads were surveyed in the Music Room level, and 575.4 feet of new survey was accomplished on the other three levels. A profile across Devils Mound, Devils Den, the Music Room, and the ledge where the section is accessed from the tourist trail was completed. The various profiles required an additional 1,829.31 feet of redundant survey. Leads down and east remain below MA3B8. An additional lead was observed on a ledge above Devils Mound that requires a 20-foot ladder to reach it. Much work remains in this section of Carlsbad Cavern.

February 25–March 5, 2019

Our goal this year was to focus on the Upper Mid-Level and the Devil's Hump Level of the Music Room Section. Participants were Karen Willmes, Ed Klausner, Elizabeth Miller, Mark Jones, Chris Beck, Jeanette Muller, Paul McMullen, and myself. We accomplished thirteen of our objectives in the Upper Mid-Level, and have four remaining there.

A profile over the center of the Devil's Hump was begun and tied to a chamber below the Music Room. A few loose ends on it will need clarification next visit. On the north side of the Hump are the MA300 survey of Windowlands and the MA100 survey of an area now called Osteoporotic Boneyard. In Windowlands, an effort to simply get more detail showed that much resurvey or re-sketch would also be required in this area. All of that was accomplished, as well as additional profile detail, and six of eight leads were eliminated or surveyed.

The Osteoporotic Boneyard proved to be much more extensive than expected from the old sketch, which is being replaced. I will not know how many leads actually remain until I get it drawn up.

Surveyed lengths:

- New survey: 929.1 feet
- Redundant survey: 553.75 feet
- Resurvey: 250.7 feet
- Total: 1733.55 feet

Some areas were simply re-sketched over existing survey.

Much work remains, and will likely take one, two, or even three additional expeditions. A new "Do List" will be provided prior to our next visit along with and updated version of the map.

Measuring Erosion of a Scalloped Limestone Cave Passage

Roaring River, Mammoth Cave

Rachel Bosch, Aaron Bird, and Dylan Ward

Introduction

The extent to which chemical dissolution and mechanical abrasion each contribute to the erosion of cave passages in limestone is an open question. In cave riverbeds that are mixed alluvial and limestone bedrock, we sometimes see clearly scalloped bedrock. The uniquely soluble properties of limestone imply that these scallops are the result of chemical dissolution. However, because we see silt, sand, and gravel deposits that shift in size and location, we infer that there may also be physical abrasion from sediment impacts on the scalloped bedrock surface. In this study we installed micro-erosion stations to measure the rate of erosion of the scalloped floor in Roaring River to learn more about the erosional processes that contribute to cave passage enlargement.

To investigate the time scales involved in karst limestone erosion, we performed repeat structure-from-motion (SfM) scans and established micro-erosion monitoring (MEM) stations on a sculpted bedrock surface of the St. Louis Limestone that experiences frequent submersion. The field area for this micro-erosion study is located past the end of Silliman Avenue, near the shore of Roaring River just upstream from its confluence with Echo River on the Main Cave map sheet of the Mammoth Cave System. This passage has a cross section of about 50 m^2 and is submerged approximately 60% of the time (Figure 1). The ceiling and walls are in the St. Louis limestone with light streaks in the otherwise dark ceiling that we interpret as tool marks (Figure 2). The floor of this stretch of Roaring River passage is heavily scalloped and the exposed streambed surface area at the field site is approximately 20% bedrock, 20% limestone breakdown blocks, and 60% alluviated by siliciclastic sediments of the thalweg and channel facies (see Bosch and White, 2018, for descriptions of siliciclastic facies in caves), although these percentages shift from one flood event to the next.

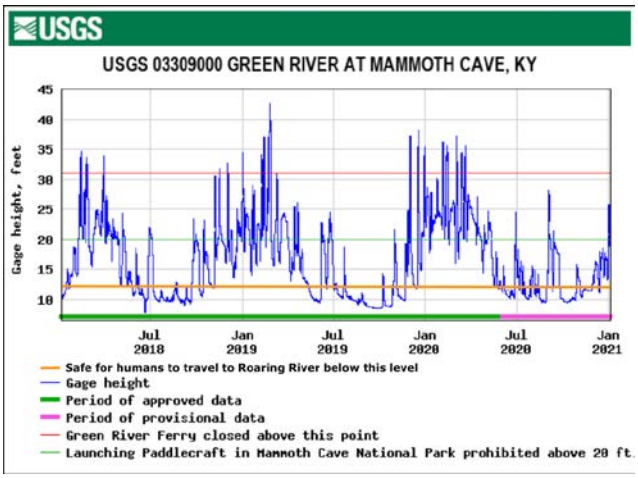


Figure 1. Three years of gage height data at the Green River Ferry, Mammoth Cave National Park, Kentucky (USGS, 2020).

Figure 2. Aaron Bird stands in the passage of Roaring River, which is sometimes flooded to pipe-full. Are those tool marks on the ceiling from gravel scaping the bedrock during a flood?

Methods

Hanna (1966) first described the usage of micro-erosion meters in cave settings. His approach has been implemented in several studies (e.g., Luritzen, 1986; Cucchi et al., 1987; Stephenson and Kirk, 1996; Muhammad and Beng, 2002; Allred, 2004; Gabrovšek, 2007, 2008; Furlani et al., 2008, Sanna et al., 2015). Gabrovšek (2009) and Stephenson and Finlayson (2009) used MEM in conjunction with pins set in bedrock in cave erosion studies and reported repeat precision to within 2.5 µm.

We are using a variation on that technique, with a

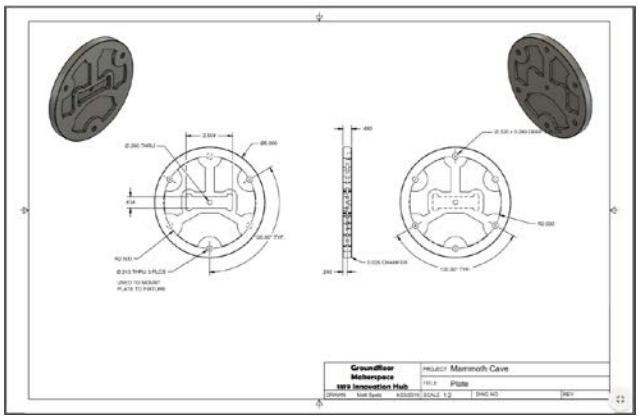


Figure 3. Micro-erosion meter plate design drawing by Matt Spetz.

Figure 4a. Erosion measurement in-action.

Figure 4b. Erosion measurement close-up.

precision depth micrometer held by an MEM plate designed for this project and custom machined by Matt Spetz at the University of Cincinnati Innovation Hub. The top side of the plate has one pocket to fit the depth micrometer. The bottom side has three small pockets to fit the pins that

Figure 5. Locations of Micro-erosion measuring stations in Roaring River passage, from left to right, top to bottom: RRMEM1, RRMEM2, RRMEM3, RRMEM4.

get installed at each field site. These are located 120° from one another. Halfway in between each of the pin pockets is a hole that goes through the thickness of the plate. The threaded rods that are installed at the monitoring site go through the holes, and wing nuts are used to secure the plate firmly into place before taking a measurement with the micrometer (Figures 3, 4).

In addition to measuring a single point at each monitoring station, we are performing repeat SfM scanning. As described by Gómez-Gutiérrez et al. (2014) and Smith and Vericat (2015), SfM scans repeated of the same surface with geolocation control can be used to measure the differences in surface position over time. Direct comparison of SfM and MEM measurements of the same site taken at the same times makes this study unique.

In the cave, site selection criteria included picking the fewest sites possible to represent the different hydrologic and sedimentological conditions that may occur in Roaring River (Figures 5, 6, 7). We chose two sites that are very close to the water when it is at base level (RRMEM1 and RRMEM3). These are likely to be submerged more frequently that the two downstream sites. Additionally, the scallops at RRMEM3 had pea-sized gravel in them. Sites RRMEM2 and RRMEM4 are less than 100 m downstream from 1 and 3, on a bedrock ledge about 1 m above the floor of the passage. RRMEM2 had a small amount of silt on it and in its scallops prior to bedrock washing and pin installation. RRMEM4 is in a location where a several-centimeter-thick layer of silt was removed prior to pin installation. At each station, RRMEM 1 through RRMEM4, we collected baseline data including a precise location survey (Figure 9) from known cartographic points in the cave using established cave survey techniques (Dasher, 2011), photographic images for SfM reconstruction of the surface, and the distance to

Figure 6a. RRMEM1 up-close.

Figure 6b. RRMEM1 up-close.

the bedrock using the MEM. For each MEM site, we took photographs for SfM documentation before pin installation. We then drilled holes and installed the pins and threaded rods using marine-grade epoxy. We seated the template on the rods during installation to ensure that the tops of the rods would coincide with a level plane. The template remained in the cave while the epoxy cured.

Since this field location is in the bed of a baselevel river, the erosion monitoring sites are frequently submerged. This makes it an ideal place to study erosion rates in a cave, but it also introduces a challenge with field site access. In an average year, water levels are low enough to reliably permit safe access intermittently from July through November. To account for the flooding hazard, we closely monitor USGS stream gages on the Green River at the Green River Ferry in Mammoth Cave National Park, and upstream at Dennison's Ferry in Munfordville, Kentucky (Figure 1). Since the Green River defines baselevel for its in-cave tributary,

Figure 7a. RRMEM2 up-close.

Figure 7b. RRMEM3 up-close.

Roaring River, these two gages indicate directly whether the erosion monitoring sites will be submerged. Furthermore, the approach via Silliman Avenue is safely above the flood zone, and when the water is high, Roaring River can be observed visually from this passage before researchers begin hiking down the sand bank toward river level.

Figure 8. Cavers! **Top left:** ***Aaron Bird, Rachel Bosch, Tyler Bosch-Bird, Zach Bosch-Bird outside the Elevator Building (2019);*** **top right:** ***Rachel Bosch, Chris Sheehan, Ron Manning, and Gerek Patrick at the shore of Roaring River (2019);*** **bottom left:** ***Bryce Belanger, Rachel Bosch, Aaron Bird, Ron Manning at RRMEM4 (2019);*** **bottom right:** ***Hannah Lieffring, Zach Bosch-Bird, Rachel Bosch, Tyler Bosch-Bird, Aaron Bird, Alec Matheus in Silliman Avenue (2020).***

Results

We have collected about one year's worth of MEM and SfM data. The differences in the bedrock surface that we measured (Tables 1, 2, and 3) are within the range of human measurement error and do not yet represent a sufficient data set to calculate long-term erosion rates. The preliminary data we present here is a baseline for a longitudinal study that we hope others will want to contribute to.

Future Work

Data for this project is available at the online data repository, Pangaea, in association with Bosch's Open Researcher and Contributor ID (ORCID), 0000-0002-8682-1816 (Bosch et al., 2019; Bosch et al., 2020). Specific in-cave station locations, SfM images, and MEM measurements will continue to be stored there and available for open access indefinitely. Investigators interested in collaboration to continue this long-term project are encouraged to contact the authors.

Acknowledgements

This study is being conducted in cooperation with Mammoth Cave National Park under National Park Service Scientific Research and Collecting Permits # MACA-2017-SCI-0019 and # MACA-2017-SCI-0020. Many thanks to Rick Toomey, Rick Olson, Barclay Trimble, Tim Pinion, Kurt Helf, for supporting this project at MACA, as well as Zachary Bosch-Bird, Tyler Bosch-Bird, Chris Sheehan, Gerek Patrick, Ron Manning, Bryce Belanger, Hannah Lieffring, Alec Matheus, Arthur Spoelman, Bill Spoelman, Seth Spoelman, and Heather Levy for all of your hard work in the cave.

A big thank you to Chris Anderson for filming my explanation of this project for the YouTube series, Science Around Cincy. The video, "Measuring Cave Erosion," can be viewed at https://www.youtube.com/watch?v=196_F9C6vgc&t=10s.

Site	Julian Date	Depth (inches)	Change in time (days)	Change in depth (inches)
RRMEM1	2458630.417	1.2075	0	0
RRMEM1	2458727.056	1.1500	96.638	-0.0575
RRMEM1	2458754.417	1.1520	124.000	-0.0555

Table 1. Roaring River Micro-erosion monitoring data for site RRMEM1.

Site	Julian Date	Depth (inches)	Change in time (days)	Change in depth (inches)
RRMEM2	2458633.097	1.6915	0	0
RRMEM2	2458727.056	1.6225	93.958	-0.0690
RRMEM2	2458754.417	1.6860	121.319	-0.0055
RRMEM2	2459035.146	1.6695	402.049	-0.0220

Table 2. Roaring River Micro-erosion monitoring data for site RRMEM2.

Site	Julian Date	Depth (inches)	Change in time (days)	Change in depth (inches)
RRMEM3	2458727.056	2.0735	0	0
RRMEM3	2458754.417	2.0640	27.361	-0.0095

Table 3. Roaring River Micro-erosion monitoring data for site RRMEM3.

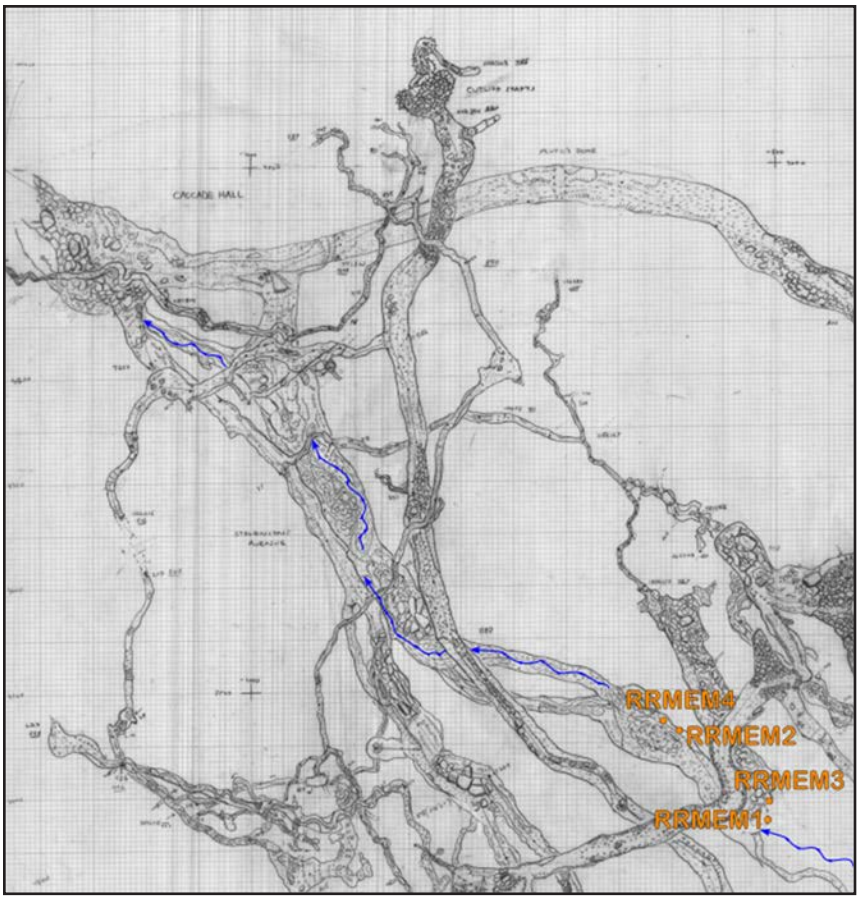


Figure 9. Relevant section of Main Cave map sheet (House, 1988). Micro-erosion station locations and blue arrows to indicate flow of Roaring River added by author.

References

Bosch, Rachel; Bird, Aaron; Ward, Dylan J (2020)**:** Micro-erosion meter images for structure-from-motion, Roaring River, Mammoth Cave, Kentucky, USA. *PANGAEA*, https://doi.pangaea.de/10.1594/PANGAEA.915420.

Bosch, Rachel; Ward, Dylan J; Bird, Aaron (2019): Micro-erosion meter measurements, Roaring River, Mammoth Cave, Kentucky, USA. University of Cincinnati, PANGAEA, https://doi.org/10.1594/PANGAEA.902223.

Bosch, Rachel F, and William B White. "Lithofacies and Transport for Clastic Sediments in Karst Conduits." In *Karst Groundwater Contamination and Public Health*, 277–81. Springer, 2018.

Dasher, George R. *On Station: A Complete Handbook for Surveying and Mapping Caves*. National Speleological Society, 2011.

Hanna, FK. "A Technique for Measuring the Rate of Erosion of Cave Passages." *Proceedings University of Bristol Spelaeology Society* 11 (1966): 83–86.

House, Scott. "Main Cave Map Sheet, Mammoth Cave." Mammoth Cave National Park, Kentucky: Cave Research Foundation, 1988.

Merideth, Johnny. "Vadose Zone Hydrology near the Vicinity of Edna's Dome, Mammoth Cave, Kentucky," 2009.

Moses, Cherith, David Robinson, and John Barlow. "Methods for Measuring Rock Surface Weathering and Erosion: A Critical Review." *Earth-Science Reviews* 135 (2014): 141–161.

Muhammad, Ros Fatihah, and Yeap Ee Beng. "Estimating Limestone Dissolution Rates in the Kinta and Lenggong Valleys Using the Micro Erosion Meter: A Preliminary Study," 2002.

Richardson, Keith, and Paul Carling. *A Typology of Sculpted Forms in Open Bedrock Channels*. Vol. 392. Geological Society of America, 2005.

Sanna, Laura, Jo De Waele, José Maria Calaforra, and Paolo Forti. "Long-Term Erosion Rate Measurements in Gypsum Caves of Sorbas (SE Spain) by the Micro-Erosion Meter Method." *Geomorphology* 228 (2015): 213–225.

Spate, AP, JN Jennings, DI Smith, and MA Greenaway. "The Micro-Erosion Meter: Use and Limitations." *Earth Surface Processes and Landforms* 10, no. 5 (1985): 427–440.

Stephenson, Wayne J, and Robert M Kirk. "Measuring Erosion Rates Using the Micro-Erosion Meter: 20 Years of Data from Shore Platforms, Kaikoura Peninsula, South Island, New Zealand." *Marine Geology* 131, no. 3–4 (1996): 209–218.

Stephenson, WJ, and BL Finlayson. "Measuring Erosion with the Micro-Erosion Meter—Contributions to Understanding Landform Evolution." *Earth-Science Reviews* 95, no. 1–2 (2009): 53–62.

USGS, Kentucky Water Data Support Team. "USGS Current Conditions for Kentucky." USGS 03309000 GREEN RIVER AT MAMMOTH CAVE, KY. United States Geological Survey. Accessed January 5, 2021. https://waterdata.usgs.gov/ky/nwis/uv?site_no=03309000.

Philip M. Smith Graduate Research Grant Recipients

2018 Grant Recipients

Amanda Vicente-Santos ($2,000)

Rachel Kaiser ($2,000)

Chelsey Kipper ($2,000)

Fernando Hernandez ($2,000)

2019 Grant Recipients

Morgan Smith ($2,975)

Pamela Hart ($2,000)

Anna Harris ($2,800)

Sarah Burgess ($2,325)

Sulfur Cycling in the Karst Aquifers of South-Central Indiana

Sarah Burgess

Introduction

The Mitchell Plateau is a classic karst landscape of south-central Indiana underlain by Mississippian age carbonates with interspersed layers of siliciclastics and evaporites. Drainage in the plateau is through extensive, epigenetic cave systems; surface streams in are generally short and ephemeral. Water-rock interactions and mixing water sources dictate the resultant geochemistry. This report will focus on my current thoughts on the role of sulfur in these systems.

This study includes work in two karst basins. The Bluespring karst basin is located northwest of the town of Mitchell. Recharge in this catchment is largely autogenic. Bluespring Caverns is a 34-km-long surveyed cave in this karst basin, and is Art Palmer's type example of a dendritic drainage pattern. Flow at Bluespring Caverns discharges in a submerged canyon on the bank of the East Fork White River. Adjacent and to the south of Mitchell, the 125-km^2 Lost River karst basin includes the largest sinking stream in Indiana and Lost River Cave, also with 34 km of surveyed passage. Groundwater flow roughly parallels the westward-trending regional dip and rises from the ground near the community of Orangeville. Recharge in the karst basin is a mix of allogenic and autogenic waters. In low flow, allogenic recharge sinks in the dry-bed of Lost River and flows through caves to the springs. In high flow, the dry bed is activated.

Stratigraphy

The spatial extent and the internal morphology of the Mitchell Plateau is guided by the outcrop of relatively-pure carbonates of the Sanders and Blue River Groups. The Sanders Group consists of the mixed carbonates/siliciclastics of the Ramp Creek Formation and the Harrodsburg Limestone, which limit involvement in regional karst aquifers, and the overlying Salem Limestone, dominated by fossiliferous carbonate grainstone that is a key unit of karst aquifer development.

The Blue River Group overlies the Sanders Group and is composed largely of carbonates with locally significant beds of gypsum, anhydrite, shale, chert, and calcareous sandstone. Regionally, the group includes the St. Louis, Ste. Genevieve, and Paoli Limestones. The St. Louis Limestone is a suite of shallow-water carbonate facies with cycles of lagoon, tidal flat, sabkha, and subaerial exposure. Downdip of the Mitchell Plateau, the St. Louis includes thick interbedded evaporites. In the outcrop belt, evaporite deposits

were thinner and were removed by meteoric groundwater. The Ste. Genevieve Limestone is composed of oolitic, skeletal, micritic, and detrital limestone with minimal dolomite. The lower 5–12 m contains significant chert, organized into regionally conformable beds. The Lost River Chert Bed in particular is an important stratigraphic marker and a hydrogeologic impediment to groundwater flow. The Paoli Limestone, the upper formation of the Blue River Group, includes four sub-members of carbonates and calcareous shale.

Methods

As part of a larger study of carbon systematics of karst groundwater in the Mitchell Plateau, we have been collecting bimonthly water samples and monitoring data from four field sites since early 2019. The sites are: Bluespring Caverns in the Salem and lower St. Louis Limestones, Flood Creek draining the soils and landscape near the town of Orleans, Wesley Chapel Gulf—a karst window in the lower Ste. Genevieve Limestone, and Orangeville Rise where water boils up from submerged conduits in the St. Louis Limestone.

Ion concentrations were measured using ion chromatography and ion-coupled plasma mass spectrometry at the Indiana State Department of Health. Sulfate concentration was measured on a HACH DR2700 Spectrophotometer using 0.45-µm-filtered water stored at 4°C until analysis. Sulfate was isolated from 1 L of filtered sample by acidifying to a pH of 3-4 with HCl and adding excess $BaCl_2$ to form $BaSO_4$ precipitate. This included a composite precipitation sample as an end member. The precipitate was collected on a 0.45-µm glass fiber filter and stored in individual sample bags inside a desiccator. The precipitate was loaded into silver capsules, combusted, and analyzed for $\delta^{34}S$ in a Delta V IRMS at Indiana University's Stable Isotope Research Facility. Samples with limited precipitate mass required analysis of sulfate trapped within the glass fiber filter and were shipped for special preparation to the University of Kentucky's Stable Isotope Lab.

Additional samples from gypsum in rock core at the Indiana Geological and Water Survey provide another possible end member. Gypsum bearing sections were identified, extracted, and dissolved in water. Sulfate was then isolated from the water following the above procedure. These sulfate samples were analyzed for $\delta^{34}S$ at Indiana University's Stable Isotope Research Facility.

Results and Discussion

Sulfate concentrations and isotopic data produced by these analyses provide key information about the circulation of groundwater and the sulfur cycle in the Mitchell Plateau. Figure 1 includes the time-series of selected ion

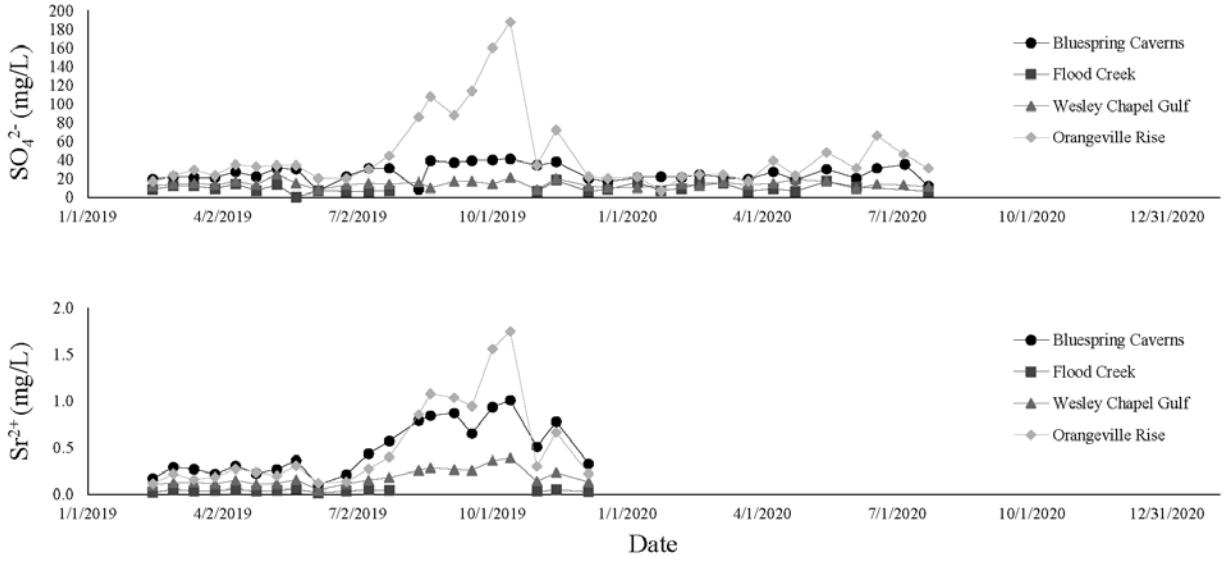


Figure 1.

concentration data. At Bluespring Caverns the $\delta^{34}S$ ranges between -0.559‰ and -3.086‰ (n = 8). At Orangeville Rise the $\delta^{34}S$ ranges between +4.763‰ and +11.676‰ (n = 9). At Wesley Chapel Gulf, samples returned $\delta^{34}S$ between +3.210‰ and +3.837‰ (n = 3). Core samples of regional gypsum produced $\delta^{34}S$ between +11.03‰ and +17.91‰. Remaining samples from all sites, including from Flood Creek and the composite precipitation, are currently in process.

Common sources of sulfate in groundwater include meteoric recharge and water-rock interactions. Our composite precipitation returned a sulfate concentration of 5 mg/L. Values at Flood Creek are similar, indicative of meteoric sources. Concentrations from other sites are mostly higher than this background due to geochemical reactions. At Orangeville Rise, samples during higher flow conditions have much lower sulfate concentration than during the dry season; sulfates continuously increase throughout the dry season of 2019 to a peak value of 188 mg/L and are directly proportional to strontium ($R^2 = 0.979$) (Figure 1). At Bluespring Caverns, sulfate concentration increases during the dry season to a plateau averaging 38 mg/L while the strontium concentration continues to increase beyond this plateau.

Previous isotope work at Orangeville Rise by Noel Krothe suggests that the spring outflow is a combination of shallow, primarily meteoric waters, and those that sink and travel along a deeper flow path where gypsum beds are encountered and dissolved. The observed continuous increase in sulfate concentrations throughout the dry season at this site supports this hypothesis by demonstrating that as the proportion of meteoric waters decreases and baseflow proportion increases, sulfate concentrations increase. Concurrently, the strong association between sulfate and strontium concentrations at Orangeville Rise provides another indicator that the baseflow component is related to evaporite dissolution reactions freeing strontium that was originally deposited as a trace component in sea water alongside the sulfates. Further analysis will include solubility/saturation modeling to better understand how gypsum dissolution affects carbonate flux.

Preliminary $\delta^{34}S$ values in the Lost River karst basin can be seen to agree with the proposed system. $\delta^{34}S$ at Orangeville are depleted with respect to regional $\delta^{34}S$ gypsum values, but enriched relative to those at Wesley Chapel Gulf. This indicates that the increased sulfates at Orangeville Rise must be coming from a source different than those at Wesley Chapel Gulf. Furthermore, $\delta^{34}S$ at Orangeville Rise became more enriched as meteoric input decreased

Figure 2.

from April to October, 2019. These trends suggest that the isotopic signature of sulfates at Orangeville Rise are the product of mixing between gypsum and meteoric sulfate. Once a $\delta^{34}S$ value is returned for composite precipitation, a mixing model for the spring can be defined from this data.

Sulfate concentrations and $\delta^{34}S$ analyses in Bluespring karst basin suggest another different sulfur source. $\delta^{34}S$ values at Bluespring Caverns are much more depleted than any other sample analyzed in this data set. In spring of 2020, a tour guide at Bluespring Caverns mentioned having seen a natural sulfur seep in the cave. The siting was confirmed on March 7, 2020, and is pictured in Figure 2. In a preliminary test, the seep water was shown to have significant concentrations of sulfides. Seeps of this kind in the Bluespring karst basin could explain the plateaued concentrations of sulfates coming from a reduced source of sulfur that is limited by seep discharge instead of evaporite solubility. Biological fractionation, like that associated with microbial sulfur metabolism, can cause depletion of $\delta^{34}S$. These sorts of processes are expected at a reduction-oxidation interface like a sulfur seep.

The preliminary results of our investigations have already yielded insight into the diverse role of sulfur in the karst of the Mitchell Plateau. Sampling and sample analysis will be ongoing through this summer and fall to corroborate the trends observed in the dry season of 2019. Additionally, sulfide samples will be collected from Bluespring Caverns and Orangeville Rise to quantify what we now recognize is a critical part of the sulfur cycle in the Midwest. $\delta^{34}S$ analysis of the remaining samples already collected is currently in progress at the University of Kentucky and will be incorporated into future reports.

Final Report

Anna Harris

I wish to extend my sincere thanks to the Cave Research Foundation for granting the 2019 Philip M. Smith Graduate Research Grant for Cave and Karst Research to my thesis project. This grant made a crucial contribution to the completion of my research. The objective of my research was to collect data that would characterize the impact that timber harvest and land management practices have on karst systems in southeast Alaska. My research was conducted on Prince of Wales Island in the Tongass National Forest from June through November 2019. During that time, I collected data that is being used to characterize the hydrogeochemistry of two temperate rainforest (old-growth and second-growth) karst systems and compare dissolution rates in the different canopy settings.

The funds from the CRF were used to purchase vital equipment: Davis AeroCone rain collectors, HOBO Micro Stations, HOBO pressure transducers, calibration buffers, site setup materials, and other various water sampling supplies. The value of these resources cannot be underestimated, especially given the challenges inherent in managing the remote logistics, extreme weather conditions, and the challenging terrain of the study area. The funds allowed for the research team to be able to modify and customize the installation so that the instrumentation was robust enough to stand up to the rugged Tongass rainforest.

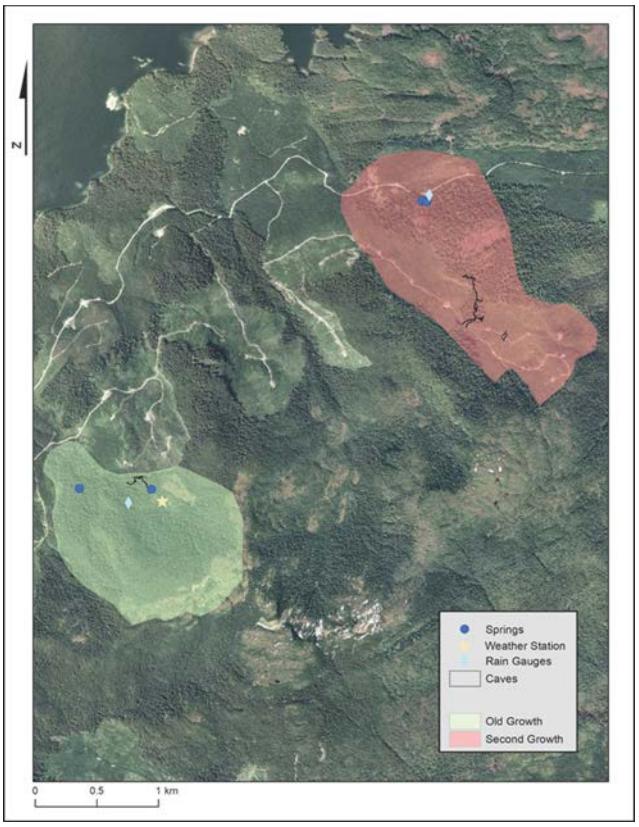


Figure 1: Study sites in the Twin Peaks Mountain Watershed. The springs (blue) are where multiparameter water sondes and pressure transducers were installed. Note the different canopies between the two sites (old and second-growth).

Figure 2:* (a) *Sub-alpine weather station,* (b) *old-growth rain gauge station, and* (c) *second-growth rain gauge station.

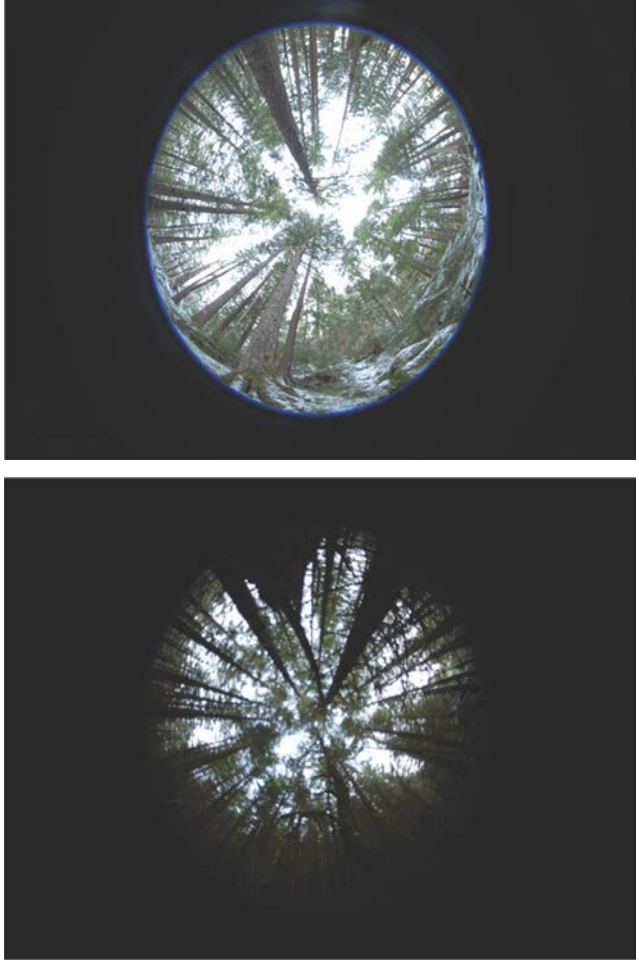


Figure 3: Pictured above are the two varying canopies, the photographs were taken looking up, with a fisheye lens directly above the rain gauge locations. These photos help characterize the differences between old-growth **(top)** *and second-growth* **(bottom).**

Three sites in the Twin Peaks Mountain Watershed in Staney Creek were chosen based on their varying canopy densities (Figure 1). The selected sites included an old-growth and second-growth forest, both over karstic basins. Walkabout Cave was chosen as the old-growth site and Zina Cave was chosen as the second-growth site. The third site was in a sub-alpine muskeg, where there is no canopy cover (Figure 2 and 3). The muskeg site is adjacent to Walkabout Cave.

Multiparameter water quality sondes and pressure transducers were installed at a point of insurgence for Walkabout Cave, and one point of resurgence for Walkabout Cave, and a point of resurgence for Zina Cave (Figure 4). The sondes and pressure transducers collected high resolution data (10-minute intervals) for temperature, pH, SpC, and water level. Grab samples were also collected at these locations for cations (Ca^2+ and Mg^2+) and alkalinity (HCO_3^-), which were utilized to statistically develop a relationship with geochemical parameters and to calculate dissolution rates within the karst systems at high-resolution. Rain gauges were installed in both the Walkabout and Zina karst basins to measure throughfall in the different canopy settings. A weather station was installed in the sub-alpine muskeg and recorded net precipitation, temperature, and barometric pressure.

Results from this research show the uniqueness of karst systems in southeast Alaska, even those in close proximity to one another. Major contributing factors that varied from site to site include canopy throughfall, the result of land-management practices; topography; and local geology. Additionally, seasonal fluctuations were found to show moderate change, due to the temperate rainforest environment. However, the rainy season, which typically starts in July in the Tongass, instead began mid-September in 2019, which may indicate a trend toward greater volatility in precipitation. This trend may influence long-term geochemical changes, since the studied systems showed a greater reaction to rain intensity, for example, during storms, than to overall precipitation. As predicted, each site received different amounts of precipitation through the treetops, as measured by our rain gauges under each of the three canopies (Figure 5). In general, the rain gauge installed in the open muskeg received (836 mm) nearly one and a half times as much precipitation as the old-growth site, which received (598 mm) over two times as much precipitation as the second-growth site (266 mm). However, future research would benefit from more robust precipitation data to confirm these findings.

A good example of the influence of local geology on geochemistry is Walkabout Cave, located on the edge of a muskeg in the sub-alpine and in an old-growth forest. Of particular interest is the calcareous till blanket, underlying the muskeg, where the majority of the water pools before it insurges into Walkabout. Previous studies have characterized muskeg waters in this region to have extremely low pH, generally the acidity largely contributes to rapid cave formation in adjacent carbonate areas. However, the calcareous till buffered muskeg water at the insurgence of Walkabout Cave, which resulted in slightly basic waters (average pH of 7.5) entering the cave. Water at the resurgence was slightly more acidic (average pH of 7.2) than the insurgence. Lower pH numbers at the resurgence can be attributed to other inputs of high CO_2 water into the cave downstream of the insurgence. However, similarities in the geochemistry between the insurgence and resurgence may be attributed to the lack of storage in the system. SpC and pH behave similarly at the insurgence and resurgence, with dilution occurring during rain events. The SpC values at the insurgence had an average of 80.5 µS/cm and the resurgence average was 106.8 µS/cm. The temperature average for the entire system was 7.1 degrees Celsius (Figure 6 and 7). Due to the topography and geology of the area, water flows through Walkabout Cave quickly, leaving little time for chemical changes to occur.

Nearby, located in the second-growth forest, the Zina Cave baseflow spring shows different geochemical

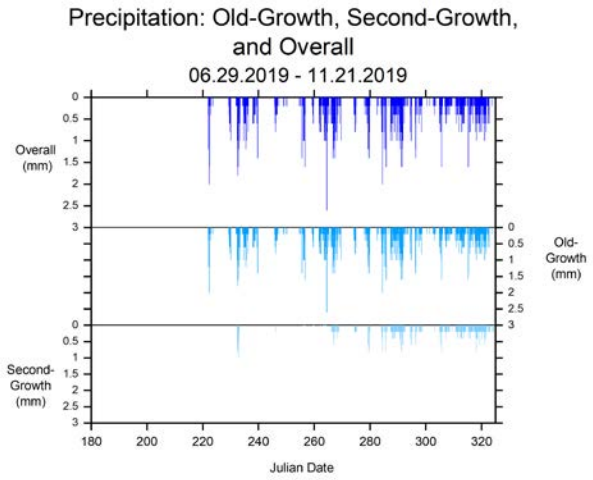


Figure 5: Precipitation from all three sites. Overall: Muskeg site, Old-growth: Walkabout Cave site. Second-growth: Zina Cave site.

responses than Walkabout (Figure 8). Geochemically, the Zina baseflow has an average pH of 8, an average SpC of 183 µS/cm, and temperature averaged at 5.7 degrees Celsius. The lack of dramatic responses may be attributed to longer water/rock time interaction that occurs in Zina due to its larger size. Zina likely has some storage, which is flushed through the system during storms, shown as rapid increases in pH following large storm events.

The Palmer dissolution equation was applied to both karst systems to calculate wall retreat in mm/yr. The estimated average dissolution rate was 0.75 mm/year at Walkabout Insurgence, 0.76 mm/year at Walkabout Resurgence, and 0.17 mm/year at Zina Baseflow. Little variation in dissolution rates between Walkabout Insurgence and Resurgence shows that water flowing through Walkabout Cave does not evolve much as it flows through the karst system. Dissolution rates at the resurgence are slightly higher than the insurgence likely due to another input along the flow path. Dissolution at Zina Baseflow is about one-fifth that of dissolution at Walkabout. Lower dissolution rates at Zina Baseflow may be due to the size of the Zina karst system. Due to the spatial distribution of the Zina Cave and Zina Resurgence, the karst system is assumed to be larger than the Walkabout karst system; therefore, waters discharging at Zina baseflow are likely buffered with respect to waters discharging at the Walkabout Resurgence. Additionally, canopy cover is thicker in the Zina karst basin (second-growth forest) compared to

Figure 4: Stilling wells at the following study sites: **(a)** ***Zina Cave baseflow,*** **(b)** ***Walkabout Cave insurgence,*** **(c)** ***Walkabout Cave resurgence.***

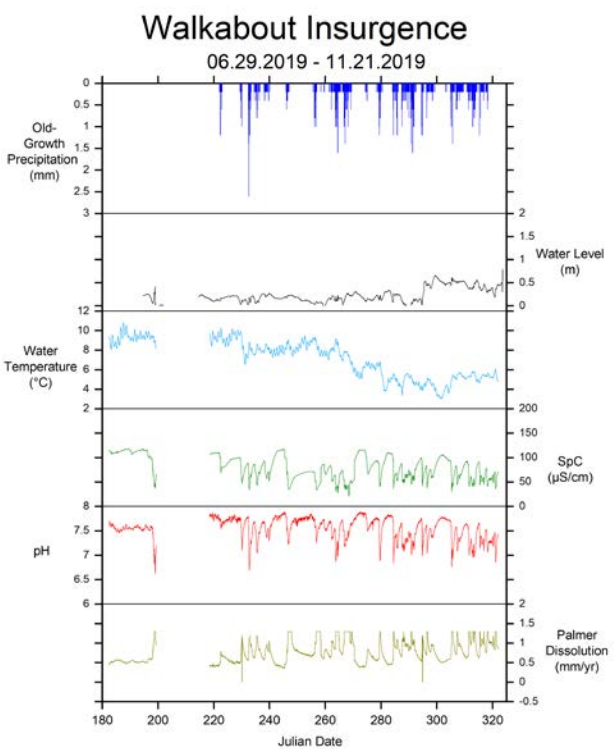


Figure 6: Walkabout insurgence geochemical graph for the duration of the study.

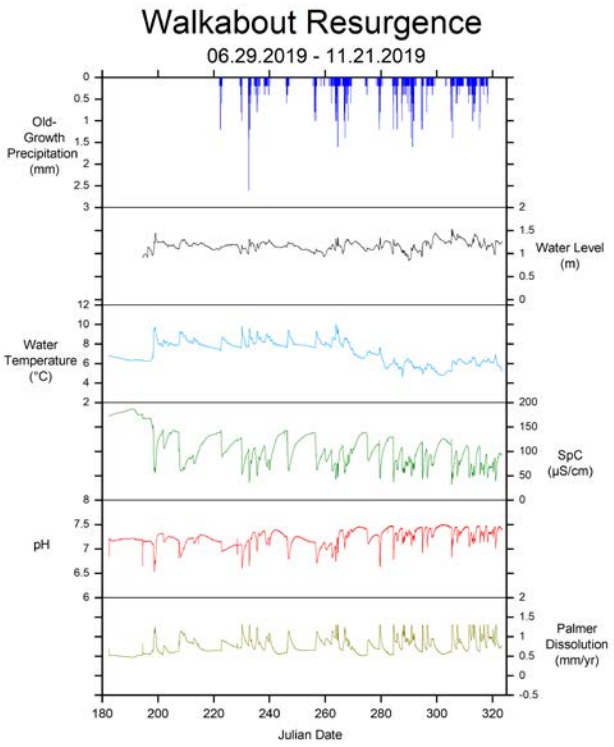


Figure 7: Walkabout resurgence geochemical graph for the duration of the study.

the Walkabout karst basin (old-growth forest), where the canopy is more dispersed. A thicker canopy cover limits the amount of throughfall and infiltration, and ultimately vegetation growth in the understory. Therefore, these conditions limit the amount of aggressive water, containing dissolved soil CO_2, into the Zina karst system.

It is challenging to make any definitive correlations between precipitation and geochemistry data, due to the time constraints and equipment limitations of the study. However, these two contrasting systems provide good baseline geochemistry data and some insight into the interaction between southeast Alaska karst systems, land management, and dissolution rates. This research can serve as baseline knowledge for the US Forest Service to assist in land management decisions on karst lands. This is a valuable contribution to the few karst studies that have been done in the Pacific Northwest, especially in a time where land management practices and climate change is altering these ecosystems. Results from this research form the basis of my master's thesis in support of my graduate degree and will be submitted for publication once my thesis is complete and results are further analyzed. Thank you again for your invaluable support and the opportunity to learn how to conduct my own research.

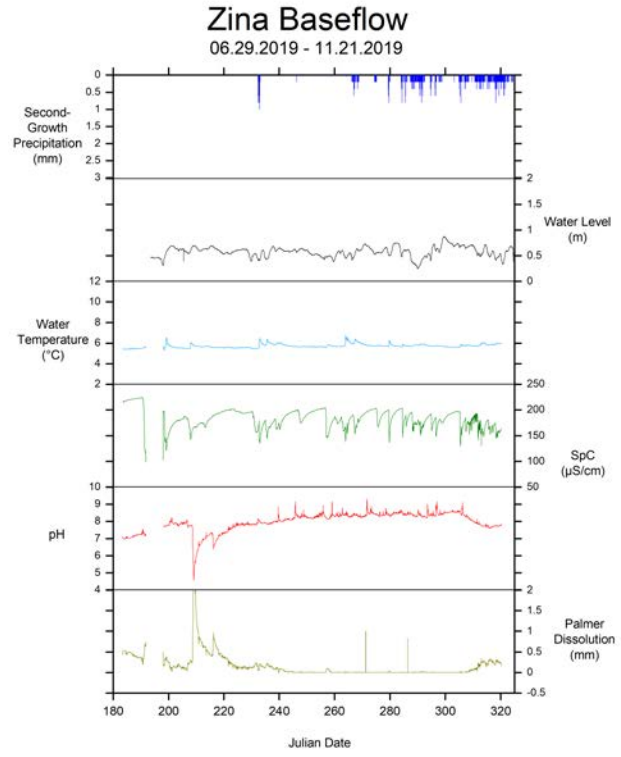


Figure 8: Zina baseflow geochemical graph for the duration of the study.

Population Genomics of a Cavefish Species Complex

Implications for Conservation and Aquifer Connectivity

Pamela B. Hart

Louisiana State University

Project Description

Aquatic cave-obligate organisms are difficult to monitor due to cryptic diversity (genetic lineages that do not show physical differences) and unknown cave and water connectivity. These animals are at immense risk due to anthropogenic impacts on the health of the groundwater they inhabit. I proposed to use Next Generation genomic sequencing to examine the diversity and genetic connectivity of one of the widest ranging cavefish species, the Southern Cavefish. Multiple genetic lineages of the Southern Cavefish have been reported as high conservation concern; however, lineage ranges and connectivity are still not well understood. To examine genetic structure and relatedness among Southern Cavefish genetic lineages, I harvested Single Nucleotide Polymorphisms (SNPs) from Ultraconserved Element loci. My null hypothesis was that there is no genetic differentiation within the Southern Cavefish (i.e., one species). I tested the alternative hypotheses that: 1) a single cave is a lineage or 2) multiple caves comprise a lineage.

Methods

I collected tissues from cavefishes across the range in the Southeastern U.S. and the Ozarks. With funding provided by the Cave Research Foundation, I acquired 82 cavefish tissue samples from 40 cave localities (Figure 1). I collected representatives from each previously hypothesized lineage in the Southern Cavefish (*Typhlichthys subterraneus*) as well as its sister species, Eigenmann's Cavefish (*Typhlichthys eigenmanni*).

I then collected genetic sequences and performed further population genomic analyses. I used the PHYLUCE pipeline (Faircloth et al. 2015) and the seqcap_pop pipeline (Harvey et al. 2016, respectively) to identify and isolate 976 Single Nucleotide Polymorphisms (SNPs). STRUCTURE (v.2.3.3) was used to infer the ancestry of individuals using a model-based clustering method (Pritchard, Stephens, and Donnelly 2000). I visualized STRUCTURE output using STRUCTURE Plot (v 2.0; http://omicsspeaks.com/strplot2/). I used STRUCTURE Harvester to identify the best *K* value (*K* 2- 13*;* Earl and vonHoldt 2012).

Results

Current results suggest three genetic clusters within the Southern Cavefish. These results support the second alternative hypothesis: multiple caves comprise a genetic

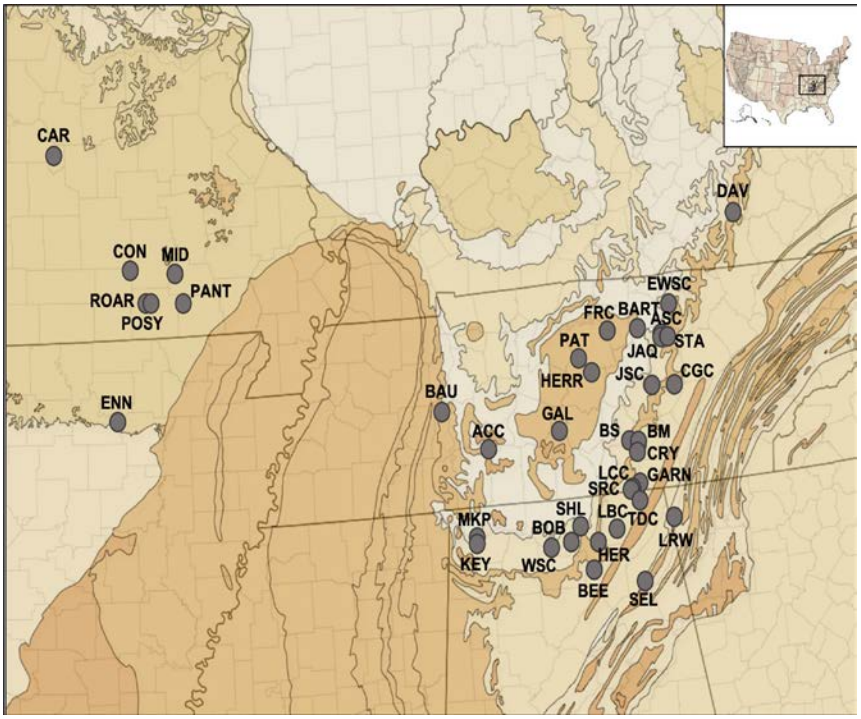


Figure 1. Sampling map of the genus* Typhlichthys *across several North American karst aquifers in the southern United States. The light brown colors show modern karst aquifer boundaries.

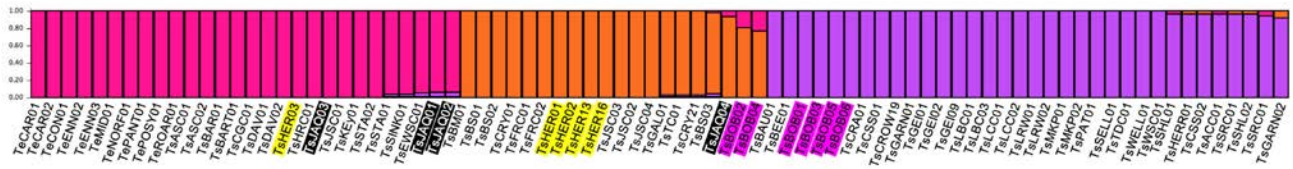


*Figure 2. STRUCTURE plot of the Southern Cavefish (***Typhlichthys subterraneus***, Ts) and Eigenmann's Cavefish (***T. eigenmanni***, Te) created using the estimated optimum cluster value of* $K = 3$ *and colored by each population cluster. Each bar indicated the genetic composition of one individual sample. Individual labels are coded by species, locality, and identification number. Individuals from caves assigned to multiple genetic clusters are highlighted in yellow (Hering Cave), magenta (Bobcat Cave), and black (Jacque's Cave).*

lineage. In three cases, individuals from the same cave grouped with different genetic clusters (Figure 2). This result may be due to gene flow among caves and lineages or there may be multiple lineages in a single cave. Further testing needs to be done to determine which of these scenarios is most likely.

I examined the evolutionary relationships geographically and found that some of the Southern Cavefish in Tennessee and Kentucky are more closely related to Eigenmann's Cavefish found in the Ozarks than they are to other Southern Cavefish even in the same state (Figure 3). Previous examinations have found genetic structuring based on geographical boundaries (Niemiller et al. 2012). Further examination is needed to determine if the genetic structuring found through STRUCTURE shows geographic patterns. Though not complete, this project already shows novel relationships among the Southern Cavefish lineages and shows the complex evolutionary history of cave-adapted organisms. Multiple genetic lineages in a single cave or gene flow among caves are two interesting possibilities that could suggest more connectivity between caves than previously thought.

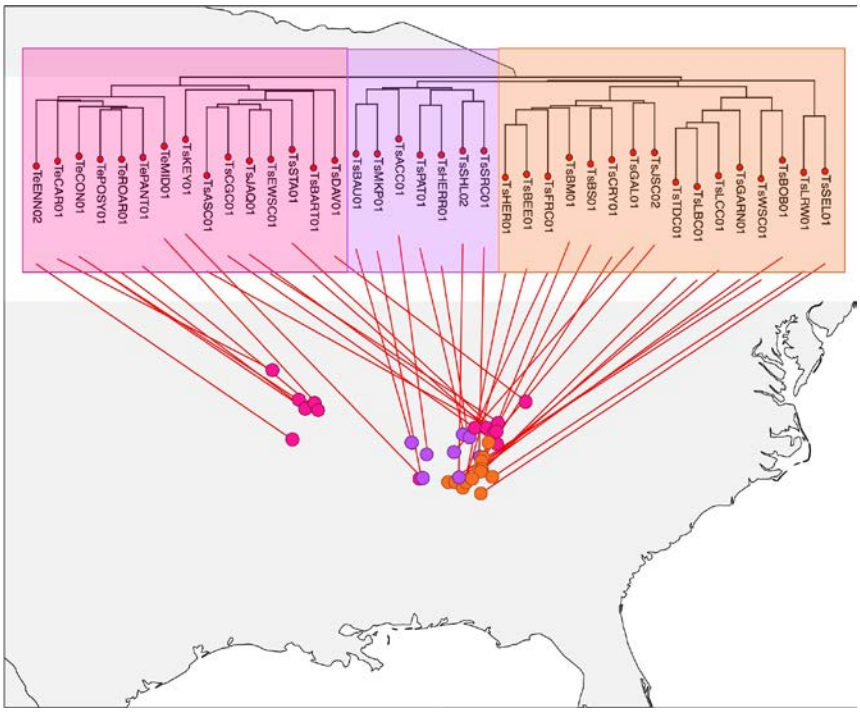


Figure 3. Phylogenomic tree plotted onto the sampling map of the Southern Cavefish with Phytools (v.0.6). Large colored boxes surrounding the phylogeny indicate the majority genetic cluster of each individual. Localities are colored on the map by the genetic cluster to which they were assigned. One individual per locality was chosen as a representative for this visualization.

Future Directions

When allowed to sample again after the COVID-19 pandemic, I will utilize the remaining Cave Research Foundation funds to resample the caves from which individuals were assigned to multiple genetic clusters. I will further sample Eigenmann's cavefish and continue to search for new localities to connect lineages and populations. Phylogenetic and evolutionary networks will help to determine cause for individuals assigned to different genetic clusters. The single nucleotide polymorphisms will be used to reconstruct phylogenetic relationships. I will also further examine the biogeography of the Southern Cavefish and Eigenmann's Cavefish. I look forward to continuing my research with the funding from the Cave Research Foundation. These results are being prepared as a publication to be submitted to the journal *Molecular Phylogenetics and Evolution*.

Grant Update

Morgan Olivia Smith

Current Results

This study investigates manganese (Mn) oxidation in two cave systems in the southern Appalachians in Tennessee and Virginia. In Sullivan County, Tennessee, Worley's Cave (WC) is an epigenic cave that is frequently visited by humans and contains agriculture runoff. This is considered an anthropogenically impacted cave. Daniel Boone Caverns (DBC) in Scott County, Virginia is privately owned, gated and locked and is located in an isolated, forested ridge far from agriculture or industrial development, making it a pristine cave environment. In each cave, clay and rock samples that tested positive for Mn oxidation and negative for Mn oxidation were returned to the lab for DNA extractions. Extracted DNA was sent to Mr. DNA (Shallowater, TX) for PCR amplification and Illumina sequencing. Upon receiving results, raw data was processed with RStudio and Python for quality assessment. Once filtered, taxonomic identity was assigned utilizing the ribosomal database project (RDP) taxonomic framework.

Cave	Sample Sites
DBC	CAUS.CC
	CAUS.Mn.plus
	FCP.CC
	FCP.Mn.plus
	MCSB.CC
	MCSB.Mn.plus
WC	CP.CC
	CP.Mn.plus
	CS.CC
	CS.Mn.plus
	DDE.CC
	DDE.Mn.plus
	MA.CC
	MA.Mn.plus
	SF.CC
	SF.Mn.plus
	FSD.CC
	FSD.Mn.plus
	STFF.CC
	STFF.Mn.plus

Table 1: Sample site names for reference.

For the fungal community analysis, we recovered 2,711 OTUs, most of which were not identified to the species level. (2,172 OTUs were amplified within WC and 539 OTUs were amplified from DBC). Six fungal phyla were represented through sequencing. All sites were dominated with either Mortierellomycota (1.3–93.7%), Ascomycota (5.0–69.8%), Basidiomycota (9.8–100%), and/or Unclassified Fungi (1.0-30.8%) (Figure 1). Ascomycetes appear to be in higher abundance at sites where Mn (II) oxidation occurred in both cave types. At the order level, the Mn positive and clay control sites in DBC (CAUS, FCP, and MCSB) (Table 1), were more abundant with Agaricales (11.8-79.5%), while the WC samples were more abundant with Unclassified Fungi, excluding sites FSD and STFF. Sordariales was more abundant at site FSD specifically in the Mn positive site and Mortierellales was more abundant at site STFF specifically in the clay control site (Figure 2 and Table 2).

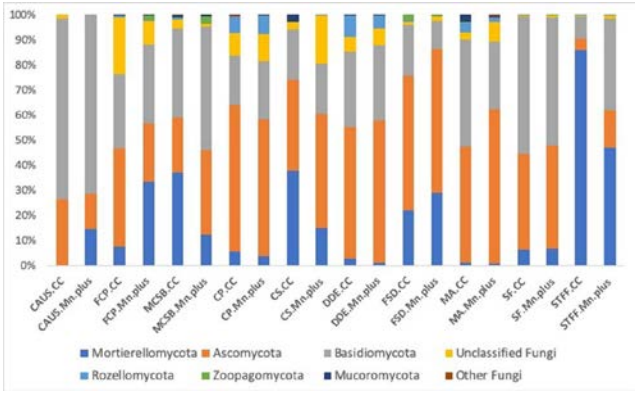


Figure 1: Phyla-level distribution of fungal communities of baseline samples in Worley's Cave and Daniel Boone Caverns.

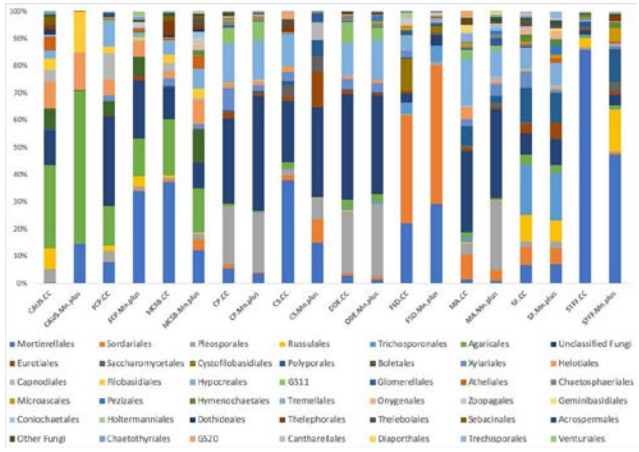


Figure 2: Order-level distribution of fungal communities of baseline samples in Worley's Cave and Daniel Boone Caverns.

A Principal Coordinates Analysis (PCoA) plot was created to visualize the difference of the fungal communities in the baseline samples. It was expected that the sample sites would cluster based on the presence or absence of Mn oxides, but instead the sites clustered by the location they are in each cave (Figure 3). The PCoA plot agrees with the genus level bar plot indicating that each cave contains different types of fungi with some being more abundant than others.

A Non-metric Multi-dimensional Scaling (NMDS) plot using Bray Curtis (a statistic used to quantify the dissimilarity between two different sites, based on counts at each site) was created to visualize how similar the microbial communities are to each other in the baseline samples. The NMDS plot agrees with the PCoA plot in that the samples cluster based on the cave and site locations rather than if Mn is present or not (Figure 4).

Cave	Sample Sites	Most Abundant Order Species	Abundance
DBC	CAUS.CC CAUS.Mn.plus FCP.CC FCP.Mn.plus MCSB.CC MCSB.Mn.plus	**Agricales**	**11.8-79.5%**
WC	CP.CC CP.Mn.plus CS.CC CS.Mn.plus DDE.CC DDE.Mn.plus MA.CC MA.Mn.plus SF.CC SF.Mn.plus	**Unclassified Fungi**	**1.3-30.8%**
	FSD.CC	**Sordariales**	**42.3%**
	FSD.Mn.plus	**Sordariales**	**62.0%**
	STFF.CC	**Mortierellales**	**93.7%**
	STFF.Mn.plus	**Mortierellales**	**42.1%**

Table 2: Most abundant order level of fungi at each site in Daniel Boone Caverns and Worley's Cave.

Work in Progress

The goal of this study is to identify Mn oxidizers that preferentially colonize on certain rock or mineral surfaces versus others. Currently, I am working on the baseline 16s DNA sequences that were also sent to Mr. DNA for PCR amplification and Illumina sequencing. The samples will be analyzed the same way as the fungi samples to create similar figures. Due to COVID-19 and restrictions on campus access, lab research has been suspended since March 2020. Laboratory research will begin again in August 2020 but may

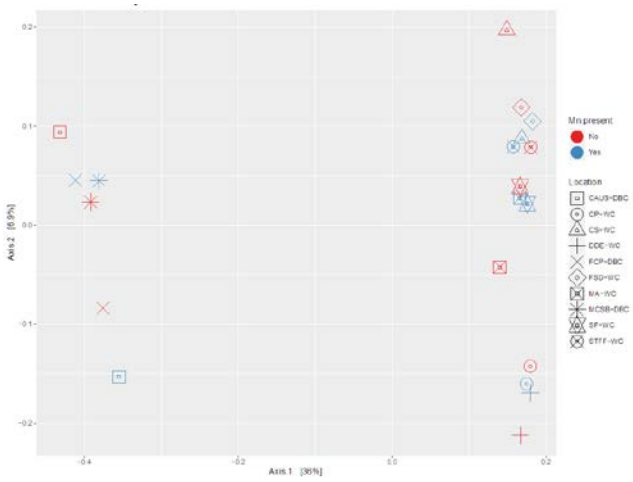


Figure 3: Unweighted PCoA plot of baseline community samples in Worley's Cave and Daniel Boone Caverns.

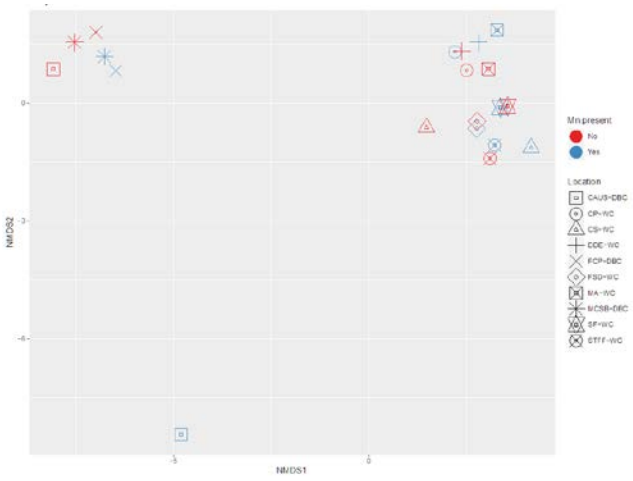


Figure 4: Bray Curtis NMDS plot of the baseline community samples in Worley's Cave and Daniel Boone Caverns.

be curtailed depending on the university administrations rules regarding on campus access if there is a surge in infections. Currently, WC and DBC have quartz, calcite, and feldspar pebbles that are incubating in Mn positive sites and clay control sites. In the future, these samples will be returned to the lab for DNA extractions and be sent to Mr. DNA for PCR amplification and Illumina sequencing. Cultured isolates in the lab will also be analyzed with scanning electron microscopy with energy dispersive X-ray microanalysis (SEM-EDS) and scanning transmission electron microscopy (STEM) element mapping to visualize microbial morphologies of the environmental samples. Bulk cave sediment/mineral substrate compositions will be analyzed using X-ray diffraction (XRD) in the Department of Geological Environmental Sciences, with mineralogy confirmed via SEM-EDS.

Developing a Threat Assessment and Monitoring Framework for Urban Karst Groundwater Management

March 2018–February 2019

Rachel Kaiser

Co-Principal Investigator Jason Polk, Western Kentucky University

Urbanization is a global phenomenon that has both positive and negative impacts on the economy, society, and the environment which has evolved with modern societies and influences the alteration of the natural landscape as urban sprawl occurs and populations grow. The development associated with urban landscapes includes impervious surfaces, such as blacktop and concrete, where precipitation is unable to infiltrate into the ground. As a result, stormwater runoff contributes surface pollutants to hydrologic systems in urban environments, while increased sewer and septic system infrastructure and industrial waste provide additional sources for pollution. This growth leads to issues, such as flooding and groundwater contamination, which have negative impacts not only on the environment but urban communities as well because they can affect water quality. Although a global issue, urban karst landscapes were studied on a local scale in the Bowling Green, Kentucky Metropolitan Area and the Tampa Bay Metropolitan Area. Every continent in the world has karst landscape features, with nearly a quarter of the human population living on or near karst regions and using karst aquifers as drinking water sources (Ford and Williams 2007). Karst landscapes are very sensitive to pollution because there is little to no separation between the surface and subsurface,

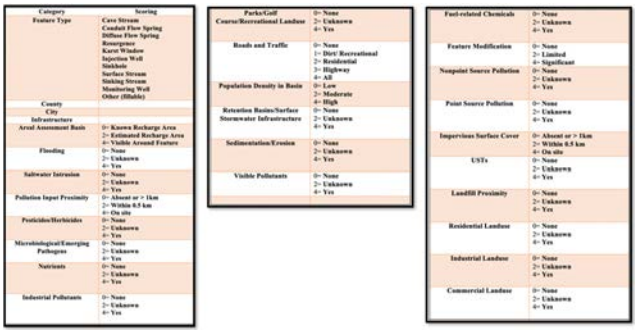


Figure 1. UKARE Threat Evaluation Criteria.

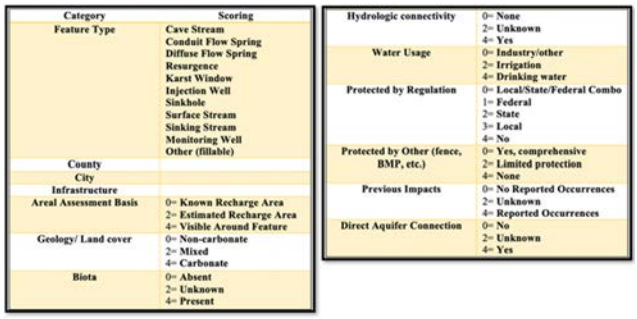


Figure 2. UKARE Vulnerability Evaluation Criteria.

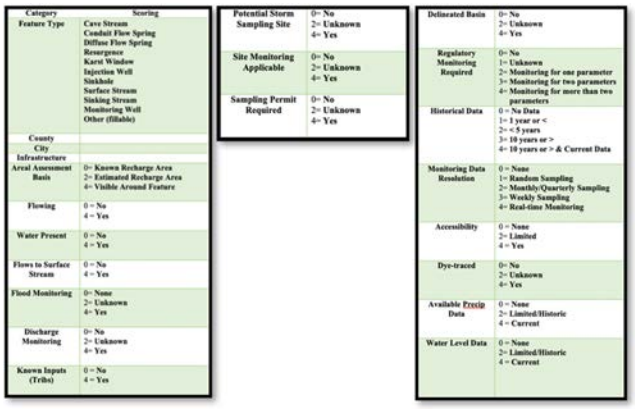


Figure 3. UKARE Monitoring Evaluation Criteria.

Score Range	Indicator
0-25	Low
26-50	Moderate
51-75	High
76-100	Urgent

Table 1. UKARE Scoring Indicators.

Bowling Green Sample Site Descriptive Statistics for Significant Sampling Parameters

		Monitoring Locations									Regulatory Limits	
		Carver Cave	Lost River Rise	Barren River	Lost River Spring	ByPass Cave	New Spring	927 Payne	Whiskey Run Spring	Durbin Estates	1126 Vine	WHO	State of KY
TSS	Max	138.000	82.000	58.000	26.000	267.000	29.000	44.000	42.000	212.000	754.000		
	Min	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	20.000		
	Mean	15.826	8.848	14.891	1.717	34.130	1.978	5.174	3.630	16.565	203.690		
	Std. Dev	32.049	17.766	12.791	5.119	60.716	4.955	10.765	9.445	35.031	209.845		
Turbidity	Max	75.000	84.000	87.000	41.000	245.000	625.000	526.000	55.000	195.000	650.000		
	Min	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
	Mean	7.913	8.174	16.500	1.500	29.978	15.261	14.413	2.370	13.891	182.276		
	Std. Dev	17.341	15.706	16.389	6.225	56.494	92.165	77.388	9.569	31.697	194.373		
BOD	Max	2.470	3.750	4.930	1.630	11.590	2.210	32.540	5.450	5.700	197.120		
	Min	0.640	0.000	0.320	0.000	0.760	0.170	0.890	0.000	0.540	4.760		
	Mean	1.353	0.616	1.160	0.380	3.849	0.672	6.663	0.635	2.864	38.540		
	Std. Dev	0.434	0.603	0.669	0.246	2.441	0.376	5.503	0.767	1.158	38.741		
COD	Max	26.000	13.000	17.000	17.000	191.000	13.000	69.000	25.000	26.000	1039.000		
	Min	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	5.000		
	Mean	3.848	3.457	6.457	2.174	23.609	3.870	10.457	3.630	9.130	204.621		
	Std. Dev	5.366	3.897	4.288	3.234	36.691	3.462	10.889	5.335	6.284	209.847		
E. coli	Max	5794.000	1918.000	2224.000	6488.000	41060.000	24196.000	15531.000	6488.000	7701.000	24196.000		
	Min	0.000	30.000	10.000	10.000	20.000	84.000	0.000	10.000	10.000	20.000		
	Mean	835.325	410.978	304.644	525.429	3395.400	2111.304	792.033	458.818	830.093	7181.652		0 MPN
	Std. Dev	1481.989	403.726	494.323	1512.778	7757.242	4376.187	2871.781	1057.469	1679.744	8227.714		
Oil and Grease	Max	5.930	7.310	9.670	20.300	10.800	5.840	16.170	7.900	7.250	32.670		
	Min	0.770	0.620	0.000	0.440	0.430	0.000	0.000	0.110	0.000	2.470		
	Mean	2.426	2.097	2.487	2.446	3.841	2.409	2.533	2.090	2.033	8.812		
	Std. Dev	1.057	1.040	1.845	2.830	2.031	1.164	2.334	1.319	1.157	6.304		
Nitrate	Max	11.630	26.910	11.220	13.010	11.110	16.910	26.220	26.340	6.780	8.380		
	Min	2.910	12.860	2.320	5.740	0.880	6.070	0.210	8.340	0.630	0.650		
	Mean	9.375	21.340	7.618	10.650	4.992	11.513	5.910	15.706	2.781	2.654	3 mg/L	
	Std. Dev	1.531	3.545	2.122	1.526	3.307	2.575	6.640	4.582	1.751	2.219		
Arsenic	Max	0.030	0.057	0.024	0.048	0.040	0.038	0.037	0.041	0.038	0.018		
	Min	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
	Mean	0.008	0.010	0.008	0.008	0.007	0.010	0.009	0.009	0.007	0.006	0.01 mg/L	
	Std. Dev	0.008	0.013	0.008	0.011	0.008	0.011	0.010	0.011	0.009	0.005		
Iron	Max	1.594	0.508	0.646	0.380	0.965	0.930	1.270	0.878	1.527	7.008		
	Min	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.049		
	Mean	0.092	0.069	0.087	0.070	0.189	0.065	0.136	0.080	0.178	1.406		0.3 mg/L
	Std. Dev	0.270	0.106	0.129	0.104	0.249	0.150	0.207	0.168	0.263	1.826		
Lead	Max	0.025	0.024	0.016	0.022	0.019	0.018	0.026	0.020	0.014	0.023		
	Min	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
	Mean	0.005	0.006	0.005	0.006	0.005	0.005	0.007	0.006	0.004	0.009	0.01 mg/L	
	Std. Dev	0.006	0.006	0.005	0.006	0.005	0.005	0.007	0.005	0.004	0.006		
Antimony	Max	0.013	0.0178	0.010	0.014	0.016	0.014	0.013	0.016	0.016	0.018		
	Min	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
	Mean	0.001	0.002	0.001	0.003	0.002	0.002	0.002	0.002	0.002	0.003		0.0056 mg/L
	Std. Dev	0.003	0.004	0.003	0.004	0.004	0.003	0.003	0.004	0.004	0.005		
Selenium	Max	0.080	0.099	0.076	0.071	0.062	0.061	0.075	0.082	0.080	0.114		
	Min	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.000		
	Mean	0.024	0.026	0.020	0.028	0.022	0.027	0.029	0.028	0.022	0.029	0.04 mg/L	
	Std. Dev	0.018	0.018	0.015	0.015	0.014	0.016	0.018	0.018	0.017	0.024		
Thallium	Max	0.046	0.046	0.054	0.054	0.046	0.065	0.096	0.048	0.066	0.043		
	Min	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
	Mean	0.005	0.008	0.007	0.006	0.005	0.007	0.010	0.008	0.007	0.006		0.00024 mg/L
	Std. Dev	0.011	0.011	0.013	0.011	0.010	0.013	0.023	0.013	0.013	0.010		

* All parameters in mg/L except for *E. coli* (MPN) and Turbidity (FAU)

Table 2. Descriptive Statistics of Bowling Green Sampling Sites.

meaning that surface pollutants are directly introduced to groundwater sources. Urban development not only threatens the quality of groundwater supplies but also their availability and management, due to the challenges in studying and understanding urbanized karst areas (Jiang and Yan 2010; van Beynen and Bialkowska-Jelinska 2012; Parise et al. 2015a).

The goal of this study was to develop a data-driven urban karst groundwater monitoring toolbox that is holistic and universally applicable. The development of the Urban Karst Aquifer Resource Evaluation Toolbox (UKARE) achieved this goal and is an initial attempt at a universal data-driven set of evaluation tools that determine where to sample, at what resolution, and what parameters need to be sampled in order to develop a site-specific urban karst monitoring and management plan. The UKARE scoring system is designed to be consistent between application sites in order to have a universal tool with scores that can be comparable between urban karst landscapes, unlike pre-existing tools that produce different evaluation results for the same area (Table 1, Figures 1–3). The UKARE is holistic and evaluates urban karst features with interdisciplinary criteria for threat, vulnerability, and monitoring capabilities. The toolbox helps communities to understand threats to urban karst groundwater and assist in mitigating them through policy and best management practices. This study created the baseline for an urban karst groundwater management plan, and it is expected for the UKARE toolbox to be improved upon with more case studies and alterations in the future. As the UKARE develops through future studies, the final goal is for a universal, holistic, and data-driven management tool, that can be customized to each urban karst setting, but with consistent guidelines and parameters between study areas in order to have a consistent tool for urban karst management.

The UKARE tool is useful for the development of management and monitoring plans by determining which urban karst features need to be prioritized for management in order to protect the feature and the groundwater quality associated with it. The two study areas within this study have different levels of urbanization but are both impacted through development and are in need of stronger management plans and protective policies for urban karst and karst groundwater quality. The UKARE toolbox is designed to aid in determining which features need to be managed, but the collection of primary data within this study was needed to fully determine what pollutants are impacting the quality of the features within both study areas. The overall purpose of the primary data collected was to validate the UKARE scoring system, which was achieved in both study areas, and the data can contribute to the development of effective management plans in order to properly protect urban karst groundwater quality that can be mirrored by other urban karst areas. Significant parameters for groundwater quality are noted in Table 2 and the presence of antibiotic resistant bacteria in urban karst groundwater is noted in Tables 3 and 4. Bacteria resistant to ESBL are typically resistant to carbapenems, fosfomycin, beta-lactamase inhibitors, non-beta-lactam antibiotics, and colistin, which are used when other medications have failed (CDC 2013). The presence of

Percent Positive				
Site	ESBLs Resistant Acinetobacter	ESBLs Resistant Pseudomonas	ESBLs Resistant KEC	ESBLS Resistant *E. coli*
ByPass Cave	61	93	83	83
Durbin Estates	59	93	65	65
Barren River	50	89	63	85
Carver Cave	48	98	67	63
Lost River Rise	26	91	80	89
New Spring	26	93	83	96
Whiskey Run Spring	35	91	15	46
Lost River Spring	35	98	28	50
927 Payne Injection Well	65	59	41	22
1126 Vine Injection Well	52	93	72	65
Sites Total	45	94	59	66

Table 3. Percent of Samples Positive for ESBLs Resistance in Bowling Green, KY.

ESBLs resistant bacteria continuously throughout the study at all sites is concerning for urban groundwater resources as it indicates the growing impact urbanization is having on water resources and public health. KPC resistant bacteria are resistant to nearly all antibiotics, and infection typically results in death making the presence of this bacteria continuously throughout the study and the entire study area, concerning for water resources and public health in this area.

The significant importance of resolution in urban karst landscapes is vital to protecting groundwater quality and human health. Over a quarter of the world's population rely on groundwater for drinking water and the threat of common pollutants and emerging pathogens jeopardizes this vital resource. The primary challenge of high-resolution monitoring and sampling is the limited budget of interested stakeholders. One purpose of this study was to determine which parameters should be sampled at a higher resolution in order to capture the variability of the pollutants present within the groundwater system. Parameters including *E. coli,* total suspended solids, turbidity, metals, anions, and antibiotic resistant bacteria displayed variability at all ten sampling sites throughout the eleven-month study, indicating that these parameters should be sampled at a higher resolution within the study area. Parameters including oil and grease, biological oxygen demand and chemical oxygen demand displayed consistent values from week to week and can be sampled at a lower resolution. In order to meet the interest of stakeholders, the collection of prevalent water quality data can be collected at a few select sampling sites determined by the UKARE toolbox within the study area that accurately represent the groundwater system in order to capture contaminants without requiring high resolution sampling at several different sites. The parameters selected in this study are an indicator suite that is utilized to develop an understanding of the study areas groundwater quality needs. The parameters in need of high-and-low resolution sampling display common trends in urban karst landscapes, but are primarily used as indicators and sampling needs and resolution may differ between urban karst areas. The use of high-resolution monitoring of significant parameters is vital to the protection of urban karst groundwater systems throughout the world.

Karst landscapes, especially urban karst, are unique and require an equally unique monitoring plan, and the UKARE toolbox and primary data collected in this study can aid in the development of effective monitoring programs for urban karst groundwater systems. A targeted approach to groundwater quality monitoring in urban karst landscapes is needed to not only effectively monitor the groundwater system, but meet the needs, interests, and budgets of interested stakeholders in order to develop realistic and beneficial monitoring programs to ensure the protection and quality of urban karst groundwater.

Percent Positive				
Site	KPC Resistant Acinetobacter	KPC-Pseudomonas	KPC Resistant KEC	KPC Resistant *E. coli*
ByPass Cave	85	98	50	15
Durbin Estates	89	98	48	8
Barren River	87	97	15	33
Carver Cave	80	93	35	4
Lost River Rise	76	93	28	8
New Spring	70	89	26	11
Whiskey Run Spring	63	89	17	0
Lost River Spring	70	91	17	0
927 Payne Injection Well	80	98	22	2
1126 Vine Injection Well	79	93	38	0
Sites Total	78	94	29	8

Table 4. Percent of Samples Positive for KPC Resistance in Bowling Green, KY.

Final Report

Chelsey Kipper

Western Kentucky University

Thank you again for granting me the 2018 Philip M. Smith Graduate Student Research Grant for Cave and Karst Research. My research would have been incomplete without your generous financial support. The funds from the fellowship were crucial to my thesis research and key to evaluating the hydrologic and geochemical changes associated with spring flow reversals in Mammoth Cave National Park (MCNP). Beginning in June of 2018, my research focused on the interactions between the Green River, River Styx Spring, and Echo River Spring during spring flow reversals in MCNP. This grant was used to purchase HOBO data loggers, replacement probes for multiparameter sondes, and stilling well supplies.

Spring flow reversals had previously been found to significantly affect water chemistry, dissolution processes, and the karst environment in the eogenetic karst of Florida. Until this most recent study, spring flow reversals in a telogenetic karst system had not been the focus of extensive research. Initially, I did not expect a great difference in the dissolution processes between the two karst environments. However, thanks to your support, the findings from my research indicate that spring flow reversals affect dissolution processes quite differently in the Mammoth Cave system than they do in the karst springs of the Sewanee River watershed in Florida.

Spring flow reversals occur in Mammoth Cave's River Styx and Echo River Springs when the hydraulic head in the Green River is greater than the hydraulic head within the karst basins. Under normal flow conditions, water from the conduit system flows out of River Styx Spring and Echo River Spring and discharges into the Green River. However, when the hydraulic head of the Green River rises above the hydraulic head of the River Styx karst basin, the flow reverses, and river water flows into River Styx Spring and into the base level conduit system. The river water then flows over a drainage divide that separates the River Styx and Echo River drainage basins, and finally discharges out of Echo River Spring. Because this flow pattern may last days or even weeks, it was termed "stable reverse flow."

To understand this unusual flow pattern, five sites were chosen for data collection: Green River, River Styx Spring, Echo River Spring, River Styx Boardwalk (River Styx in cave), and Minnehaha Island (Echo River in cave, but outside of the stable reverse flow route). HOBO pressure transducers were used to collect water-level data at

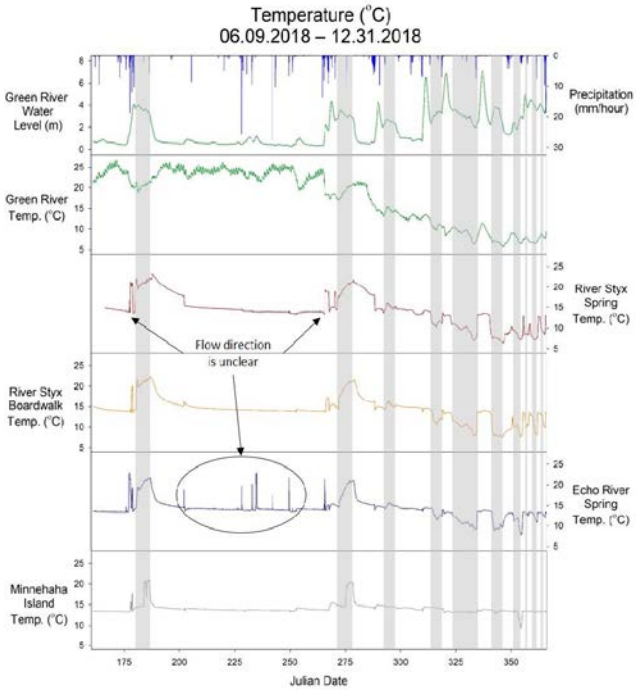


Figure 1. During flow reversals, temperature of the cave rivers and springs are reflective of Green River's temperature. Reverse flows in River Styx and Echo River are traced in the summer by the presence of warm water and in the winter by the presence of cold water. During the transitional seasons, temperature identification can be difficult as the Green River temperature is similar to the average cave water temperatures. Extreme temperature changes at Minnehaha Island show events where Green River water is backflooded upstream, outside of the flow reversal route. (Flow reversals are indicated by gray shading.)

two-minute resolution. YSI multiparameter sondes were used to collect pH, SpC, and temperature data at ten-minute resolution. In addition to high-resolution monitoring, water samples for major ion concentrations, alkalinity, total carbon, and carbon isotopes were collected weekly, when accessible. A statistical relationship between grab sample SpC data and weekly concentrations of Ca2+, Mg2+, and HCO3- was established for each site using linear regression. The derived, high- resolution concentrations of Ca2+and HCO3- and pH were used to calculate EpCO2, SIcal, and dissolution. Dissolution was calculated using the Palmer equation for wall retreat (S). The ten- minute interval calculations were summed and averaged over specific periods of time, as a method of characterizing seasonal and storm-driven dissolution rates. Carbon isotope values (δ13CDIC) were entered into EPA's IsoSource software program to develop a mixing model. This mixing model was used to understand the contribution of carbon sources to DIC

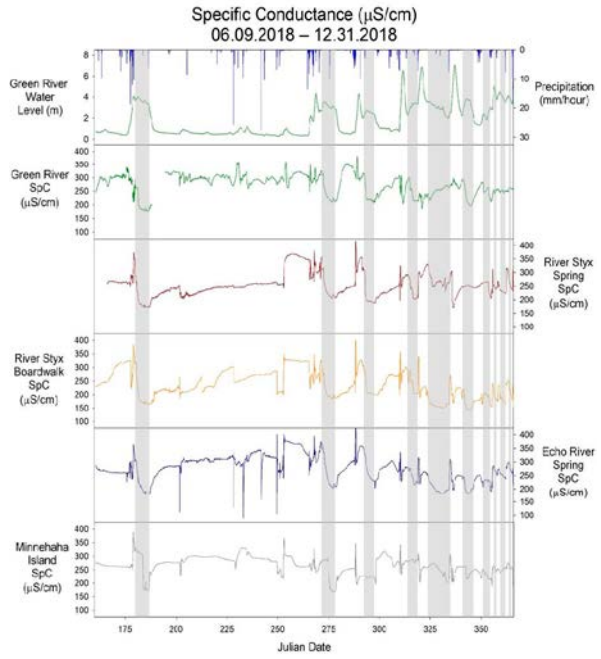


Figure 2. During flow reversals, SpC follows the same trend as the Green River's SpC. (Flow reversals are indicated by gray shading.)

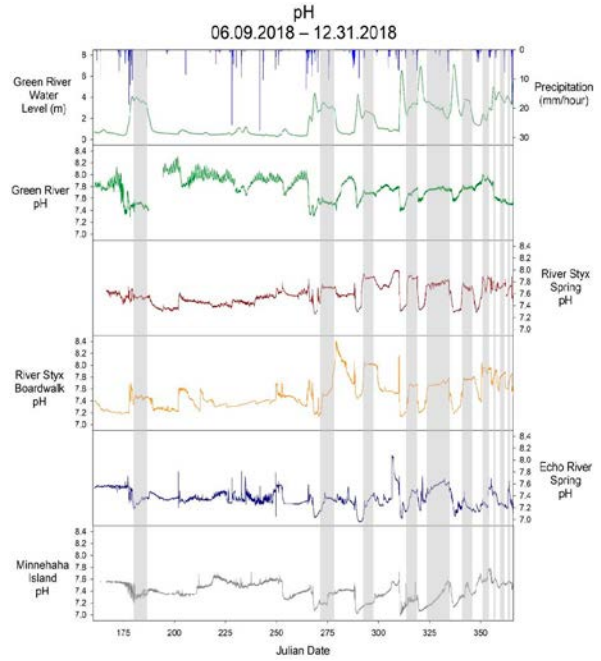


Figure 3. Identifying flow reversal events with pH is problematic; therefore, pH data were only used to supplement temperature and SpC data. However, pH was useful for showing clear seasonal trends in the Green River, with clear impacts from diel cycles in the summer and plateaus in pH values associated with dam releases. (Flow reversals are indicated by gray shading.)

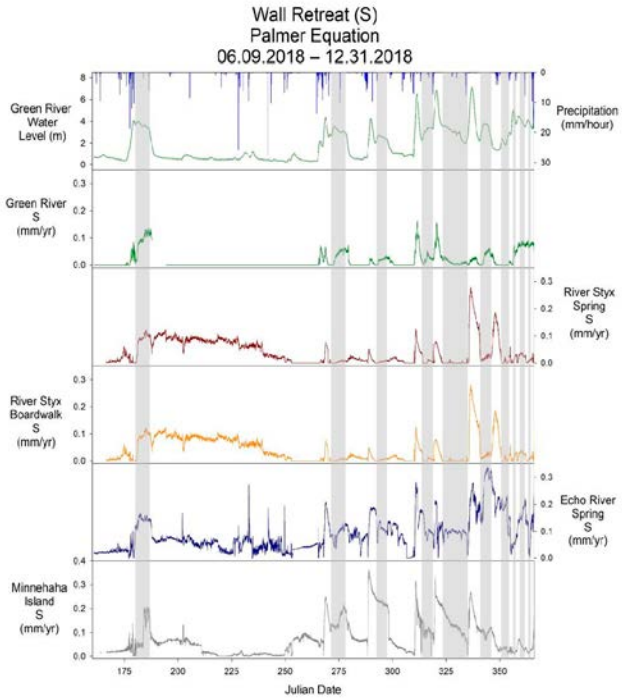


Figure 4. The highest rates of wall retreat typically occur during the initial storm pulse. Wall retreat during flow reversals is low compared to storm events and is often similar to normal, baseflow dissolution rates. The one exception is in Echo River Spring where dissolution rates during flow reversals are higher than normal flow conditions. This is likely due to mixing of waters and contribution of CO2 rich epikarstic water near the spring. (Flow reversals are indicated by shading.)

originating from rock dissolution, the atmosphere, and the soil into the River Styx and Echo River karst basins.

Results from my research show that flow reversals in Mammoth Cave's River Styx and Echo River Springs are not rare occurrences. Based on changes in geochemical parameters, the River Styx Spring's flow was identified as reversing 34% of the time from June 2018 to December 2018 (Figure 1). The flow direction control for the system is the difference between the hydraulic head of the river and the hydraulic head of the karst basin. Changes in hydraulic head during this study period were primarily influenced by a dam, located 169 kilometers upstream, on the Green River Lake. The ten stable reverse flows that occurred during the study period occurred in response to increases river stage caused by dam releases at Green River Lake. Other factors that influenced the frequency and duration of spring flow reversals are: rainfall intensity and duration, rainfall location (upstream Green River basin vs. Mammoth Cave karst basins), antecedent moisture conditions in the soil, and rates of evapotranspiration. These factors

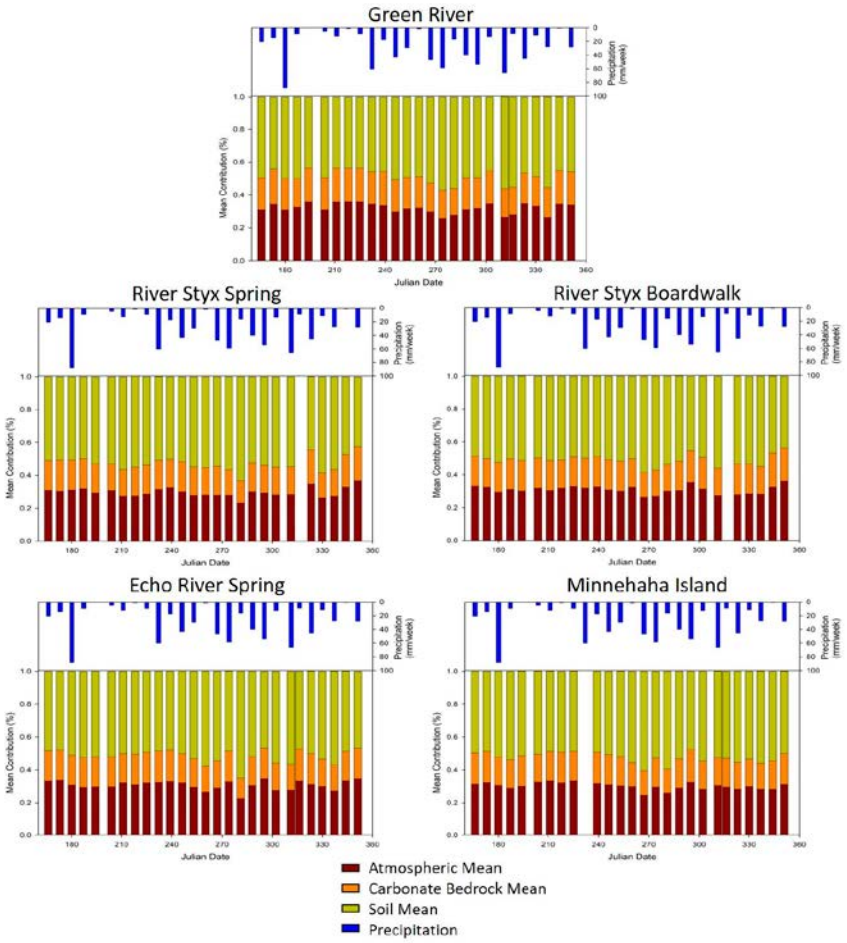


Figure 5. Mixing model results of the mean contributions to DIC calculated with the IsoSource software. Graphs do not indicate absolute percentages of carbon sources. The dominate source of carbon at all sites through the year was soil CO2, followed by the atmospheric CO2. Dissolution of carbonate rocks contributes the least to DIC at all five sites.

influence the overall seasonal hydrologic regime. During the winter, for example, increased rainfall, higher soil moisture content, and lower evapotranspiration rates increase the height of the water table, causing changes in hydraulic head. These factors combine to establish the stable reverse flow pattern as the usual flow regime during the winter; the Green River flowed into River Styx Spring 72.5% of the time from November 18 to December 31. Flow direction at River Styx Spring returned to normal flow conditions during the winter season following intense precipitation events in the Mammoth Cave karst basins, which temporarily reversed the hydraulic head gradient between the basins and the Green River. Once this precipitation discharged into the Green River, the River Styx–Echo River system returned to a stable reverse flow regime.

In contrast to the expected results, dissolution in the River Styx and Echo River Basin is often not enhanced during stable reverse flows, based on calculations of pCO2, SIcal, and dissolution rates. In fact, dissolution during stable reverse flows is often lower than stormflow conditions, nor is it significantly greater (<0.1 mm/year) than baseflow conditions. Calculations of dissolution during a stable reverse flow indicate that the estimated maximum amount of wall retreat at Echo River Spring was 0.003 mm, significantly lower than the 3.4 mm of estimated, single-event, wall retreat calculated in Florida (Gulley et al. 2011). Lower rates of dissolution during flow reversals in Mammoth Cave, when compared with Florida, are likely due to differences in pH, residence time, and bedrock porosity. pH values of the Green River are more basic (seasonal average between 7.65 and 7.86) than base flow cave waters (seasonal averages between 7.27 and 7.58). Throughflow of river water from River Styx Spring to Echo River Spring has a lower residence time than the waters in Florida, preventing a complete mixing and bedrock infiltration of the waters. Additionally, telogenetic karst has a lower matrix porosity, which also limits infiltration of aggressive waters.

Analysis of δ13CDIC shows that DIC is controlled by soil CO2 in the Green River and River Styx and Echo River groundwater basins. No seasonal shifts in sources were observed. However, week to week δ13CDIC values became more variable as the hydrologic regime changed into the fall and winter months. Overall, the waters were isotopically homogenized throughout the study period, indicating a concentrated soil CO2 reservoir that slowly depletes over the course of these seasons. Shifts in δ13CDIC values toward 0 do not correlate with flow reversals. This analysis of δ13CDIC supports the findings, based on the dissolution estimates, that dissolution is not enhanced during stable reverse flows.

In November, I successfully defended my master's thesis. It is now available on WKU's Topscholar. The results of this research will be presented at the UNESCO 2020 Karst Meeting and the 2020 GSA Annual Meeting. Additionally, multiple publications are in the composition process. Thank you again for your invaluable support.

Human Disturbance Effects in Ecosystem Health of Cave-Dwelling Bat Communities in Costa Rica

Amanda Vicente-Santos

During the dry season, we were able to reach through "new" passages of a cave. And we also reach to a big colony of* Pteronotus mesoamericanus *(about 3000 individuals).
Ferdinand Salazar

Project Description

From Ebola to the novel Coronavirus, bats have been implicated as the source of emerging infectious diseases (EIDs).[1] Furthermore, throughout the tropics, where bats represent a substantial proportion of diversity and biomass, the devastating pace of deforestation has created highly fragmented landscapes, and these degraded ecosystems have been associated with increased risk of EIDs of concern not only to human health but also animal health and wildlife conservation.[2] Despite the established linkages between habitat degradation and disease dynamics, few studies to date have explored the extent to which human disturbance simultaneously influences species abundances, their physiological stress and immune responses, and patterns of parasite and disease prevalence and transmission. Besides, most studies fail to consider the role that habitat disturbance has on roost sites, where bats spend nearly half their lives[3] and where human disturbance has the potential to be an inescapable physiological stressor.[4] Caves represent intriguing, complex systems where several species of bats interact in extreme proximity, promoting the potential for multispecies transmission.[4] Caves also have an important influence on the local bat assemblage structure across fragmented landscapes, and serve as important population reservoirs, which subsidize diversity levels in forest fragments that might otherwise be expected to decline over time.[5] Still, caves are more vulnerable to disturbance than other ecosystems.[6] The degradation or loss of foraging habitat has the potential to erode population viability as the energetic costs of commuting progressively greater distances, or foraging in poorer habitats, reduces individual health, and apparently healthy populations in modified landscapes may be compromised.[4,7–9]

My study addresses a critical gap in our understanding of how multi-host, multi-parasite disease dynamics change with anthropogenic impact by explicitly focusing on the simultaneous (and potentially opposing) effects of changes in host densities and epidemiological (immunological) traits. My work integrates empirical field data and mathematical modeling focused on cave-dwelling bat assemblages in Costa Rica and three dominant generalist pathogens (*Bartonella*, *Leptospira*, and *Trypanosoma*).

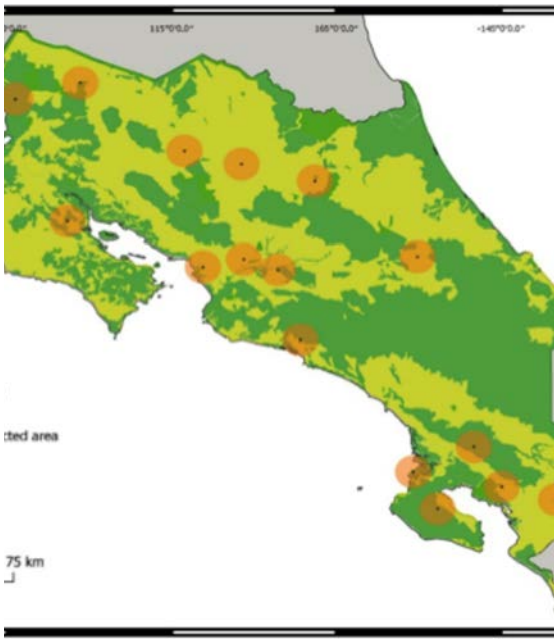


Figure 1. Caves sampled in Costa Rica.

Methods and Findings

From June to August of 2018, I continued conducting the pilot study and did more cave explorations to select new potential sites to study. From this field season, we located and surveyed 11 caves, from which four were new for our country's cave records. The aims were to: 1) define the caves to study based on location, bat populations and field logistics; 2) implement the methodology to conduct the cave survey and bat sampling; 3) test and standardize the protocols for the molecular detection of pathogens in the lab. We successfully collected 274 samples (i.e., fecal, urine, and blood) from 18 species of bats, and 114 ectoparasites samples from 48 individuals. After testing this samples in the lab, in Emory University, we found 12.04% (33/274) positive for Bartonella, 11.35% (26/299) for Trypanosoma, and 4.84% (3/62 urine samples) for Leptospira. We will consider screening the samples for other common pathogens, that could

Here I am taking a urine sample from a common vampire bat (*Desmodus rotundus*), which were very common in most of the caves we sampled. *Ferdinand Salazar*

We implemented several methods to capture bats. This is an example of one of them: a combination of a hand net and a mist net. *Ferdinand Salazar*

potentially provide more information for the modeling component of the project, such as hemoplasmas. After finalizing the pilot study, we decided to delimit the study to 16 caves, due to logistic constrains. Also, this pilot study was crucial to build and prepare the team that was going to join me in the field the coming year.

From January to August of 2019, I successfully surveyed the beforementioned 16 caves along a gradient of human disturbance ranging from undisturbed caves in protected areas, to caves subject to high levels of disturbance resulting from previous mining and surrounded mostly by agriculture, livestock and other human disturbed landscape (Figure 1). The selected caves range in species composition from two to 12 species of bats, and range in elevation from one to 721 m.a.s.l. Approximately half of the caves are located in tropical rainforest, while the other half are in tropical semi-deciduous forest. The latter has a more marked dry season than the rain forest. The caves were surveyed twice, in the dry (January to April 2019, less than 100 mm rainfall / month) and the wet (May to August 2019, more than 250 mm rainfall / month) season, in groups from two to four people using standard caving equipment (i.e., helmet, two independent light sources and protective clothing). We collected fecal, urine, blood, ectoparasites, tissue and hair samples from 1325 individuals of 19 bat species. In the 16 caves we report the presence of 23 bat species: *Anoura cultrata, Artibeus jamaicensis, Carollia perspicillata, Chrotopterus auritus, Desmodus rotundus, Diphylla ecaudata, Glossophaga commissarisi, Glossophaga soricina, Lonchophylla robusta, Lonchorhina aurita, Macrophyllum macrophyllum, Mormoops megalophylla, Natalus mexicanus, Peropteryx kappleri, Phyllostomus discolor, Phyllostomus hastatus, Pteronotus fulvus, Pteronotus gymnonotus, Pteronotus mesoamericanus, Pteronotus personatus, Saccopteryx bilineata, Tonatia saurophila, Trachops cirrhosus.*

From this successful fieldwork, we reported a new bat species for Costa Rica (*Mormoops megalophylla*), reported interesting cases of leucism (in *Artibeus jamaicensis*) and albinism (in *Carollia perspicillata*) in bats, as well as exciting new natural history data from bats in the Neotropics (publications in preparation). We also identified potential sites of importance for bat conservation, referred as SICOM by RELCOM (Latin American Network from Bat Conservation). These include two caves privately owned, surrounded by a degraded habitat (i.e., with agriculture and cattle), which are fairly complex caves with underground rivers and about 3Km long, that hold 10 and 12 species of bats.

Currently, I am in the process of analyzing the collected data, from the bat population census and spatial analyses, to the molecular and immunological work in the lab. I started working with the samples at the University of Costa Rica and shipped the samples to Emory (DNA samples) and the Leibniz Institute for Zoo and Wildlife Research, in Berlin (plasma samples) to continue with the analyses. Since returning to Emory in September, I have been engaged in laboratory (pathogen screening, immunological assessment) and spatial analyses of the data and samples collected. Thus far, I have extracted DNA from 1,739 bat samples (blood and urine) and initiated conventional PCR for the three selected pathogens.[10–12] To date, I have screened 646 blood samples, for which 8.8% are positive for Bartonella (57/646), and 21.4% are positive for Trypanosoma (138/646). I have screened 60 urine samples, for which 25.0% are positive for Leptospira (15/60). Interestingly, 5.3% of bats have co-infections (34/646). Altogether, these preliminary results show intriguing patterns, and I expect that formal analysis will clarify them. Further, I plan to sequence a subset of positives, to 1) confirm and determine pathogen strain with phylogenetics, and 2) inform our mathematical model by defining if it is the same bacteria strain or protozoan that is being transmitted between and within bat species. Additionally, I plan to perform qPCR to a subset of positive samples to quantify the parasite load in blood and/or urine, [13–15] to further inform our mathematical model.

For the immunological component of my project, I am employing white blood cell counts as a proxy of chronic stress and investment in cellular immunity (neutrophil: lymphocyte ratios and total white blood cells, respectively). I have screened 652 bat blood smears to date, where I have found interesting divergence between bat species. Through a collaborative agreement between the Gillespie Lab at Emory and the Leibniz Institute for Zoo and Wildlife Research (LIZWR) in Berlin, Germany, I will have the opportunity to measure relative bat investment in innate vs adaptive immunity using cutting-edge immune assays, during a three-month visit to Berlin (September to November 2020).

Beautiful limestone stalactite formations in Gabinarraca Cave, in Venado, San Carlos. This cave is more than 3Km long, has an underground river, and 12 bat species.

Ferdinand Salazar

Setting a lab in the forest. Hanging, on red cloth bags, are the bats we captured. *Ferdinand Salazar*

My dissertation research will make fundamental contributions to our understanding of how multi-host, multi-parasite disease dynamics change with anthropogenic impact by explicitly focusing on the concurrent effects of changes in host densities and epidemiological traits. Simultaneously, the modeling component of my work will allow us to make and test predictions, increase the generality of the results and offer a unique opportunity to test these hypotheses in other systems.

I have a strong desire to continue doing research of disease ecology in this cave-dwelling bat tropical system, to develop a long-term study following the responses of wildlife to continuing anthropogenic pressures. By assessing the impact that human disturbance has on the epidemiology of cave-dwelling bat populations, we will be able to identify apparently healthy cave-roosting bat populations that may be compromised, due to the erosion of their immune response in degraded habitats. As a result, the study will be the baseline for future research in these constantly changing environments. Finally, having a modeling component will further allow us to make and test predictions, increase the generality of the results and will offer a unique opportunity to test the hypothesis in other systems. My main goals for the future are 1) to promote the communication between fields in science and in policy making, and favor the production of interdisciplinary research in our community with direct impacts in our society, 2) to be involved in academic boards and influence the future path of our research programs, and 3) to organize workshops and outreach activities in schools to promote the involvement of local communities in conservation efforts.

References

1. Luis, A. D. *et al.* A comparison of bats and rodents as reservoirs of zoonotic viruses: are bats special? *Proc. R. Soc. B Biol. Sci.* **280**, 20122753 (2013).
2. Cardinale, B. J. *et al.* Biodiversity loss and its impact on humanity. *Nature* **489**, 326–326 (2012).
3. Kunz, T. H. Roosting ecology of bats. in *Ecology of bats* (ed. Kunz, T. H.) 1–56 (Plenum Press, 1982).
4. Struebig, M. J. *et al.* Conservation importance of limestone karst outcrops for Palaeotropical bats in a fragmented landscape. *Biol. Conserv.* **142**, 2089–2096 (2009).
5. Hunter, M. L. *et al.* Conserving small natural features with large ecological roles: A synthetic overview. *Biol. Conserv.* **211**, 88–95 (2016).
6. Medellin, R. A., Wiederholt, R. & Lopez-Hoffman, L. Conservation relevance of bat caves for biodiversity and ecosystem services. *Biol. Conserv.* **211**, 45–50 (2017).
7. Phelps, K., Jose, R., Labonite, M. & Kingston, T. Correlates of cave-roosting bat diversity as an effective tool to identify priority caves. *Biol. Conserv.* **201**, 201–209 (2016).
8. Kingston, T. Response of bat diversity to forest disturbance in Southeast Asia: Insights from long-term research in Malaysia. *Bat Evol. Ecol. Conserv.* 169–185 (2013). doi:10.1007/978-1-4614-7397-8_9
9. *Bats in the Anthropocene: Conservation of Bats in a Changing World*. (2016).
10. Birtles, R. J. & Raoult, D. Comparison of Partial Citrate Synthase Gene (*gltA*) sequences for Phylogenetic Analysis of *Bartonella* species. *Int. J. Syst. Bacteriol.* **46**, 891–897 (1996).
11. Woo, T. H. S. *et al.* Identification of pathogenic Leptospira genospecies by continuous monitoring of fluorogenic hybridization probes during rapid-cycle PCR. *J. Clin. Microbiol.* **35**, 3140–3146 (1997).
12. Noyes, H. A., Stevens, J. R., Teixeira, M., Phelan, J. & Holz, P. A nested PCR for the ssrRNA gene detects Trypanosoma binneyi in the platypus and Trypanosoma sp. in wombats and kangaroos in Australia. *Int. J. Parasitol.* **29**, 331–339 (1999).
13. Loftis, A. D. *et al.* Surveillance of Egyptian fleas for agents of public health significance: Anaplasma, bartonella, coxiella, ehrlichia, rickettsia, and Yersinia pestis. *Am. J. Trop. Med. Hyg.* **75**, 41–48 (2006).
14. Levett, P. N. *et al.* Detection of pathogenic leptospires by real-time quantitative PCR. *J. Med. Microbiol.* **54**, 45–49 (2005).
15. Moreira, O. C. *et al.* Towards the establishment of a consensus real-time qPCR to monitor Trypanosoma cruzi parasitemia in patients with chronic Chagas disease cardiomyopathy: A substudy from the BENEFIT trial. *Acta Trop.* **125**, 23–31 (2013).