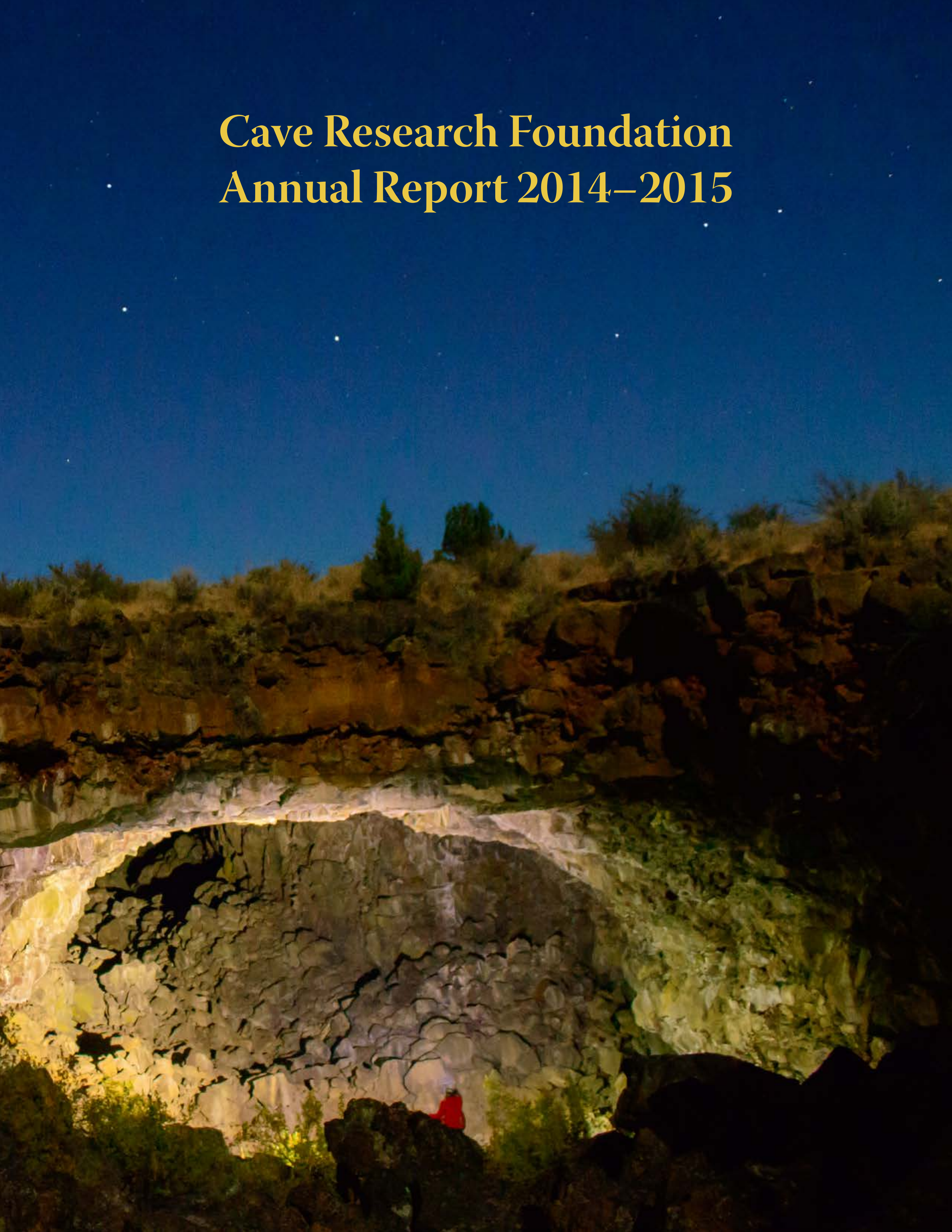
Cave Research Foundation
Annual Report 2014–2015



Cave Research Foundation Annual Report 2014–2015

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 2014–2015 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: Post Office Cave, Lava Beds National Monument. Photo by Ken Walsh.
Back cover photo: A larval grotto salamander eats the rotting remains of another in a Mark Twain National Forest cave. Photo by Mark Jones.

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ISBN-13: 978-0-939748-84-6
ISBN-10: 0-939748-84-3

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

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Operations Areas and Projects

Science

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:

2014 Fellows

Matt Bumgardner (Ozarks)

Mark Jones (Eastern)

2014 Certificates of Merit

Mike Crockett (Eastern)

2015 Fellows

Richard Young (Ozarks)

Josh Brewer (Ozarks)

Craig Williams (Ozarks)

Bill Copeland (Eastern)

Bill Koerschner (Eastern)

2015 Certificates of Merit

John Tinsley (Sequoia / Kings Canyon, Lava Beds)

Laura Lexander (National)

Ken Grush (Ozarks)

Alicia Wallace (Ozarks)

Karen Willmes (Eastern)

Tim Green (Eastern)

Bob Lodge (Eastern)

2014 Directors

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Vice President

Robert Hoke
Treasurer

John Lovaas
Secretary

Directors

Derek Bristol

George Crothers

Joyce Hoffmaster

Ed Klausner

John Lovaas

Ben Miller

Kayla (New) Sapkota

Elaine (Garvey) Scott

Science and Grants

George Crothers

National Personnel Officer

Phil DiBlasi

Newsletter Editor

Laura Lexander

2014 Operations Areas and Managers

Eastern Operations Area

Dave West

Mammoth Cave National Park
Cumberland Gap National Historical Park

Ozarks Operations Area

R. Scott House

Mark Twain National Forest
Ozark National Scenic Riverways
Missouri Department of Conservation
Missouri State Parks
Buffalo National Scenic River

Sequoia/Kings Canyon and Mineral King Operations Area

John Tinsley

Sequoia/Kings Canyon National Park

Lava Beds Operations Area

John Tinsley

Lava Beds National Monument

Hamilton Valley Operation

Patricia Kambesis

Hamilton Valley Field Station
Cave City, Kentucky

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Janice Tucker

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Cumberland Gap National Historical Park

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Ozark National Scenic Riverways
Missouri Department of Conservation
Missouri State Parks
Buffalo National Scenic River

Sequoia/Kings Canyon and Mineral King Operations Area

Fofo Gonzalez and Jen Hopper

Sequoia/Kings Canyon National Park

Lava Beds Operations Area

John Tinsley

Lava Beds National Monument

Hamilton Valley Operation

Patricia Kambesis

Hamilton Valley Field Station
Cave City, Kentucky

Operations Areas and Projects

Dan Lamping in a Missouri Department of Conservation cave. *Derik Holtmann*

Cave Research Foundation Eastern Operations Annual Report FY2014

Dave West

Eastern Operations Area Manager

Overview

Eastern Operations members conducted 134 trips investing over 10,000 hours in support of multiple projects in and around Mammoth Cave National Park. Some trips supported multiple projects. This total included the following areas:

- MCNP Cartography—89
- Hidden River Cave Cartography—7
- History—4
- Hydrology—2
- Conservation and Restoration—4
- Caves Outside the Park—32
- Roppel Cave Cartography—15
- Park Requested Assistance—25
- Biomonitoring—16
- Ecology—4

Elizabeth Winkler assisting Lisa Troyer with reading instruments in Roppel Cave. *Ed Klausner*

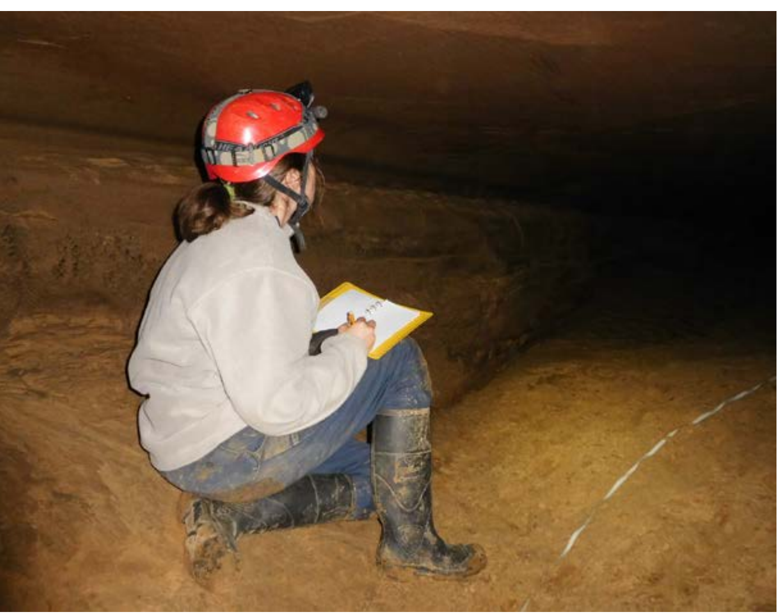
Cartography

Sixty-nine trips supported cartography in the Mammoth Cave System. Forty-four trips went in Mammoth Ridge, many continuing the resurvey of the connection between Mammoth and New Discovery to support a projected dive in downstream Roaring River for shrimp studies requested by the park. Other areas of continuing work in Mammoth Cave included East Bransford, Miller Avenue, Bottomless Pit, Carlos Way, Henry's Dome, and the Boiled Egg Passage.

Five parties worked in Proctor Cave, in Hawkins River and the Fritsch Avenue area.

On Flint Ridge, in Unknown Cave, five parties continued survey work in Ralph's River Trail, Pohl Avenue, Stort's Trail, Candlelight River, and the Tight Spot.

Six parties surveyed in Colossal Cave using the Bedquilt entrance to avoid disturbing the bats. They worked in WOW Shaft, Serpentine Canyon, the Bird Chamber dome, and the Bedquilt Route, for which a profile is being developed.



Keely Owens sketching in Roppel Cave. *Ed Klausner*

In Salts Cave five parties worked near the Pike Chapman entrance, in Salts Trunk, and in East Salts. Four parties in Crystal Cave worked in Left of the Trap and the Flat Room. Also in Crystal Cave, four parties continued restoration work on formations and gypsum crust that were broken years ago when vandals broke into the cave and stole formations to sell. Fortunately, they were caught and prosecuted but much damage remains. Those who have seen this restoration work are very impressed with both the locating of matching pieces as well as their reconnection to the cave itself.

Additional Support for Cartography within the Mammoth Cave National Park Boundaries

Two parties continued work in Great Onyx Cave extending the survey of the Lucy Kovah River and replacing an old G survey near the 90-foot pit.

Small Caves

Ridgewalking in Wilson Hollow turned up nothing new but trips to other areas were more successful, locating or re-locating various caves, of which two, Two Tiers Pit and Union City Cave #3, were surveyed and maps completed. Work was also renewed on Peter Cave near Turnhole Bend.

Rick Olson climbing to a lead in the Historic Section. *Ed Klausner*

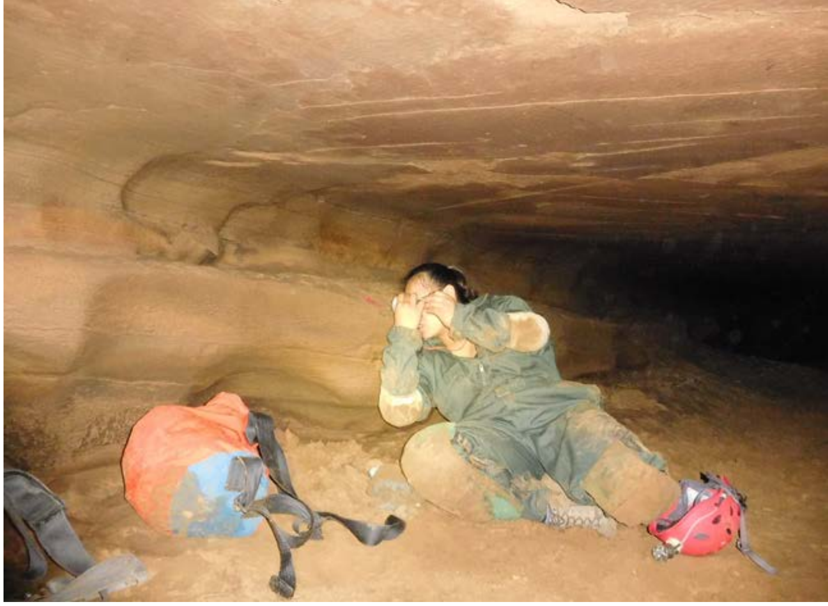
Educational and Cooperative Efforts

The park requested support for their bio-monitoring programs in the form of highly detailed maps of various small caves and system entrances. A detailed map of the Frozen Niagara entrance area was produced at ten feet to the inch. Blight Cave, Hickory Flats Cave, J.T. Cave, and Luna Cave were all surveyed and the maps provided to the park. Surveys were initiated in Dynamite Rock Cave and Cathedral Cave, where work continues. Another cave, Sanders Cave, had seen some survey effort a few years ago but had not been completed. Copies of notes from the Quinlan files showed the cave had been surveyed more extensively in the 1970s, and the two data sets were combined to produce a map. The Park also requested investigations of Alfred Cave, Bruce Hollow Cave, Collins Spring Cave, and Cave Pit Cave. Although very tight, Alfred Cave was found to be enterable, and survey is expected in the coming year. Bruce Hollow Cave was surveyed and the map completed. Collins Spring Cave could not be entered by the party sent to investigate, but they thought a party with smaller members might fit. Cave Pit Cave was found to be a fourteen-foot deep dead bottom pit. In the main system, parties assisted the Park with the placing of dye traps to better understand the potential flow paths from the surface throughout Historic Mammoth.

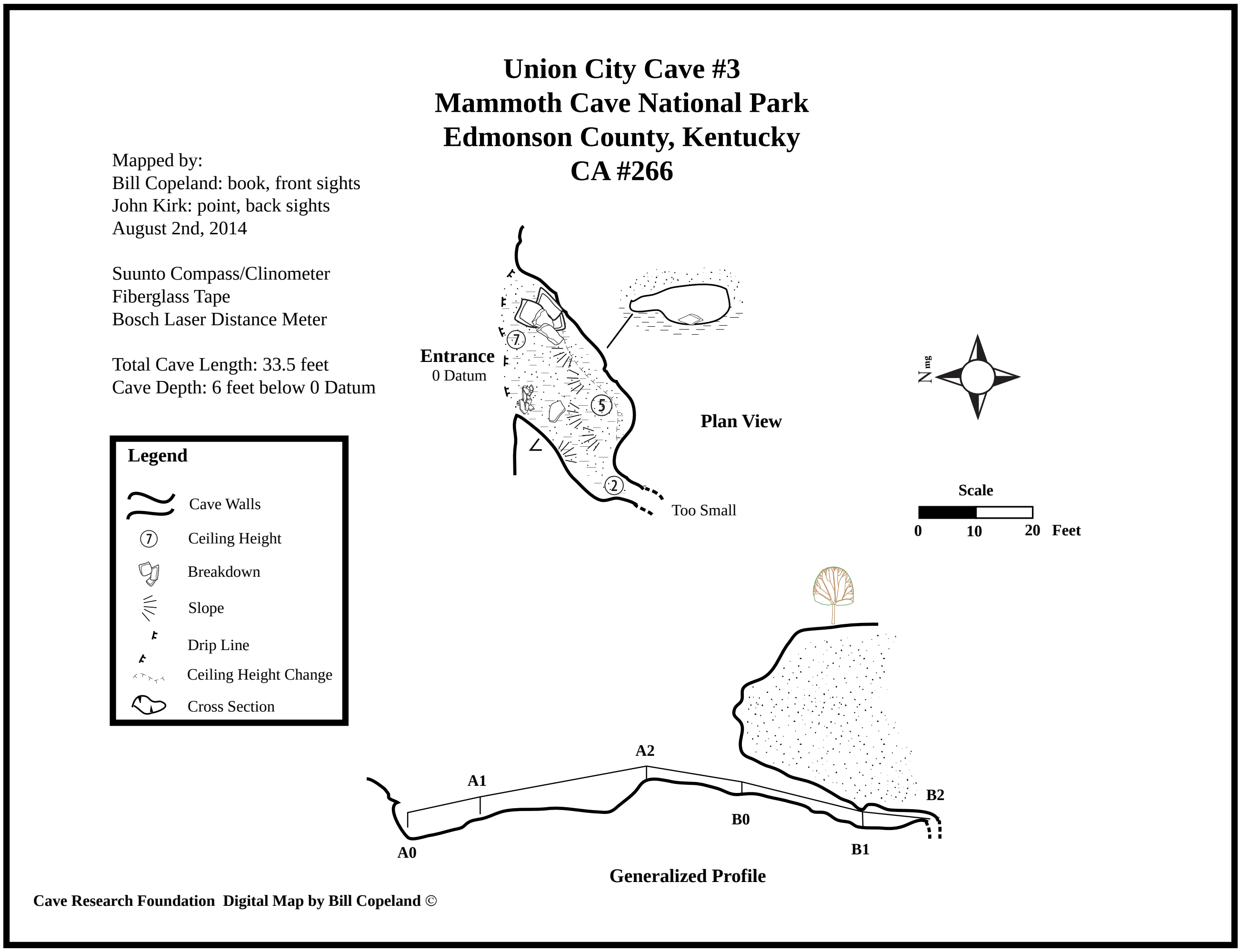
Four parties supporting historical studies being conducted by Stan Sides went to Unknown Cave, Johnson Cave, Bunyan's Way in Mammoth Cave, and Potato Cave, where a survey was also begun.

Cartography outside of Mammoth Cave National Park

Eastern Operations continued its work on cave projects outside of the Mammoth Cave system. Both new and resurvey trips were conducted in Roppel and Hidden River caves throughout the year. Other off-park projects were also supported. A trip was led to Vinegar Ridge Cave to obtain data and a sketch of the entrance area, replacing some missing information from earlier work. Six parties went to what became Turtle Cave during the July expedition, assisting a landowner that went to extraordinary means to facilitate the project. The passage found thus far



Hannah Klausner reading instruments in Roppel Cave.
Ed Klausner



was surveyed and work there is expected to continue in the coming year. Trips to Adwell Cave in Hamilton Valley helped keep the Disto-X instruments calibrated.

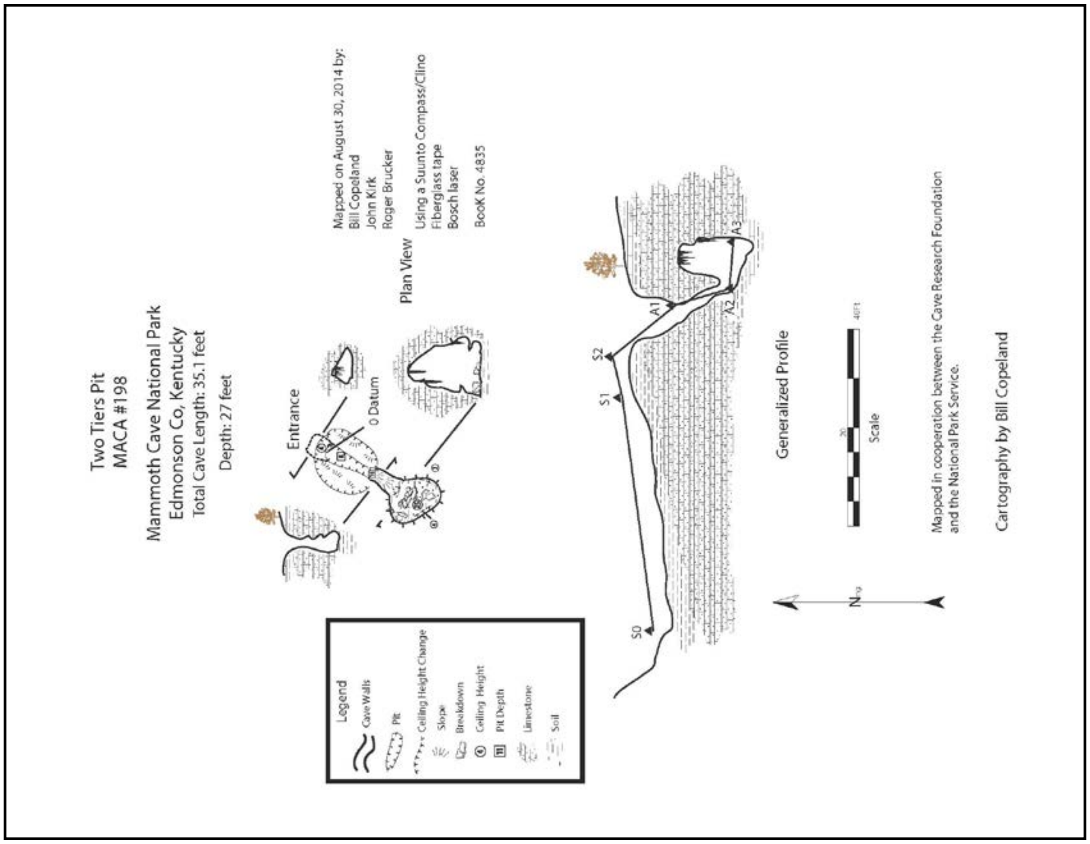
Away from the Mammoth Cave area, in West Virginia, a working group which includes CRF, the West Virginia Association for Speleological Studies, the Monongahela National Forest, the West Virginia Division of Natural Resources, and the U.S. Fish and Wildlife Service continued the development of a means for work to proceed in various cave projects throughout the Forest while working within the limitations brought about by the WNS closures. CRF had begun a project here to survey the Cave Hollow–Arbogast Cave system, but work was postponed due to the appearance of WNS in the state.

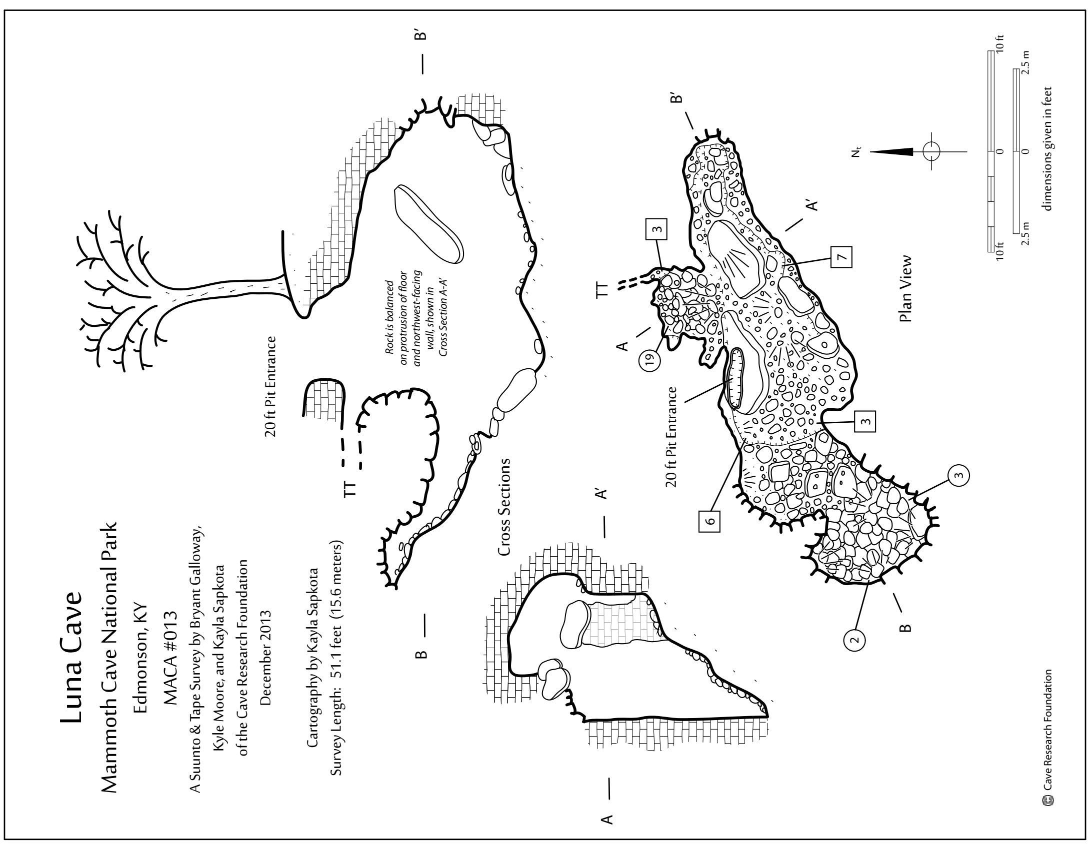
At Cumberland Gap National Historic Park, located in Virginia, Kentucky, and Tennessee, Mike Crockett has stepped down as Project Coordinator, and Stuart Daw and Bob Alderson now share his former duties. Monthly survey and cultural resource work continues in Gap Cave, now over 18 miles, as well as various small caves throughout and near the Park.

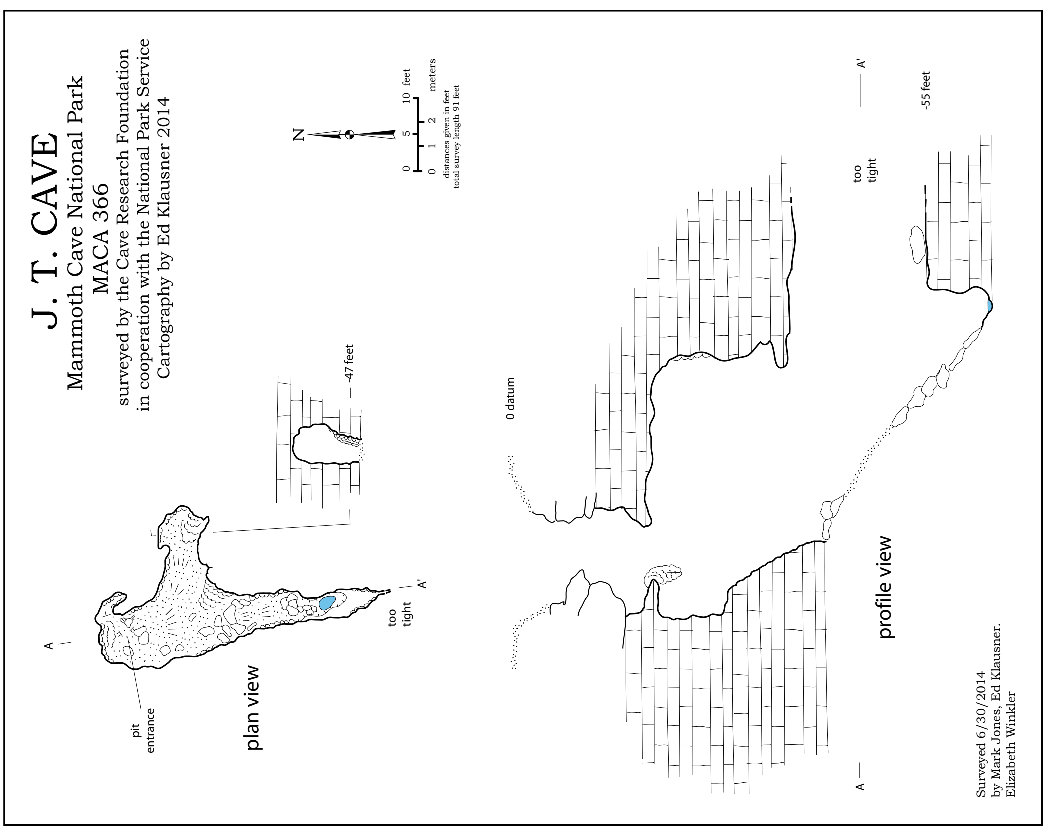
This is my last report as Eastern Operations Manager, having passed the hat to Charles Fox, and having agreed to serve as Vice President.

Dave Weller showing Roger Brucker (not pictured) and Ed Klausner (not pictured) some modifications to the entrance area of Roppel Cave (Weller Entrance). *Ed Klausner*

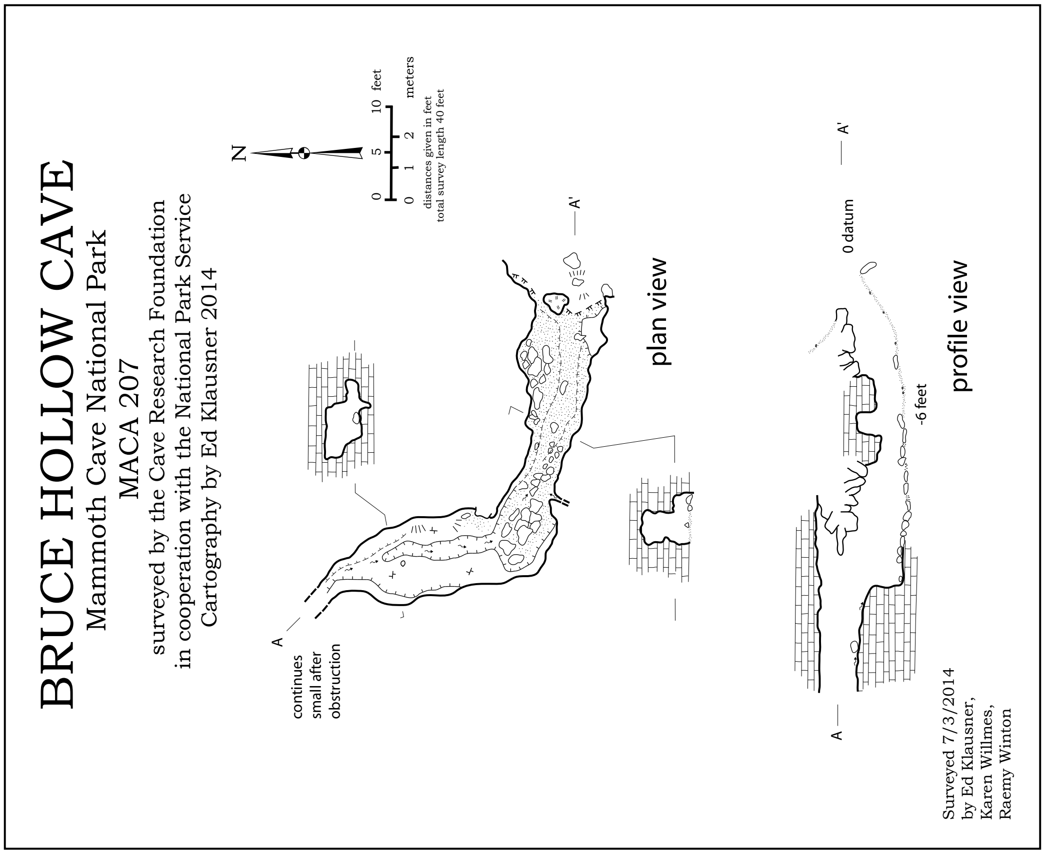
Fred Wilkinson setting stations in Roppel Cave. *Ed Klausner*


Two Tiers Pit
MACA #198
Mammoth Cave National Park
Edmonson Co, Kentucky
Total Cave Length: 35.1 feet
Depth: 27 feet
Entrance
0 Datum
Plan View
Mapped on August 30, 2014 by:
Bill Copeland
John Kirk
Roger Brucker
Using a Suunto Compass/Clino
Fiberglass tape
Bosch laser
BooK No. 4835
Legend
Cave Walls
Pit
Ceiling Height Change
Slope
Breakdown
Ceiling Height
Pit Depth
Limestone
Soil
S0
S1
S2
A1
A2
A3
Generalized Profile
Scale
Mapped in cooperation between the Cave Research Foundation and the National Park Service.
Cartography by Bill Copeland

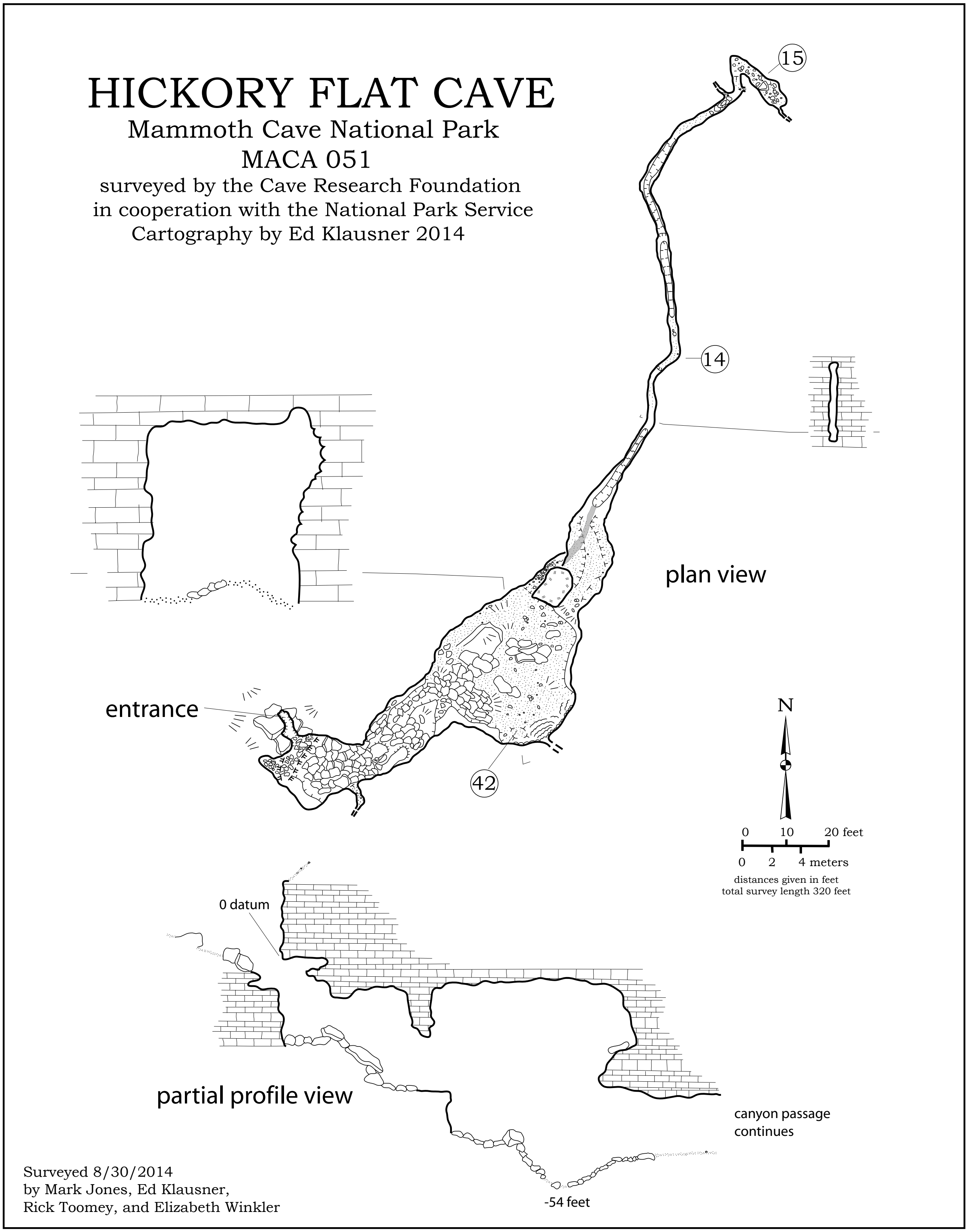

Luna Cave
Mammoth Cave National Park
Edmonson, KY
MACA #013
A Suunto & Tape Survey by Bryant Galloway,
Kyle Moore, and Kayla Sapkota
of the Cave Research Foundation
December 2013
Cartography by Kayla Sapkota
Survey Length: 51.1 feet (15.6 meters)
20 ft Pit Entrance
Rock is balanced on protrusion of floor and northwest-facing wall, shown in Cross Section A-A'
Cross Sections
A
A'
B
B'
TT
20 ft Pit Entrance
Plan View
dimensions given in feet
10 ft
2.5 m
© Cave Research Foundation



J. T. CAVE
Mammoth Cave National Park
MACA 366
surveyed by the Cave Research Foundation
in cooperation with the National Park Service
Cartography by Ed Klausner 2014
N
0 5 10 feet
0 1 2 meters
distances given in feet
total survey length 91 feet
A
A'
pit
entrance
too
tight
-47 feet
plan view
0 datum
profile view
too
tight
-55 feet
A
A'
Surveyed 6/30/2014
by Mark Jones, Ed Klausner.
Elizabeth Winkler



BRUCE HOLLOW CAVE
Mammoth Cave National Park
MACA 207
surveyed by the Cave Research Foundation
in cooperation with the National Park Service
Cartography by Ed Klausner 2014
N
0 5 10 feet
0 1 2 meters
distances given in feet
total survey length 40 feet
A
A'
continues
small after
obstruction
plan view
A
A'
0 datum
-6 feet
profile view
Surveyed 7/3/2014
by Ed Klausner,
Karen Willmes,
Raemy Winton


HICKORY FLAT CAVE
Mammoth Cave National Park
MACA 051
surveyed by the Cave Research Foundation
in cooperation with the National Park Service
Cartography by Ed Klausner 2014
15
14
plan view
entrance
42
N
0 10 20 feet
0 2 4 meters
distances given in feet
total survey length 320 feet
0 datum
partial profile view
canyon passage
continues
-54 feet
Surveyed 8/30/2014
by Mark Jones, Ed Klausner,
Rick Toomey, and Elizabeth Winkler

Eastern Operations Annual Report 2014–15

Charles Fox

Eastern Operations Area Manager

Overview

After many years of service, Dave West stepped down as Eastern Operations Manager in October 2014. Charles Fox replaced him and has completed his first year as EOM.

In the October 2014 to September 2015 year, Eastern Operations contributed over 10,400 volunteer hours and over 211,000 travel miles at Mammoth Cave National Park. In addition, the Cumberland Gap work continued in spite of restrictions resulting from WNS limiting cave access.

MACA recently eased some WNS restrictions in recognition that the disease is now well established at the park. While decontamination is still required and practiced, we have more liberal requirements for traveling between caves within the park that have made working there simpler.

Expedition participants prepare to hoist a wooden saltpeter pipe in Mammoth Cave. *Ed Klausner*

The group carrying the pipe. *Ed Klausner*

Cartography

Cartography continues to be the primary focus at both locations. Much progress is being made on sheets managed by active cartographers; less progress is being made on other sheets. There are enough active cartographers that EO has adequate work coming in to support expeditions. CRF cartographers have assumed responsibility for several map sheets in Roppel Cave in the last year.

Small Caves

The efforts of Bill Copeland have produced significant results in the small caves project. Almost every expedition fields one or more small cave parties. Maps are being produced and the database/files have been organized. Consideration is being given to expanding our surveys to include biological and resource inventories to a greater extent than we have done in the past.

Educational and Cooperative Efforts

During the previous year EO has contributed to the following projects:

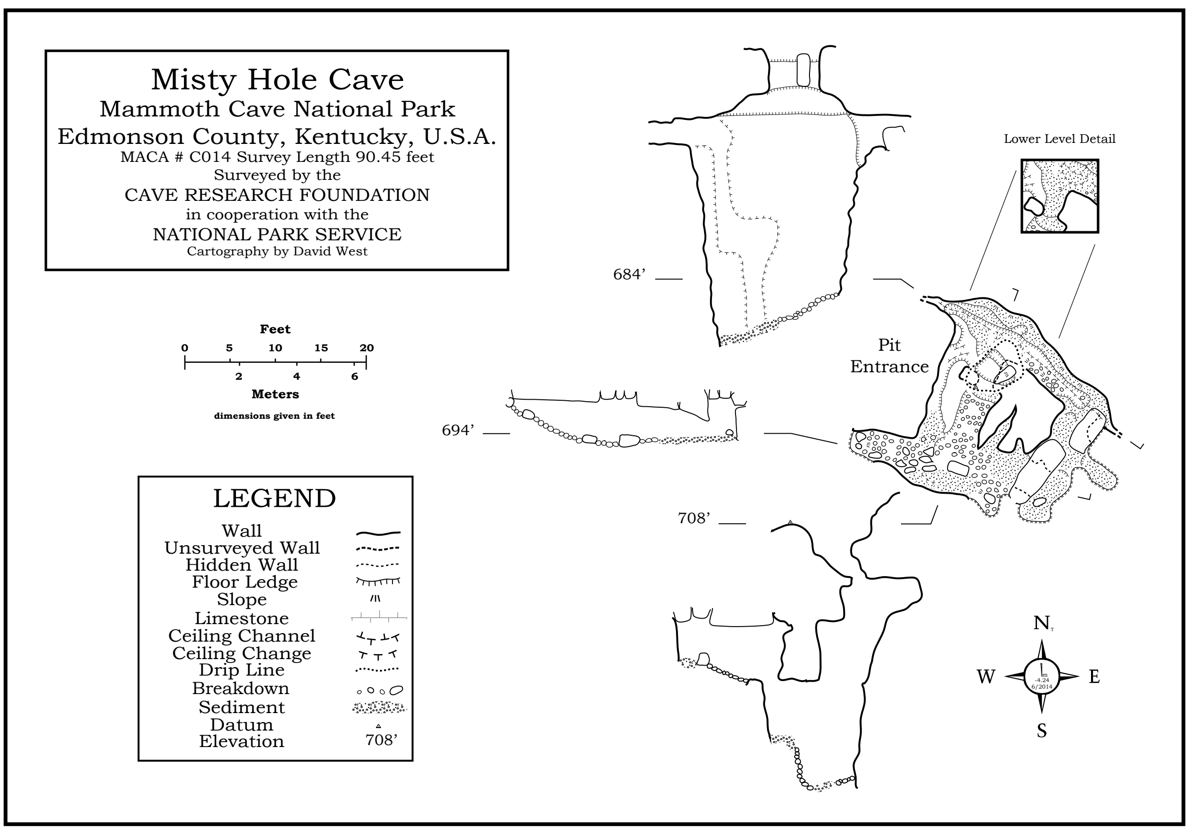
1. Two expeditions have fielded parties in the evening to assist Dr. George Crothers with the saltpeter

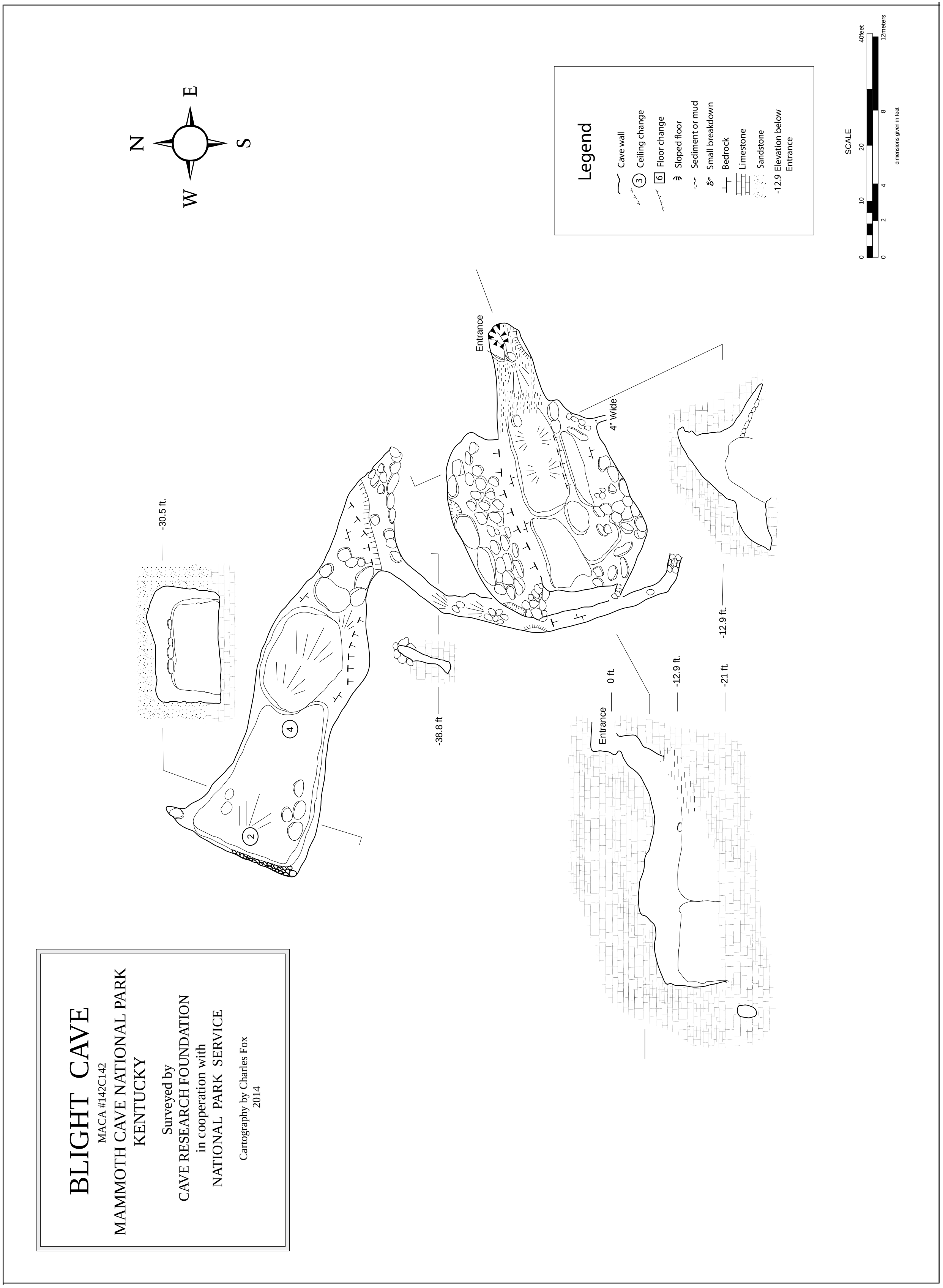
equipment preservation project by providing personnel to move wooden pipes and timbers to and from the preservation area.

2. EO is currently working on a WNS video for the Monongahela National Forest. Video footage has been completed and the final script is under development.
3. The MACA caving safety video is being revamped. Some footage has been shot, and the video will be completed after the Forest Service WNS video is finished.

Challenges/Opportunities

1. Eastern Operations has been operating at a loss for the last four years. While EO has surplus funds, this is not a sustainable situation for the long term. Several steps will be taken to fix the problem.
   a. Expedition fees will be raised by $2/day in 2016.
   b. We have identified food as a major source of cost overrun for many expeditions. A suggested per person per diem will be provided to the ELs and camp managers.
2. Many ELs are unaware that an EL manual exists. The EL manual is going to be revised and updated to reflect current procedures and practices and made available.
3. The Forest Service WNS video project provided EO funds to obtain good quality video equipment. After completing the project, we envision producing survey and other educational videos.
4. EO has made some efforts at adding restoration work as a regular activity at expeditions. We have an interest in doing small scale restoration work in New Discovery and other areas. Bill Copeland (Director, NSS Restoration Camp at MACA) and I have had an ongoing discussion concerning cooperative projects.
5. Bill Steele has contacted us about integrating Explorer Scouts into CRF expeditions at MACA, probably next July. After determining that these individuals will all be 18 years old or older, we will sign them up as JVs and provide the opportunity requested.
6. The general membership of CRF is aging. We will be looking for ways to draw in new people in the next few years.
7. EO will work with MACA to try to expand our opportunities to support research activities beyond cartography.




BLIGHT CAVE
MACA #142C142
MAMMOTH CAVE NATIONAL PARK
KENTUCKY
Surveyed by
CAVE RESEARCH FOUNDATION
in cooperation with
NATIONAL PARK SERVICE
Cartography by Charles Fox
2014
N
E
S
W
Legend
Cave wall
Ceiling change
Floor change
Sloped floor
Sediment or mud
Small breakdown
Bedrock
Limestone
Sandstone
-12.9 Elevation below Entrance
SCALE
dimensions given in feet
Entrance
4" Wide
-30.5 ft.
-38.8 ft
-12.9 ft.
0 ft.
-12.9 ft.
-21 ft.
Entrance

Small (Lesser) Cave News for 2014–2015

Bill Copeland

The last two years has been very productive for the Small Cave project in Mammoth Cave National Park. Seth Spoelman took over the project in 2014 and since I was actively ridge walking and coming to expeditions, I am serving as Seth's pseudo assistant. After taking Pat Kambesis's survey class through Western Kentucky University, my book skills got good enough to begin mapping some of the small caves as well.

During the last two years less emphasis was placed on finding new caves and more on surveying the ones we know about and drafting maps of previously surveyed caves. After reading the CRF reports for the last two years, I came up with the following numbers.

The entrance to Cathedral Cave, above the Green River.

- We surveyed 14 small caves, and in most cases, the final map was drafted.
- 8 final maps were drawn from previously surveyed caves.
- 14 new caves were added to the inventory including one new one I found on December 29th 2015.

Seth is currently reworking out database to look more like Scott House's Missouri version. It will be user friendly, and when implemented, it will help us and the NPS not only keep track of all the small caves, but more importantly, will help the NPS keep track of the diverse biota found in many of these small caves. Therefore, it is imperative that we not only make maps, but report on any biota, items or signatures of possible historical significance, and any items of possible archaeological significance. This is where the new database will come in to play. I would ask that after any trip, the trip leader after writing his/her trip report to take a few minutes to fill out the form in the small cave database (after it is implemented) to keep the database up to date. I would also ask the book person to finish the final map in a timely matter, and if you are not proficient with Illustrator, let me know, and I will see it gets done.

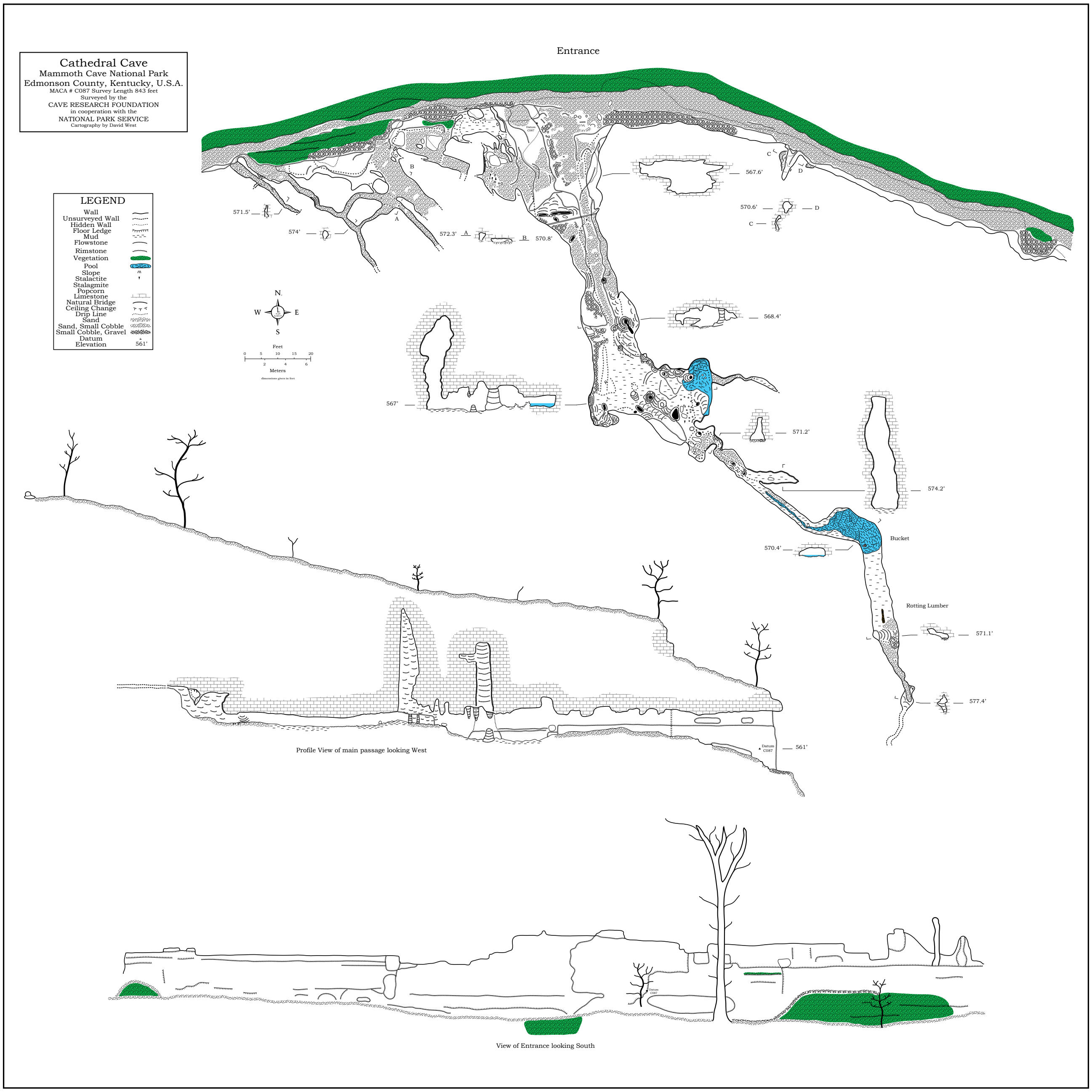
In October 2013, I spent 11 days at Hamilton Valley reworking the small cave files. The caves files north of the river were in pretty good shape, but the files south were a mess. During that time I examined all the files, and made a folder for each cave the CRF had any information on, including an entrance picture, final map, a topo map showing location, and a print out of each cave from the database.

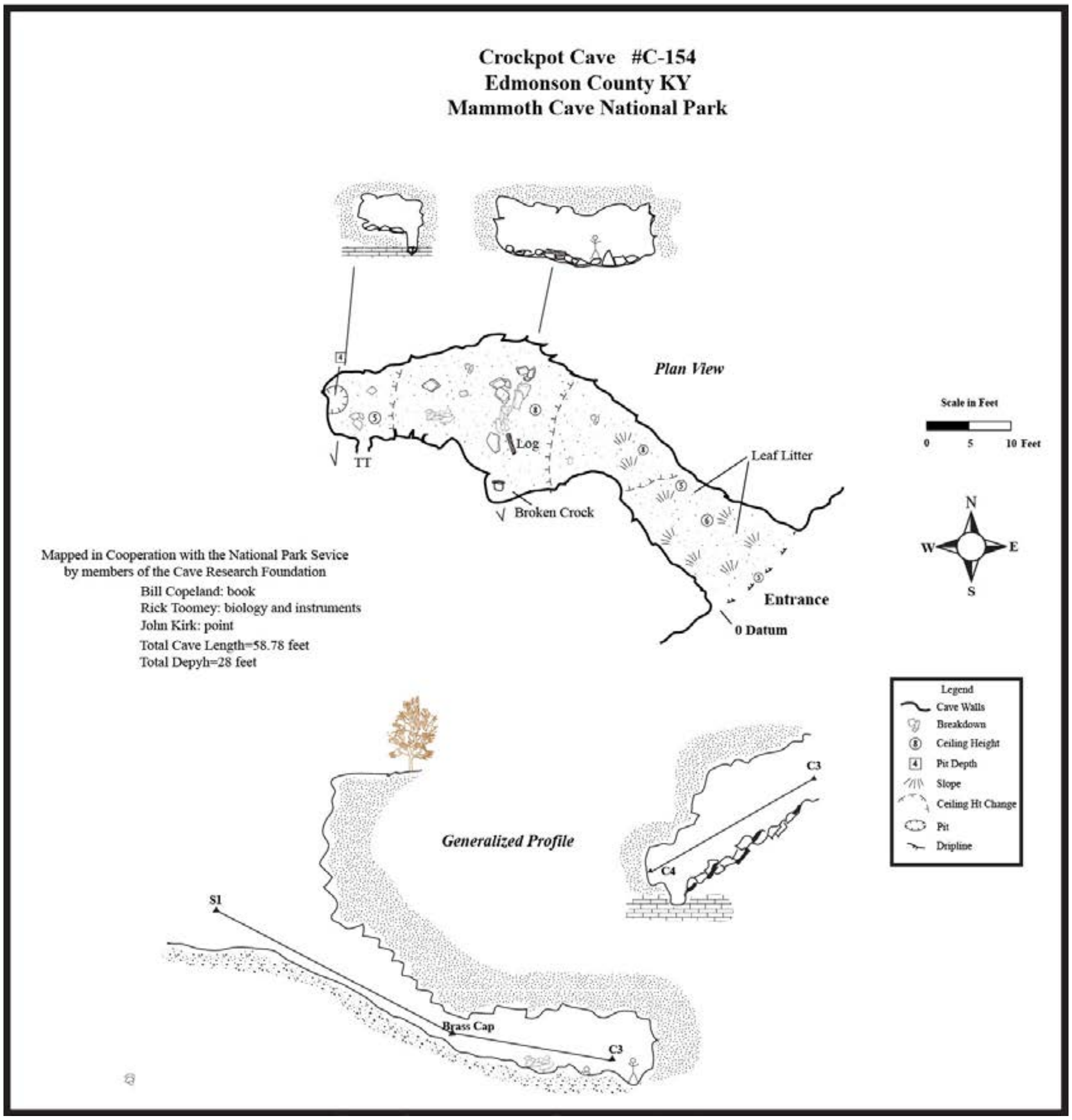
The files are arranged by cave number either north or south of the Green River. There is also a spreadsheet cross referencing cave name and cave number.

At the time of this writing, I come up with the following numbers:

• Total verified caves	424
• Need Survey	245
• Need Final Map	42
• Completed	137

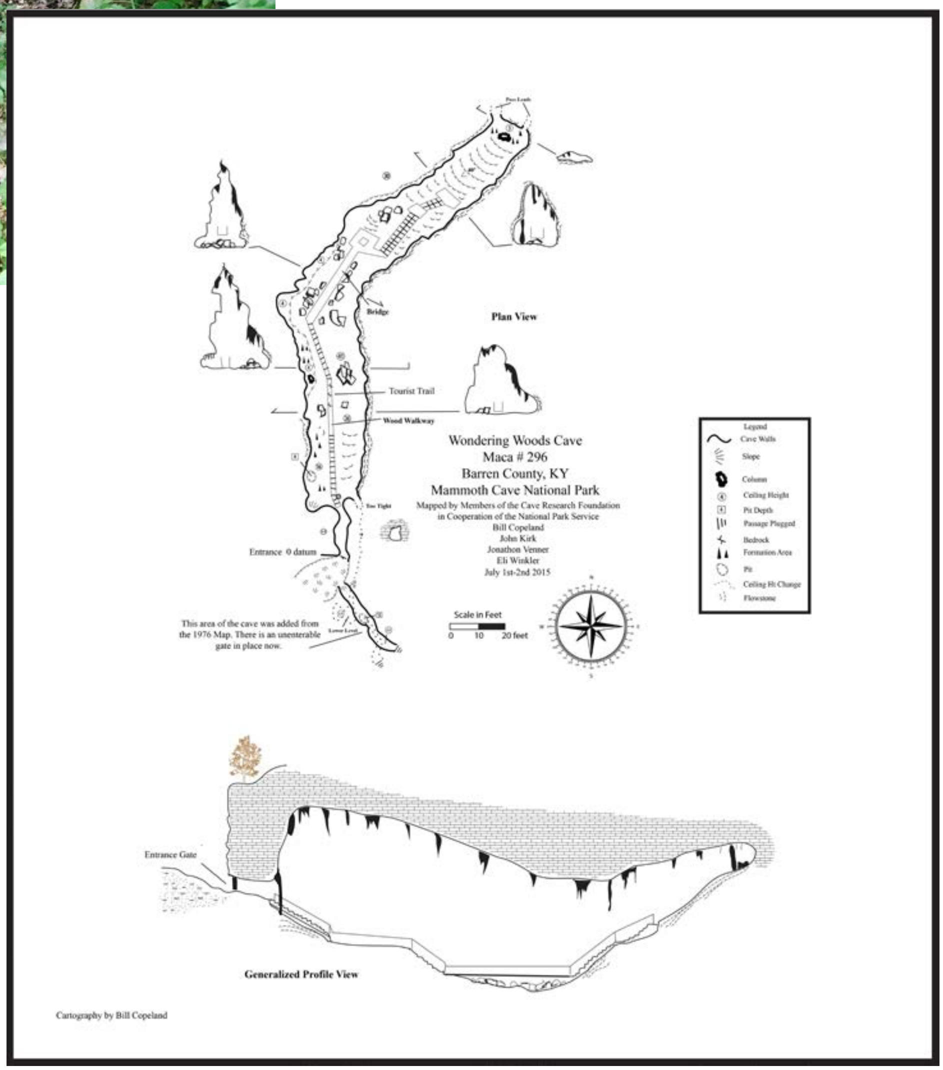
I also have 64 possible locations that need one final look. These locations are from old files, or old marks I took off some old topographic maps. As you can see, we only have about half of the total locations surveyed, so there is still plenty to do. I must confess though that most of these small caves are actually pretty small (less than 50 feet long), and most of us I would assume would not call them caves, but because these caves do contain cave biota, the Park would like them documented, and surveyed.





The entrance to Crockpot Cave.

The entrance to Wondering Woods Cave, a former commercial cave.



Overview of Lava Beds Operations 2014–2015

John Tinsley

Manager, CRF-LABE Operations

Lava Beds National Monument is situated on the north slope of Medicine Lake Volcano (MLV), an ~8000-foot high, shield-shaped volcano that, along with Oregon's Newberry Volcano, vies for the title of largest volcano (greatest volume) in the Cascades province of the western United States. Many Cascades volcanoes are taller; Mt. Shasta and Mt. Rainier, for example, are stratovolcanoes composed of lavas, ejecta, and intrusive domes that exceed 14,000 feet in summit elevation. The shield-shape of MLV compared to its stratovolcano cousins owes to the preponderance of relatively fluid lavas and multiple eruptive vents that during the past 0.5 million years or so have deposited the broad, massive but lower volcanic edifice that we observe today. MLV sits at western limit of the Basin and Range province, a geologic province characterized by crustal extension, normal faulting, and a variety of types of lavas ranging from those relatively rich in silica to low-silica. The most fluid lavas tap sources in the earth's mantle, are low in silica, erupt along major crustal fractures with little or no mixing with more silica-rich continental rocks, and thus are quite fluid and make impressive arrays of lava tube caves. Other eruptives show varying degrees of mixing with crustal rocks, or effects of magma differentiation at depth, and are significantly more viscous, less "runny" and thus form few or no lava tube systems. The vast majority of LABE's nearly 800 caves are developed in a single flow unit, the low-silica basalt of Mammoth Crater, erupted about 35,000 years ago. The youngest eruptions of MLV are less than 1000 years old. Publications by Julie M. Donnelly-Nolan (among others) convey the geological details for anyone interested in further aspects of the geology of MLV.

Karen Willmes, John Tinsley, Dave Riggs (NPS), and Dave West on a Lava Beds geology field trip. *Ed Klausner*

The 2014–2015 field seasons were highly productive for the Cave Research Foundation (CRF) at Lava Beds National Monument (LABE). NPS management has kept the Research Center operational all winter, CRF joint venturers turned out in force and the results extolled below will speak for themselves. In addition to the customary long-weekend expeditions (Presidents' Day, Memorial Day, July 4, Labor Day, Columbus Day and Thanksgiving) CRF personnel from Iowa, Missouri, Maryland, and Arkansas conducted multiple three weeklong expeditions in 2014 and another 3 expeditions in 2015 that concentrated on major cave-bearing areas of the Monument outside the Cave Loop system. Surveys of a major new find are largely complete, and the scientific potential associated with this survey has stimulated new research on the eruptive history of the Mammoth Crater flow, as articulated below.

As with most CRF operations, the chief effort in terms of person-hours is expended with cave cartography and inventory. At LABE, a concerted effort has been made to have each CRF principal investigator (PIs) work largely within particular geologic map units or in individual flow lobes within a given lava flow. The result of this practice is that over a period of years, we accumulate a suite of cave data that reflects the geology, petrology, hydrology, and biology of particular flow units, rather than random observations across the Monument's hundreds of caves. The expectation is that we will achieve unprecedented insights about geological controls on cave morphology at LABE.

Research Project Overviews

Presently there are 9 principal investigators conducting NPS- or USFS-approved research projects under the CRF umbrella at Lava Beds. Much of the CRF effort is aimed at providing the NPS Resources Management with cave maps showing plan, profile, sections, and supporting data

Paul McMullen and Mark Jones in Steamboat Frank Cave. *Ken Walsh*

for the caves of particular interest to management. Brief comments about these projects follow.

1. Bill Broeckel—Modoc National Forest: This survey and inventory project initially addresses caves that are geologically part of the caves in the Monument, but which were geographically excluded from the Monument when the enabling legislation was passed, owing to the politics at the time that wished to retain significant timber resources for commercial purposes. Most of these caves are small, but at least one is a huge new find that has stimulated additional research and contains evidence of internal eruptive events that cemented preexisting breakdown.
2. Scott House and his dedicated crews have essentially completed the cave survey and inventory of the Hardin Butte area, specifically the North Castle and South Castle flows being emphasized initially. Now with nearly 90 maps drawn and forwarded to the NPS and other maps in progress, this effort continues to unearth new discoveries and document lava flow links and systems in these units that are distinct from the basalt of Mammoth Crater. Access now requires more hiking as the NPS has abated the old Power Line Road, so future work will require stout hikes as well as able surveyors. They typically travel from the Midwestern USA for extended periods of time once or twice per annum to conduct these surveys.

3 and 4. Dave West and Ed Klausner have essentially completed the Balcony Boulevard system (West) and the Post Office system (Klausner) respectively. Post Office is a very cold multi-level cave, and surveyors tend to get chilled while working there. Balcony Boulevard is a significantly warmer system. A daily routine has evolved as morning surveys are conducted in Post Office Cave until natural refrigeration chills out the survey crews. Then they exit the cave for lunch, then survey in the warmer Balcony Boulevard system in the afternoon and early evening. Maps of these systems have been forwarded to NPS, and work continues on ancillary elements of these products of the Mammoth Crater basalt. They typically travel from the Midwestern USA for extended periods of time once or twice per annum to conduct these surveys.

Ed Klausner in Post Office Cave. *Ken Walsh*

5. Liz Wolff continues making impressive progress on the Cave Loop cave surveys, and presently is surveying Garden Bridges and environs; Liz has submitted a stream of completed maps including those showing the Labyrinth Cave and Sentinel Cave complexes to NPS and more maps are following in short order. The major elements of the Cave Loop system, truly milestones for this research project, enable cogent analyses of the potential for new finds and connections in this segment of the Mammoth Crater basalt, an area frequented by most of the public who visit caves at LABE.
6. John Tinsley has completed the re-survey of the main passage of Craig Cave, probing beyond the breakdown that halted the former survey by Aaron Waters more than 40 years ago. He has added profiles, sections, and survey data that are missing from the Monument's cave survey database. The surveying should be completed in 2015, with the surveys of Craig Temple and the extensions and a completed map is anticipated in 2016.
7. Peri and Bill Frantz conduct the principal photo-monitoring of selected LABE caves, working closely with Resources Management. This work was initiated with the initial CRF work at Lava Beds in 1989, when Janet Sowers led the effort to establish a CRF presence there at LABE.
8. Bill Devereaux conducts ice-level monitoring in selected ice caves at LABE. Initiated prior to CRF involvement at LABE by Mike Sims, Don Denbo, Devereaux and others, this monitoring effort is one of the longer-standing data collecting efforts in the Monument, and is a key aspect of learning about the impact of effects of global warming and changing climates on Monument caves. Bill has retired from NPS service and has made a concerted effort to acquaint others with the nuances of ice level monitoring of LABE caves. CRF is keenly interested in keeping this monitoring effort going.
9. Heather McDonald, Matt Leissring, and Beej Jorgensen have initiated a cartography and inventory project addressing the caves of the Valentine Cave basaltic andesite flow. This flow is about 12,500–13,000 years old, overlies the basalt of Mammoth Crater in many places, and contains Valentine Cave with its remarkable pahoehoe lava floors and other flow features. This project will yield definitive data on the distribution and morphologic features of lava caves formed in a flow that is close to the upper limit of silica content for easy flowage, and thus will be of interest to vulcanospeleologists as the data set develops.
10. John Tinsley and Julie Donnelly-Nolan initiated a study of late-stage lavas of the basalt of Mammoth Crater, to learn if decreasing potassium content of the lava can be used to distinguish the relative timing of the eruption among the various lobes of Mammoth Crater basalt. As the Mammoth Crater basalt spawned some 85% of the lava caves of LABE, learning which lobes developed first would be of interest for interpretive and for geologic purposes. The existing data for MLV's lavas relies chiefly on surface exposures. The present study led by Tinsley and directed by Donnelly-Nolan will sample the youngest lavas that came through the tube systems, these being the pahoehoe floors of lava tubes in the respective lobes of the Mammoth Crater flow. Sampling should be conducted in 2016 with results and publications to follow, data permitting.

Future Work

Prospects for future CRF work at Lava Beds are promising. John Tinsley and Julie Donnelly-Nolan are teaming up to complete a USGS Fact Sheet on Lava Beds National Monument. Julie has written a draft, Tinsley has re-photographing landscapes and features to provide digital images that make for better illustrations in a digital publication compared to what one can obtain by scanning Kodachrome slide images, and NPS management at Lava Beds has approved the content of the document.

We always are seeking new principal investigators and others with creative ideas we can beg, borrow, or conscript in order to learn more about the underpinnings of Lava Beds National Monument.

Lava Beds Expedition Report

Scott House

Principal Investigator

March–April 2014

Trying to beat the removal (restoration) of the Powerline Trail, we organized an early-year expedition to work on the North Castle Flow, near Hardin Butte.

Don Dunham and Scott House flew in from St. Louis, while Mark Jones took a detour on the way back to Illinois from Arizona and filled out our crew.

Friday, March 28, 2014: Don, Scott, and Mark, along with NPS tech Katrina Smith mapped several caves on the south end of the project area. The largest was an extension of Battlefield Cave which Mark poked around and found. Three of the caves mapped were new finds.

Saturday, March 29, 2014: Don, Scott, and Mark (The Three Amigos) surveyed six more caves on the south area of the project. At least one of these was new—sometimes hard to tell from the previous data. The most interesting was a large collapse sink of an apparent vent.

At the research center, John Tinsley spent the day working on data and other matters. Bill and Peri Frantz spent their day processing photos and updating data from their photo-monitoring project.

Sunday, March 30, 2014: Joined by John, the trio headed to the north end of the project area. We resurveyed part of Spotlight Cave and tied into old stations in order to use as much of the previous survey (from 2001) as we could. Another nearby cave was also surveyed, and we spent the remainder of the time doing some surface survey and sorting out what was what in that area.

Meanwhile Bill and Peri shot sites in Big Painted Cave as part of their project. They also did some monitoring in Symbol Bridge.

Monday, March 31, 2014: The day was spent in data work, meeting with the NPS, tidying up gear, and catching up on paperwork. An attempt was made to get to Glass Mountain, outside of the park boundaries, but deep snow prevented that.

Tuesday, April 1, 2014: April Fools' Day came and went with no pranks. Don, Scott, Mark, and John surveyed (resurveyed as it were) Circle Cave. This is an intricate mess, with two or three levels within about 10 vertical feet. The small cave mapped on Sunday was also tied into the survey and is arguably part of the same cave. All told, the cave ended up being about 1000 feet in length. In places, a long-armed individual could stick their hand through the roof and wave.

A sleeping bat. *Mark Jones*

Wednesday, April 2, 2014: Don, Scott, and Mark, reinforced by interpretive ranger Patrick Taylor and interpretive intern Larisa Proulx, successfully mapped Moat Cave, a strangely vertical cave on the south end of the project. The cave was nearly pristine because of the difficulty in traversing it. Later, we all surface searched some areas, and did surface survey between some of the caves at the north end of the area. We also located some new caves at the southwest end of the project area, which were probably in the South Castle Flow, rather than the North Castle. Scott and Mark took a different way back, being picked up on the highway by Don. Several caves along the route manifested themselves but were technically out of the project area.

Thursday, April 3, 2014: The Three Amigos, now reinforced by Katrina Smith, resources intern Amy Rasmussen, and interpretive ranger Jesse Barden surveyed another five caves, mostly at the north end of the area. The largest was Pumice Scroll Cave, a nice feature. One new, very pristine cave was located and surveyed, with Katrina doing a nice sketch on it.

Friday, April 4, 2014: We caught up on data, cleaned and packed our gear. Bill Broeckel showed up and he and Mark went to Modoc National Forest land nearby and surveyed in a cave while Don and Scott entered data and did some research on the Thomas-Wright battlefield.

During the week, 19 caves were surveyed in the Hardin Butte / North Castle Flow area, for a total of over 2700 feet. Several new caves were located and GPS locations were improved on several other caves. At least three reported "caves" were determined to not be large enough for cave status.

We very much appreciate the support of the various folks from Lava Beds who worked with us in the field and/or provided support.

- Field hours: ~204
- Onsite lab/support hours: ~40
- Miles driven by POV: ~5300

April 2015

The primary objective of this expedition was to finish up cartography and inventory work in the North Castle Flow and begin work on the South Castle Flow, as authorized in this year's research project permit. Further, work was to begin on this year's I&M caves project permit involving several high-priority caves that previously lacked vertical control.

Paul Hauck sketching in a lava tube. *Mark Jones*

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

Thursday, April 2, 2015: Two teams were fielded in the same general area north of Hardin Butte. House, Dunham, and Jones stopped at a couple of known, already surveyed caves, to proof data and sketches. They then surveyed West Trench Cave, Temptation Cave, and Bitterbrush Cave for a total of 480 feet. Hauck, Young, and NPS interpreter Casey Chalmers surveyed East Trench Cave and Funnel Cave. They also did an archaeological reconnaissance of Scapula Cave.

Friday, April 3, 2015: Two teams were again fielded in the Hardin Butte area. Young and Hauck assessed cultural evidence at Aladdin and Blowhole Caves. House, Dunham, and NPS Resource Intern Priscilla Watson-Wynn surveyed Tympani Tube and searched for new caves. All party members helped relocate a couple of brass caps, one of which had been deliberately hidden and tied in an adjacent cave to the Aladdin survey net. Later House and Dunham surveyed Sand Butte Tube, a new cave in the South Castle Flow near Hardin Butte. A third party of Jones and Bill Broeckel surveyed in a cave that originates on Modoc National Forest and runs under NPS boundaries.

Saturday, April 4, 2015: Two parties again went to Hardin Butte. Hauck, Broeckel, and Jones surveyed Witness Cave and a new cave, Little Hummock Cave. House, Dunham, and Young surveyed the following caves in the South Castle Flow: Alien Graveyard Cave, Eclipse Cave, and Trepidation Cave—the latter two are new caves. Later, the entire party surveyed a new small tube, Mossy Crawl Tube.

Sunday, April 5, 2015: House, Dunham, Jones, Hauck, and Young surveyed Castle Cave in the Merrill Trench for 295 feet. The cave was 80 feet deep and is a good cold trap.

Monday, April 6, 2015: House, Dunham, Hauck, and Young surveyed Beaconlight Cave for a total of 545 feet. The cave was very cold and had a vertical range of 68 feet.

Tuesday, April 7, 2015: House, Dunham, Hauck, and Young surveyed Kirk White's Cave and Igloo Cave in the Merrill Trench. The total survey, including surface ties, was 543 feet and the vertical range from the sink rim was nearly 80 feet.

Wednesday, April 8, 2015: The day was spent looking at a few sites, cleaning the research center, washing clothes, identifying photographs, and writing reports.

Seventeen caves were cartographically surveyed. Four of those were in the Merrill Trench, four were in the South Castle Flow, and nine were in the North Castle Flow.

For the most part, fieldwork in the North Castle Flow is finished. A final recon of the area, filling in blank areas is contemplated for next year. The South Castle Flow component of the research project is now initiated. Fieldwork on the limited I&M project (apportioned to House) is completed.

Attached to this report are two archaeological reports from field investigations in the North Castle Flow.

We very much appreciate the support of the various folks from Lava Beds who worked with us in the field and/or provided support.

- Field hours: ~226
- Onsite lab/support hours: ~30
- Miles driven by POV: ~5300

Archaeological Assessment of Scapula Cave

April 2, 2015

Richard A. Young

Scapula Cave was visited by a CRF crew comprised of Paul Hauck, Casey Chalmers, and Richard Young on April 2, 2015, during a mapping survey of tubes in the vicinity. Although previously mapped, Scapula Cave was investigated on this occasion to determine if it had been utilized as an archaeological site. This investigation consisted of only a pedestrian survey of the cave.

Upon entering the cave, it was immediately evident it contained numerous mammal bones but no articulated remains. Scattered throughout the passage, these bones appear to be those of deer. Although many of these bones are intact, close examination of the cave floor reveals that much of the skeletal material has been broken and split to access the marrow cavities. Most show no evidence of damage from the teeth of predators, and one must consider that much of the fragmentary material is the bi-product of butchering activity.

In addition to the scattered mammal bones, numerous tertiary obsidian flakes were observed on the cave floor. The largest of these lies along the right wall perhaps 50 feet from the entrance. It is approximately 1½″ wide and 2½″ tall and comprised of black obsidian with multiple flake scars on its dorsal surface. This flake is surrounded by several split mammal bone fragments. Perhaps 10 feet farther into the cave, two additional obsidian flakes lie on the floor against the right wall. These too exhibit multiple flake scars and seem to be associated with fragmented mammal bone.

Sixty feet from the entrance what appears to be a cache of four corner-notched bifaces are clustered in two pairs within one foot of each other. These projectile points are of grey chert (?), and all measure 1″ tall by ⅝″ wide. Each is carefully crafted and one is serrated. The point lying within 4″ of the serrated piece was executed on a tertiary flake and flaked on only one surface. This point was covered by a stone. The remaining two arrow points lie no more than 2″ apart and were found beneath a single flat rock fragment. These four points lay in an area containing split mammal bone fragments and a large number of chert and obsidian tertiary flakes. A milling unit (metate) sits one foot below and to the right of this small cache of bifaces. The dimensions of this milling unit are 10″ × 14½″ × 2½″. It is comprised of an unidentified igneous stone.

Except for lifting overlying stones and securing photographs, none of the described artifacts were disturbed and all remain where they were observed. Given what was seen during this brief pedestrian survey of the tube, it is apparent that Scapula Cave is an intact archaeological site that justifies further investigation.

Archaeological Inventory of Aladin Cave and Blowhole Cave

April 3, 2015

Richard A. Young

On April 3, 2015, Paul Hauck and Richard Young conducted a pedestrian survey of Aladin Cave. After descending the entry slope into the cave, two possible expedient metates were observed. The first lies on the floor on the left side of the entry room. Comprised of vesicular basalt its dimensions are 12″ × 10″ × 3¾″. It exhibits a shallow trough producing an oval basin. Also to the left, approximately 12 feet farther into the entry chamber, a second possible expedient metate was encountered. This specimen's dimensions are 20″ × 24″ × 7″ and like its companion it is composed of vesicular basalt. It exhibits a deep oval depression with relatively smooth surfaces. Both milling units sit securely on the floor with their troughs facing up. There is ample ceiling height to have allowed these units to have been comfortably utilized in situ. Despite this, a search for associated cultural material produced nothing except a few fragmented mammal bones.

The remainder of Aladin Cave was investigated for evidence of cultural material and nothing convincing was encountered. The assumed milling units were photographed and left undisturbed.

During the afternoon of April 3, 2015, Hauck and Young initiated a pedestrian survey of Blow Hole Cave. This feature contains an oval room that is 43′ wide, 80′ long, and 20′ high. At the center of this chamber, a small and inaccessible skylight would have allowed the smoke of campfires to vent out the occupation space. At the base of the entrance slope, and to its right, relatively level floors would have provided useful and relatively well-lighted activity areas. Our survey produced ample evidence of prehistoric activity within the site.

Two likely metates (grinding stones) lie within the cave's entry chamber apparently in situ upon the flat floors just below the entrance. The first lies just to the right of the entrance. Bathed in natural light during our visit, this suspected milling unit is composed of vesicular basalt and its dimensions are 16″ × 12″ × 3½″. It exhibits a deep basin with moderately smooth interior surfaces. Another possible milling unit sits on the gently sloping floor just below and to the left of the previously described metate. This specimen is rectangular in shape and measures 6½″ × 5½″ × 6″ high. Its surface is ground into a very shallow basin, which appears quite distinct when bathed in raking sunlight.

Moving along the right wall of the cave's oval chamber, a beautiful ground-stone pestle lies on the floor within a rat midden. It is cylindrical in shape with a blunt end and a moderately pointed opposite end. It is apparently constructed of country rock (local igneous) but unlike most of the nearby flows exhibits no open vesicles. There is battering on the blunt end of the artifact while the pointed end is quite smooth. Its dimensions are 10″ long and 3½″ in diameter. On the gently sloping floor, in front of the pestle, five black obsidian flakes were located. All of these were tertiary flakes, and most revealed multiple flake scars on their dorsal surfaces. None, however, exhibited evidence of utilization. The largest of these flakes measured 1¼″ × 1″ while the smallest measured ⅜″ × ⅜″.

Numerous mammal bones are scattered throughout the chamber. Unfortunately, no teeth were observed, so it was not possible to determine the species of the remains. Several ribs and fragments of long bones suggest at least some of the skeletal remains are from deer. While a small number of these bones are intact, most are fragmented and split. Although such mammal remains can be introduced through a variety of agents, it is possible at least some of this material is the byproduct of human agency.

Numerous charcoal fragments are scattered about the cave floor. These may represent evidence of human activity within the tube, but it is also likely that much of the charcoal was introduced by rats after local ground fires. There is ample evidence of rat occupation throughout the cave.

During this pedestrian survey photographs were secured, but all artifacts were left undisturbed.

Rachel Bosch using a disto. *Ed Klausner*

Elmer's Trench

Lava Beds National Monument

Ed Klausner

Elmer's Trench is one of the seven distinct flows originating from Mammoth Crater about 35,000 years ago. This flow spread north from Mammoth Crater. There are 85 known caves in Elmer's Trench, some of them mapped. A Research Permit was granted by the Monument to find and survey the caves in Elmer's Trench. Four Star Cave is in Elmer's Trench and is part of the Inventory and Monitoring program (I&M) of the National Park Service. Four Star Cave had been mapped along with neighboring Pearl Cave and Fifth Star Grotto by the CRF as part of the I&M program.

In September of 2015, the first of many trips was taken to map the caves in Elmer's Trench. Since Elmer's Bridges (consisting of Elmer's Upper Bridge, Elmer's Middle Bridge and Elmer's Lower Bridge) were known to have bats, that seemed like a good place to start mapping. These maps can be taken in the field to identify where exactly in the cave the bats are found.

On the way to Elmer's Bridges from the Balcony/Boulevard parking area in the Monument, we found several additional caves that were not part of the inventory of known caves in the flow. This is not surprising as the work of Scott House in North Castle Flow and Dave West in Balcony/Boulevard Flow showed that there were many more caves present than had been previously documented in the Monument.

We were successful in completing the survey of two of Elmer's Bridges: Elmer's Lower Bridge (Figure 1) and Elmer's Middle Bridge (Figure 2).

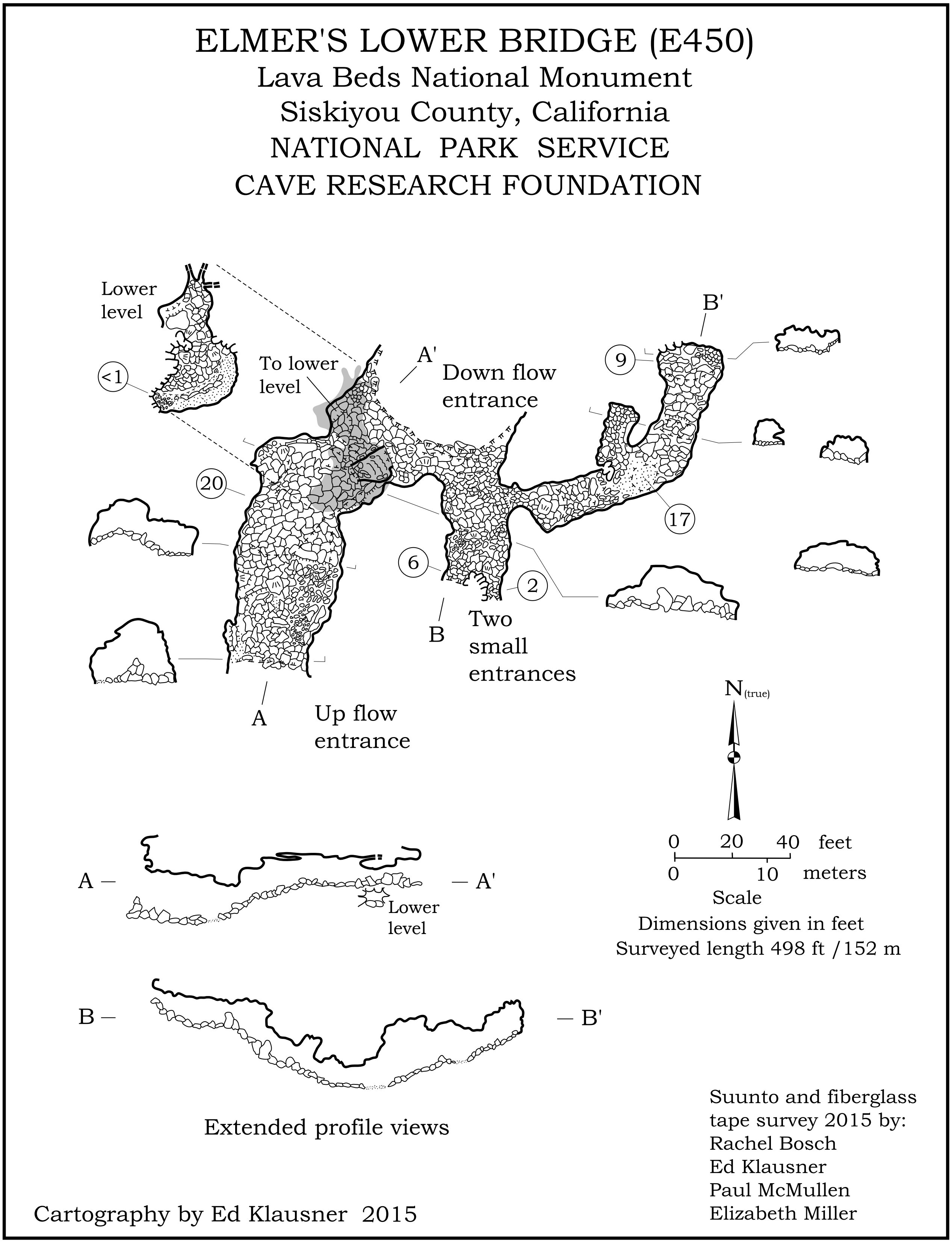


Figure 1. Elmer's Lower Bridge.

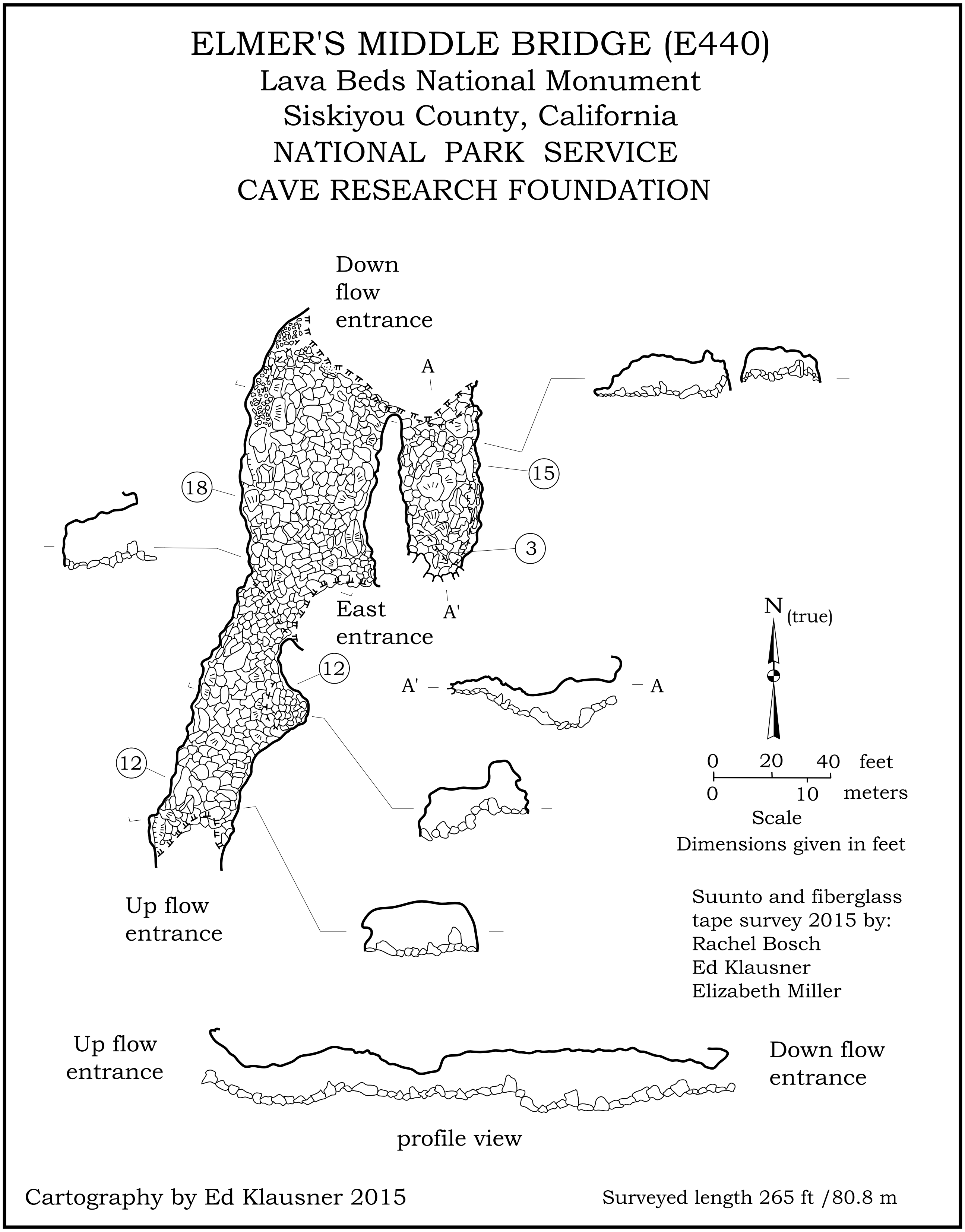
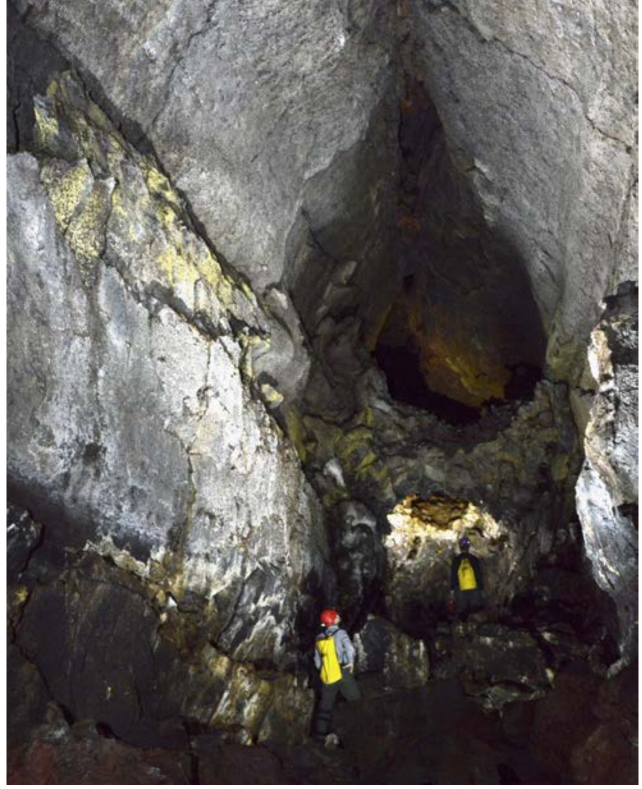


Figure 2. Elmer's Middle Bridge.

Post Office and Silver Caves

Lava Beds National Monument

Ed Klausner



Dave Riggs and Paul McMullen in Post Office Cave.
Ken Walsh

Post Office Cave is part of the Inventory and Monitoring Program of the National Park Service. As such, the Monument asked for a survey of this cave so interns, researchers, and park employees can use the map to note items they find along with the date and location. In addition, the monument wanted a map that included Silver Cave, which was thought to be a separate cave by J. D. Howard when he explored and named both in 1918.

A survey was started in 2012 and completed in 2015. Twenty-two surveyors went on a total of 23 survey trips during this time period to complete the survey. David Riggs, Physical Science Technician for the Monument, rigged the drop from Silver Cave to Post Office Cave and is thought the first to actually make the connection. The total surveyed length of the system is 7969 feet.

Post Office and Silver Caves were formed in the basalt of Mammoth Crater from a flow 35,000 years ago. The flow originated in lower north flank of Medicine Lake Volcano. The highly fluid basaltic flow was ideal for the formation of lava tubes.

The down-flow entrance of Post Office Cave reminded J. D. Howard of a post office as there are many pockets in the walls near the entrance. J. D. Howard did not find the small, corkscrew passage that led to the major part of the cave.

Post Office Cave was the result of several different flows and is thus multileveled. The route to the lowest level goes down about two hundred feet from the up-flow entrance. It is also cold at the lowest level, about 32 degrees, and it can be quite windy. Figure 1 shows some of the complexity of the cave.

Silver Cave has hydrophobic bacteria in sheets on the walls and thus produces water droplets that give off a silvery sheen when light reflected off the surface. This caused J. D. Howard to name it Silver Cave. In the up-flow direction, there is a 15-foot long low spot that stops many cavers from getting through. J. D. Howard did not make it through and thus missed several hundred feet of the cave along with the connection to Post Office Cave.

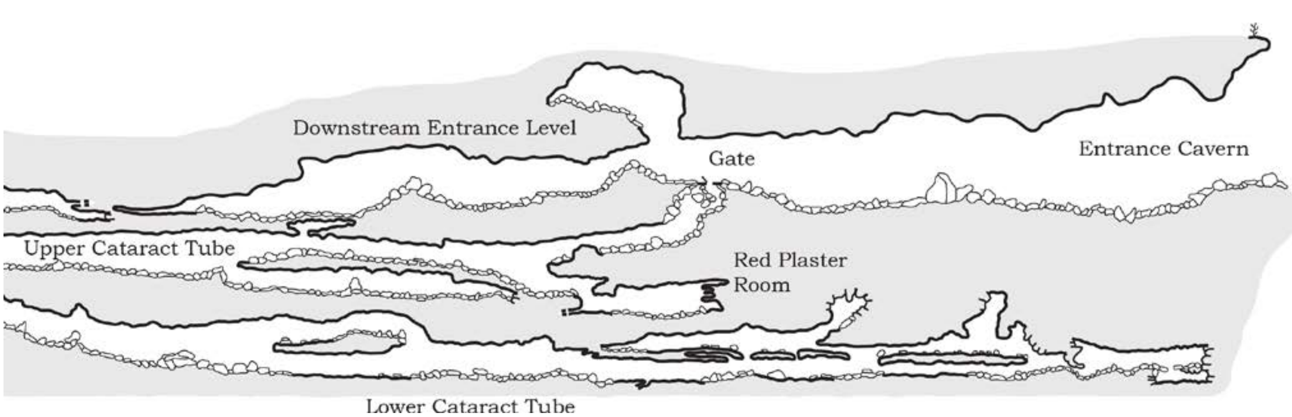


Figure 1.

Balcony/Boulevard Mapping 2014–2015

Lava Beds National Monument

Dave West

2014

In December 2013, I agreed to draw up the map of Upper Cavern in the Balcony flow, which Scott House and Don Dunham had mapped earlier that year. This cave had been included with maps of the Balcony/Boulevard caves area published by USGS, which would also be mapped for the Monument's Inventory and Monitoring program. To that end, in 2014, two week-long expeditions were held, one in June and another in October. These were in conjunction with work by Ed Klausner on Post Office Cave and John Tinsley on Craig Cave.

Having already determined that Post Office Cave was very cold, Ed and I worked together on our projects, with me assisting him in Post Office Cave in the morning. We would then come out for lunch, warm up a bit, and head over to Balcony/Boulevard where we would then work in warmer environs in the afternoon. It was decided that since the USGS maps were missing both cross-sections and profiles, we would be certain to include these in our maps, as well as more detail not only of the caves, but also of the trenches and grottos associated with them. As the overburden is relatively shallow, surface surveys would be conducted over each of the cave surveys to give a full representation in profile views.

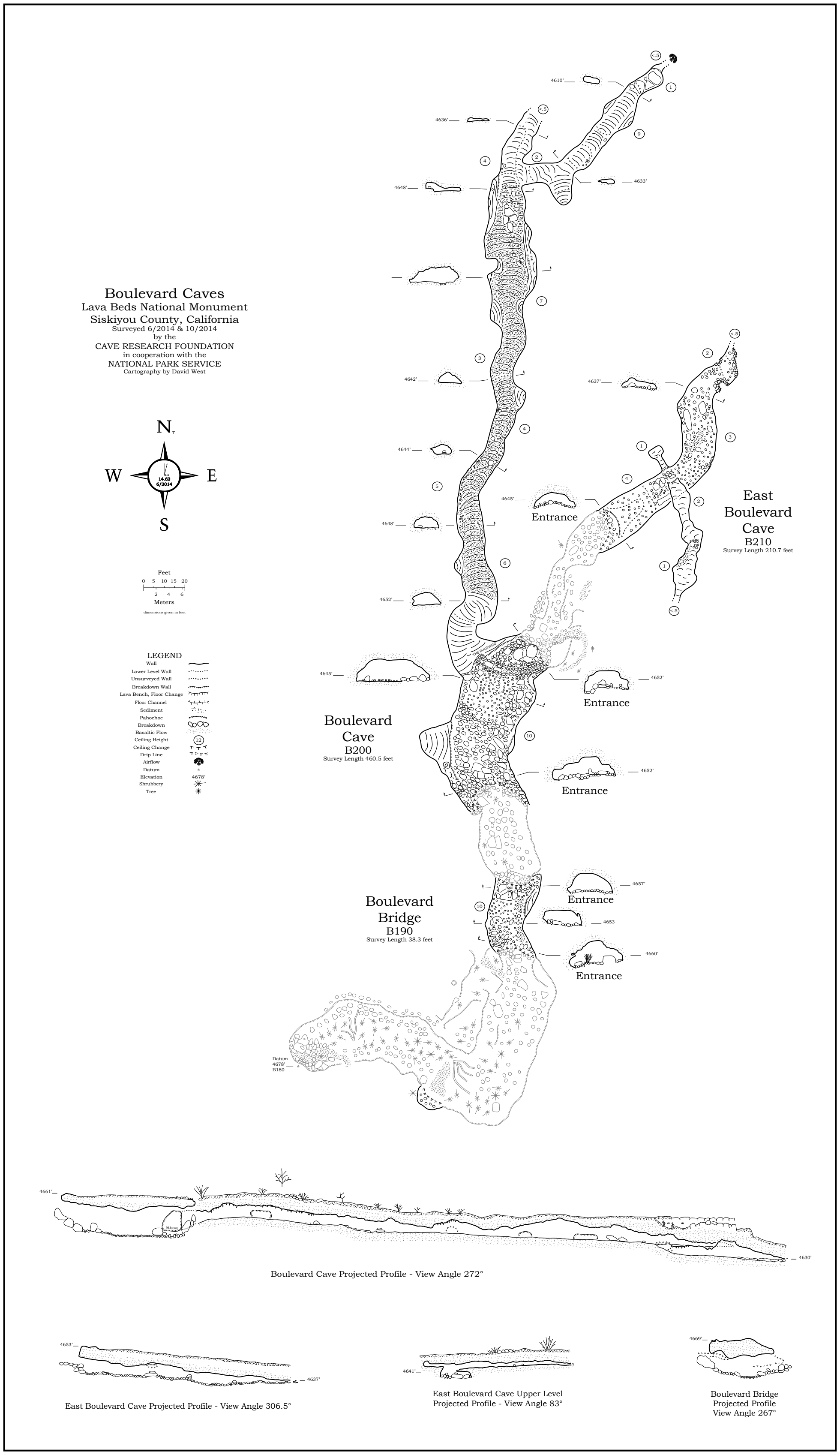
Because Balcony Cave is used by bats, we focused on finishing the bat use area there first while they were absent. This we accomplished during the first week. During the first week, we also finished the majority of survey in Boulevard Cave, East Boulevard Cave, and Boulevard Bridge. We also began survey in Shark's Mouth Cave, which was connected to Balcony Cave by a team led by Katrina Smith, from the Monument's Resource Management office. The second week of survey focused on obtaining the final details on the Boulevard Caves and continuing work on the Balcony–Shark's Mouth system.

By year's end, maps of Upper Cavern, Boulevard Cave, East Boulevard Cave, Boulevard Bridge, and Rotunda Grotto had been produced. A decision was made to extend the project to include all of the caves in the Balcony Flow, for which a research proposal would be submitted. Work will continue in 2015.

The Monument has been most accommodating in moving this project forward, and their assistance is greatly appreciated.

Dawn Ryan teaching Nancy Nordensten (NPS) how to read instruments in Balcony Cave. *Ed Klausner*

Dave West checking passage dimensions in Balcony Cave. *Ed Klausner*



Boulevard Caves
Lava Beds National Monument
Siskiyou County, California
Surveyed 6/2014 & 10/2014
by the
CAVE RESEARCH FOUNDATION
in cooperation with the
NATIONAL PARK SERVICE
Cartography by David West
N
W
E
S
14.62
6/2014
Feet
0 5 10 15 20
2 4 6
Meters
dimensions given in feet
LEGEND
Wall
Lower Level Wall
Unsurveyed Wall
Breakdown Wall
Lava Bench, Floor Change
Floor Channel
Sediment
Pahoehoe
Breakdown
Basaltic Flow
Ceiling Height
Ceiling Change
Drip Line
Airflow
Datum
Elevation
4678'
Shrubbery
Tree
East
Boulevard
Cave
B210
Survey Length 210.7 feet
Entrance
Boulevard
Cave
B200
Survey Length 460.5 feet
Entrance
Entrance
Boulevard
Bridge
B190
Survey Length 38.3 feet
Entrance
Entrance
Datum
4678'
B180
Boulevard Cave Projected Profile - View Angle 272°
East Boulevard Cave Projected Profile - View Angle 306.5°
East Boulevard Cave Upper Level
Projected Profile - View Angle 83°
Boulevard Bridge
Projected Profile
View Angle 267°

Participants: Dave West, Karen Willmes, Ed Klausner, Elizabeth Miller, Dawn Ryan, Mark Jones. NPS personnel—Nancy Nordensten, Katrina Smith, Sarina Patel, Amy Rasmussen, Megan Mason.

2015

In January a research proposal was submitted through the National Park System's Integrated Resource Management Applications (IRMA) to extend the project to include the entire Balcony Flow. This was approved and trips were scheduled for April and September.

The previous schedule of Post Office Cave in the morning and Balcony Flow in the afternoon was abandoned, as Ed Klausner had moved up to somewhat warmer levels in the cave, and was beginning survey in Silver Cave, to which it is connected. He now focused his efforts on completing that project. My work in April focused on finishing up the surveys in the Balcony–Shark's Mouth system. Since this system has multiple flow paths, the obtaining of cross sections was delayed until a plan view of the map could help determine which ones would be most useful. Balcony was finished up first, and then Shark's Mouth. Surface survey over Shark's Mouth for the profile led us to another trench and the entrance to Pango Ndogo Cave. This too, was surveyed, and led us to a sequence of downflow entrances, including Nirvana and Purgatory Caves, to which we tied our surface survey. This finished up our first week of the year.

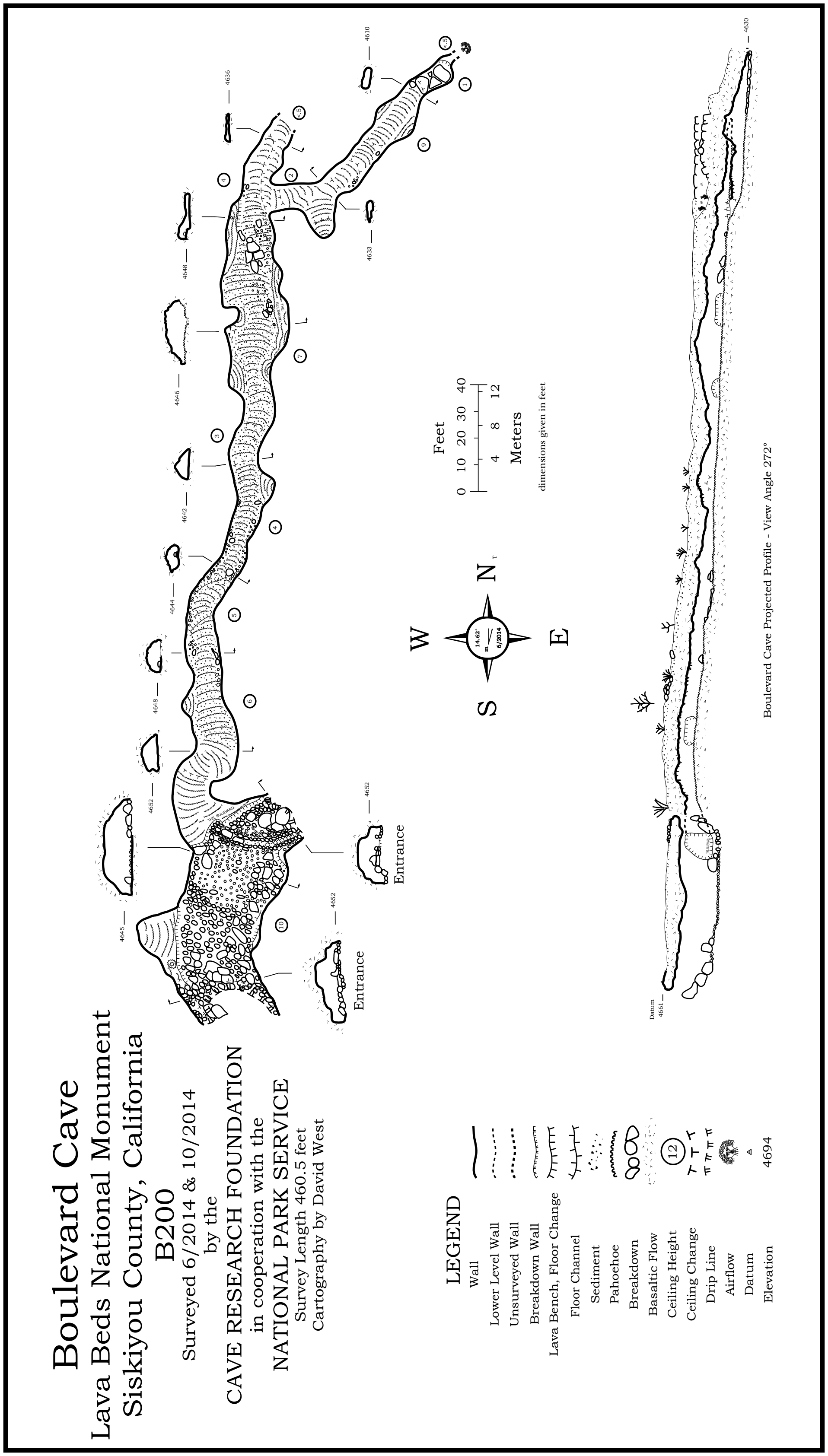
Drafting of the plan view map for the Balcony–Shark's Mouth system was begun, and sites for cross sections determined. The need for additional profile detail was also determined. A closure error in the Pango Ndogo survey precluded drafting until it could be corrected. These became the first objectives for the September trip. Fixing the error proved easier than feared. A four-degree error was found on the first shot of the cave survey. Because of the magnetic nature of the caves, back sights are done, and a two-degree deviation between sightings is generally considered acceptable. The initial sighting had a two degree difference and was accepted. The shot was located in the entrance and taken to a skylight. By laying down the tape between the two stations, getting completely out of the trench and sighting along the tape, a foresight was obtained that was four degrees different from the original, but still two degrees different than the original back sight. The process was repeated at the other end of the traverse, and an exact match of the new foresight was obtained. Problem solved! We moved on to collecting the cross sections and profile detail needed in Balcony and Shark's Mouth. Finishing that, we moved on to the survey of Nirvana Cave. This cave aligns with a passage in Balcony Cave to the south that becomes too low to follow at its north end. The south end of Nirvana is also at a point where the cave becomes too small to follow, less than 100 feet from Balcony Cave. We then began the survey of Purgatory Cave. It shares a collapse point with Pango Ndogo. It also aligns with Nirvana, and a connection was found. Not surprisingly, to traverse from one to the other one must pass through the Eye of the Needle, a very tight constriction with a small lava ball that partially blocks the way.

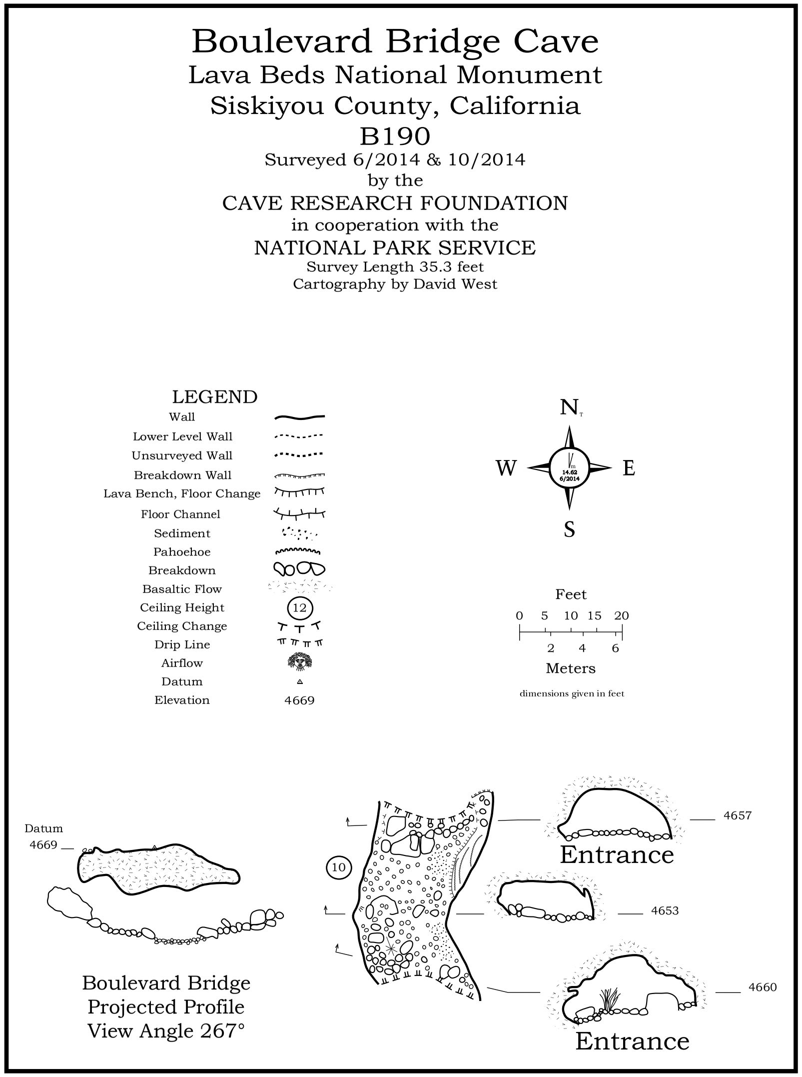
Having observed that a relatively permanent station on the shoulder of Hill Road had been removed, apparently by a snow plow, a new surface survey was run along the road to the point where the other primary (eastern) branch of the Balcony Flow crosses it, tying to the posts on either side of the entrances to the Balcony/Boulevard parking area. We also tied to the sign between them. While attempting to place a station less susceptible to plowing at the other branch, an undocumented and very small entrance was observed. Named Bitty Pit, it proved to be too small for most, and survey of it was put off for now. Another undocumented entrance was found across the street. It was surveyed for just over 100 feet and dubbed Roadside Cave. A walk up the trench here produced a few more undocumented entrances that will need further investigation.

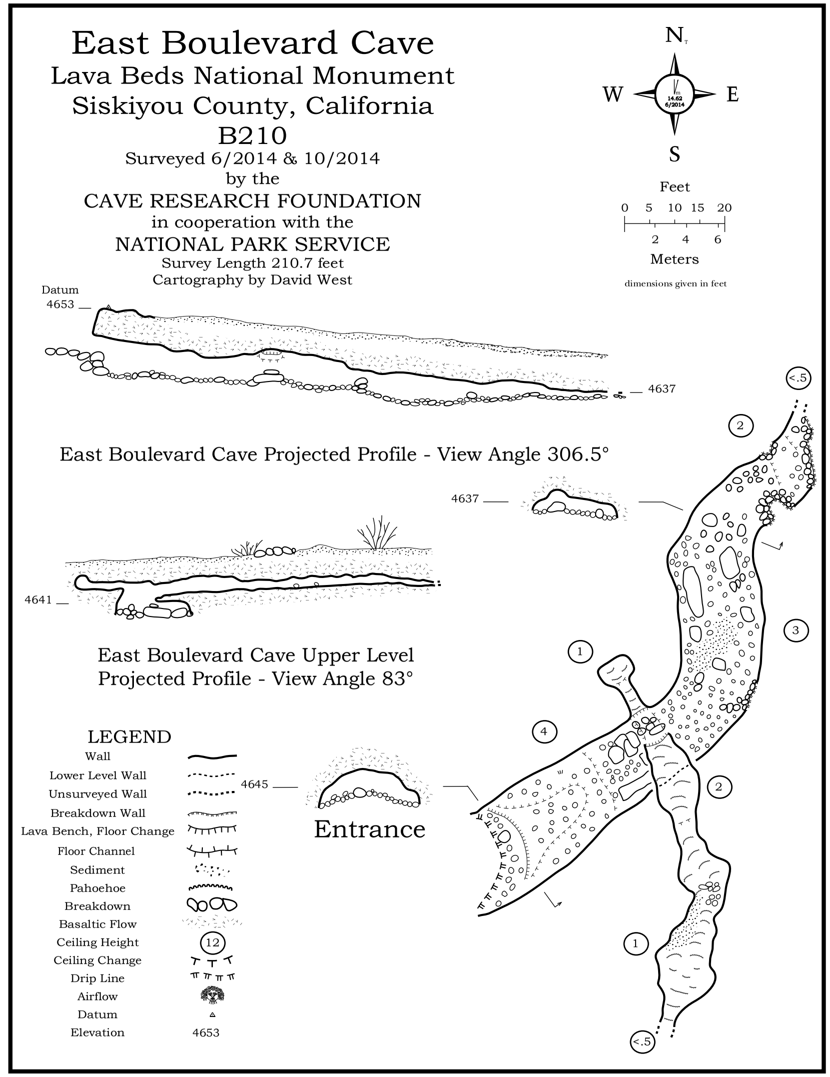
Returning to the western branch, surface survey tied in Himmel Cave, Geritol Grotto, and Obsession Cave. On our last day of field work this year, survey of Himmel Cave was begun, completing "The Earthly Passages" (crawl over aa-aa) and just reaching the "Heavenly Passages" (walking passage with pahoehoe floor) for which a clipboard sketch would be desirable. A small skylight was observed, originally reported as not suitable for entry. Using our survey data from the cave, we quickly (well, after a bit of buffoonery) found it on the surface. All agreed that while small, it was quite enterable, especially by people small enough to fit through the crawls. It will be used when we return to complete the survey.

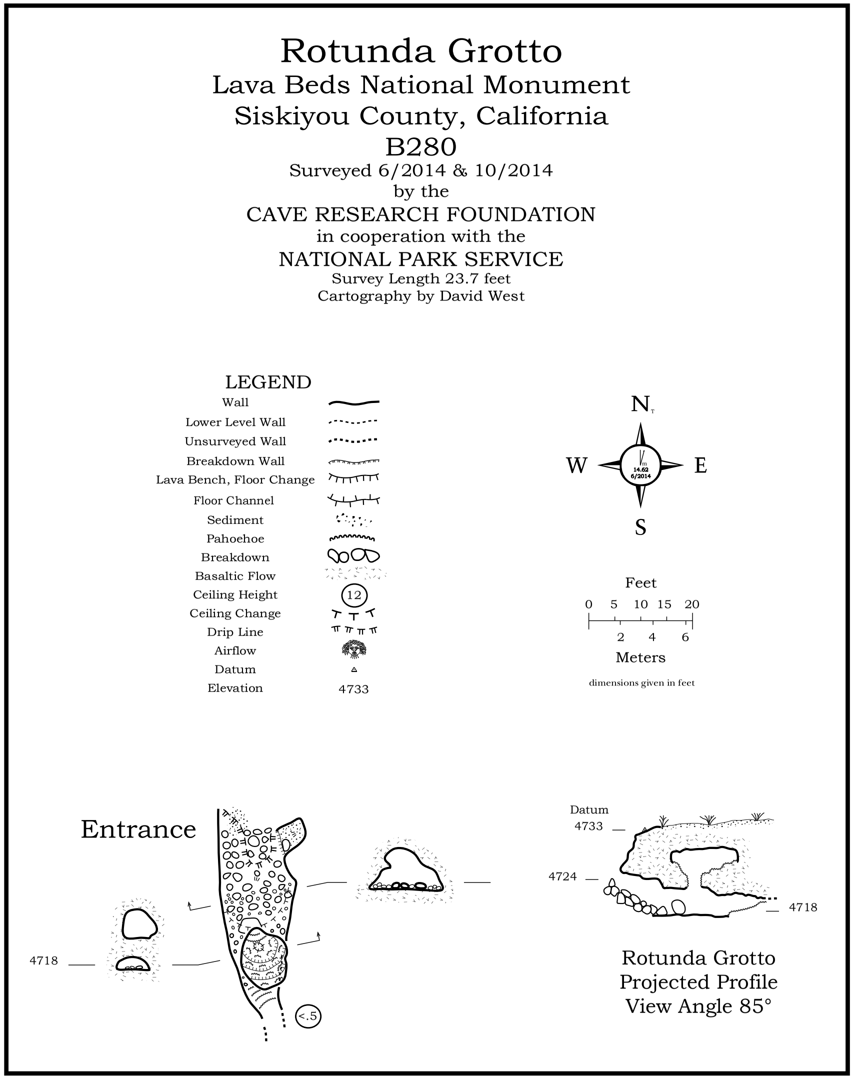
The Monument continues to be most accommodating in moving this project forward, and their assistance is greatly appreciated.

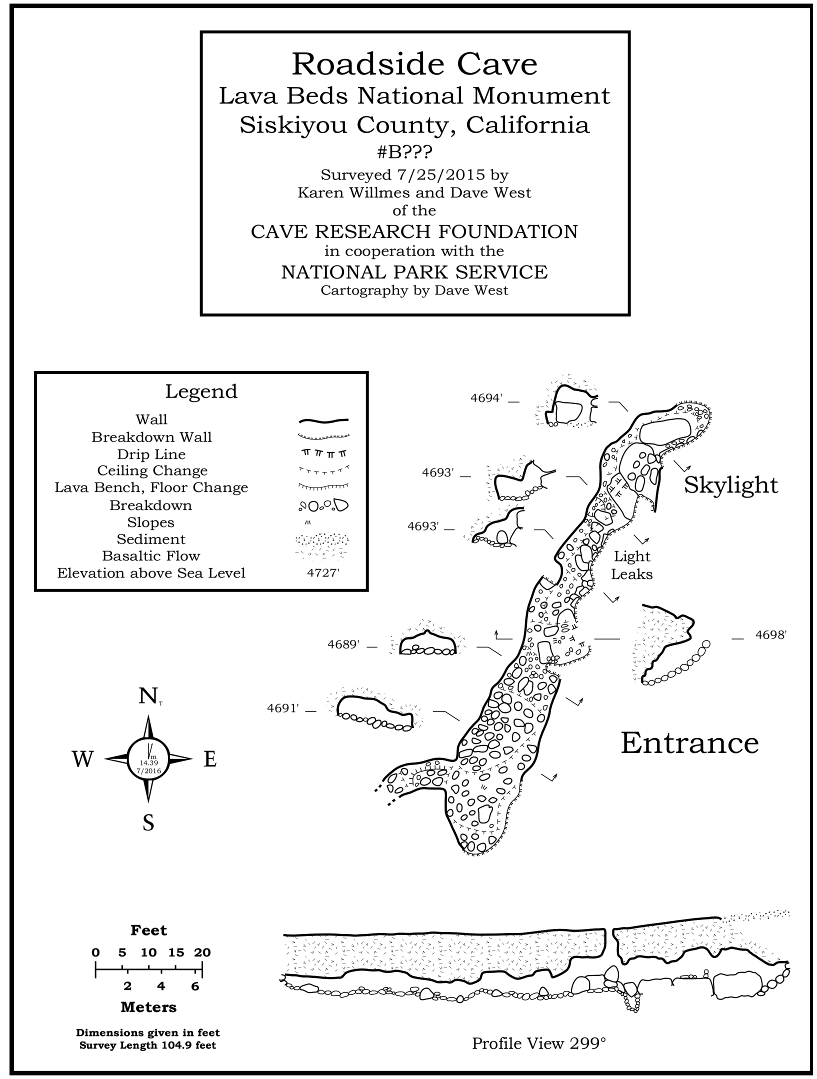
Participants: Dave West, Karen Willmes, Elizabeth Miller, Mark Jones, Paul McMullen, Ken Walsh, Rachel Bosch.

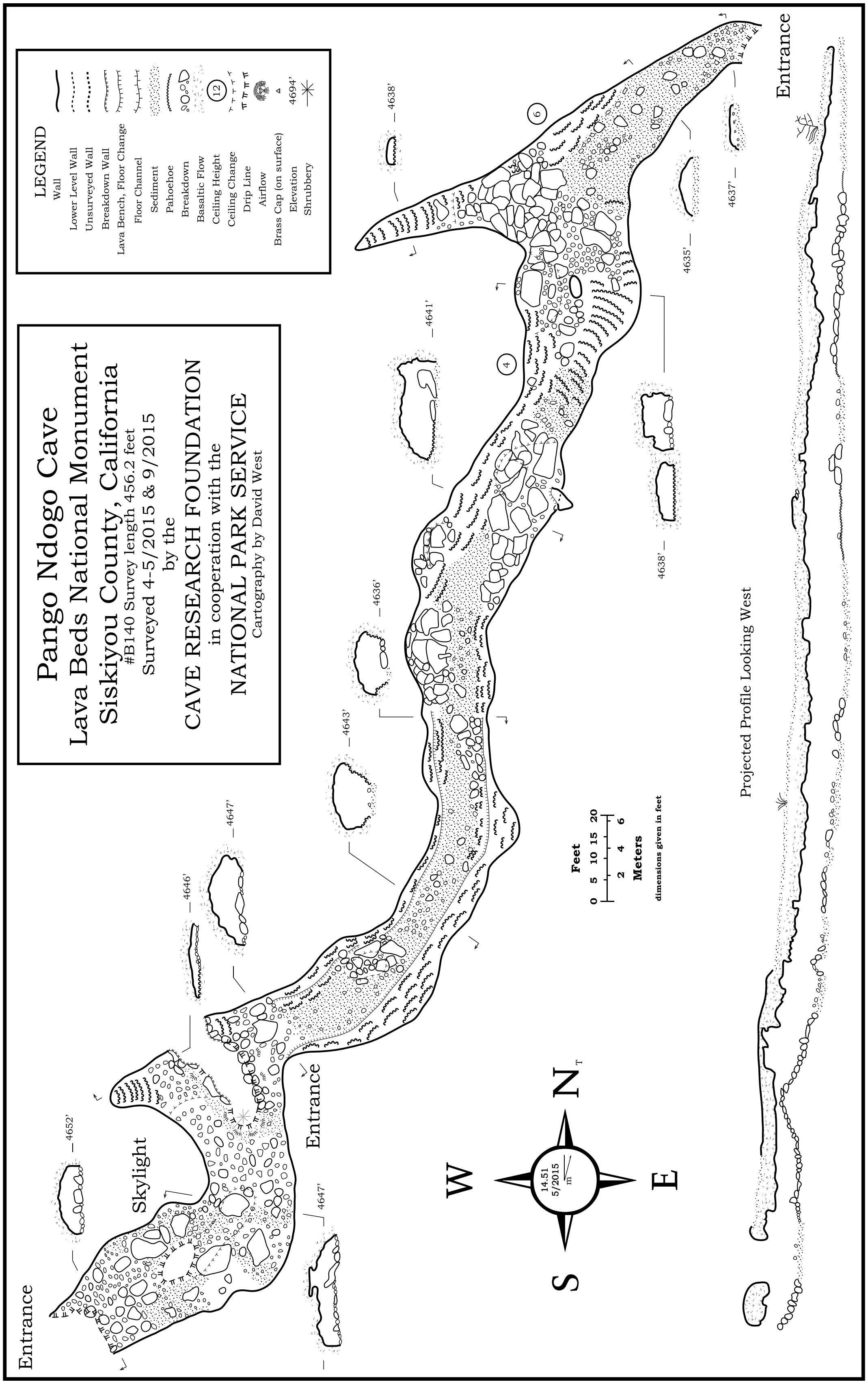

Boulevard Cave
Lava Beds National Monument
Siskiyou County, California
B200
Surveyed 6/2014 & 10/2014
by the
CAVE RESEARCH FOUNDATION
in cooperation with the
NATIONAL PARK SERVICE
Survey Length 460.5 feet
Cartography by David West
LEGEND
Wall
Lower Level Wall
Unsurveyed Wall
Breakdown Wall
Lava Bench, Floor Change
Floor Channel
Sediment
Pahoehoe
Breakdown
Basaltic Flow
Ceiling Height
Ceiling Change
Drip Line
Airflow
Datum
Elevation
12
4694
Entrance
Entrance
Feet
0 10 20 30 40
4 8 12
Meters
dimensions given in feet
W
N
S
E
Boulevard Cave Projected Profile - View Angle 272°
Datum
4661


Boulevard Bridge Cave
Lava Beds National Monument
Siskiyou County, California
B190
Surveyed 6/2014 & 10/2014
by the
CAVE RESEARCH FOUNDATION
in cooperation with the
NATIONAL PARK SERVICE
Survey Length 35.3 feet
Cartography by David West
LEGEND
Wall
Lower Level Wall
Unsurveyed Wall
Breakdown Wall
Lava Bench, Floor Change
Floor Channel
Sediment
Pahoehoe
Breakdown
Basaltic Flow
Ceiling Height
Ceiling Change
Drip Line
Airflow
Datum
Elevation
12
4669
N
W
E
S
Feet
0 5 10 15 20
2 4 6
Meters
dimensions given in feet
Datum
4669
10
4657
Entrance
4653
4660
Entrance
Boulevard Bridge
Projected Profile
View Angle 267°

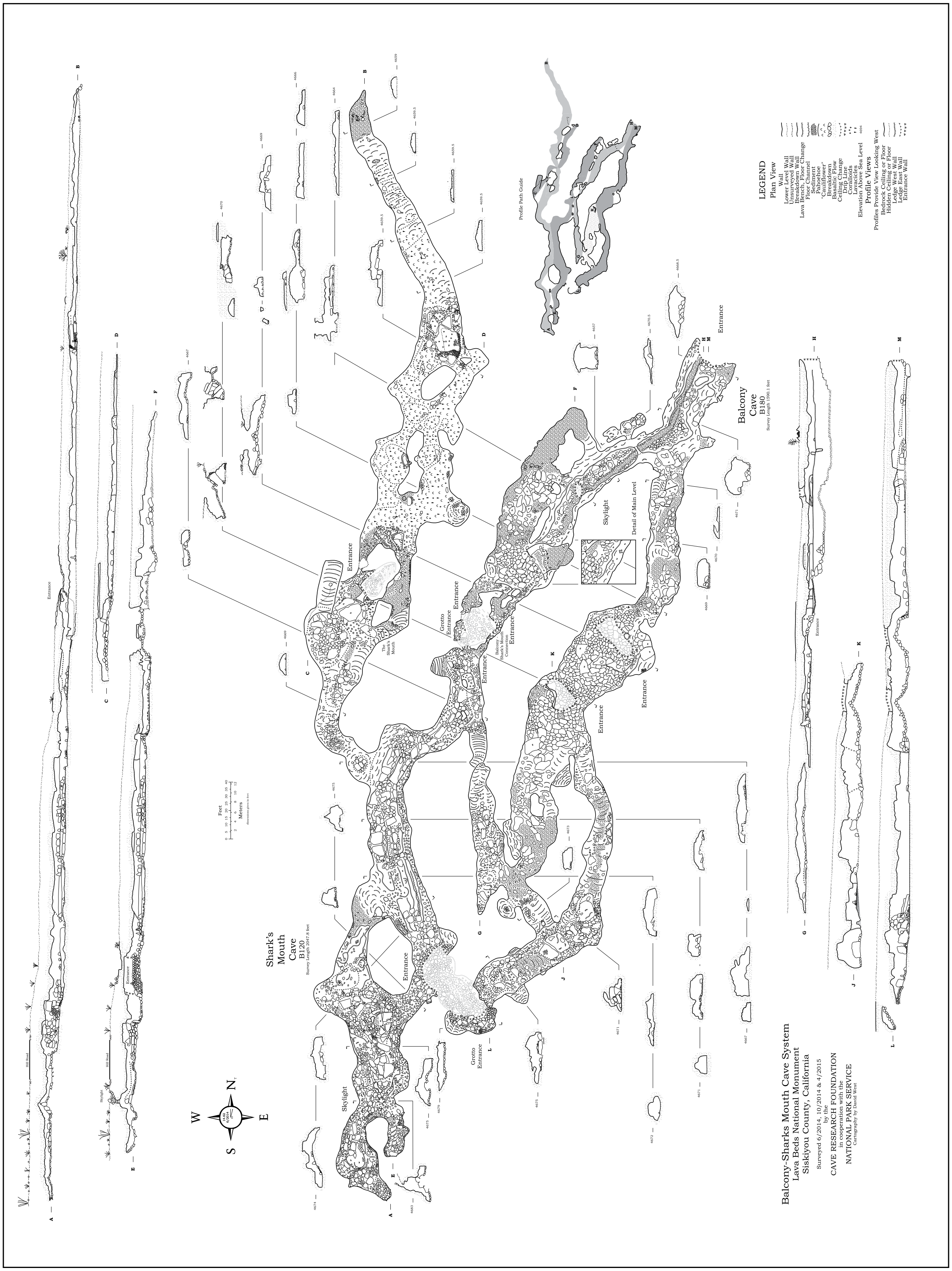

East Boulevard Cave
Lava Beds National Monument
Siskiyou County, California
B210
Surveyed 6/2014 & 10/2014
by the
CAVE RESEARCH FOUNDATION
in cooperation with the
NATIONAL PARK SERVICE
Survey Length 210.7 feet
Cartography by David West
N
W
E
S
Feet
0 5 10 15 20
2 4 6
Meters
dimensions given in feet
Datum
4653
4637
East Boulevard Cave Projected Profile - View Angle 306.5°
4637
4641
East Boulevard Cave Upper Level
Projected Profile - View Angle 83°
4645
Entrance
<.5
2
3
1
4
2
1
<.5
LEGEND
Wall
Lower Level Wall
Unsurveyed Wall
Breakdown Wall
Lava Bench, Floor Change
Floor Channel
Sediment
Pahoehoe
Breakdown
Basaltic Flow
Ceiling Height
Ceiling Change
Drip Line
Airflow
Datum
Elevation
12
4653

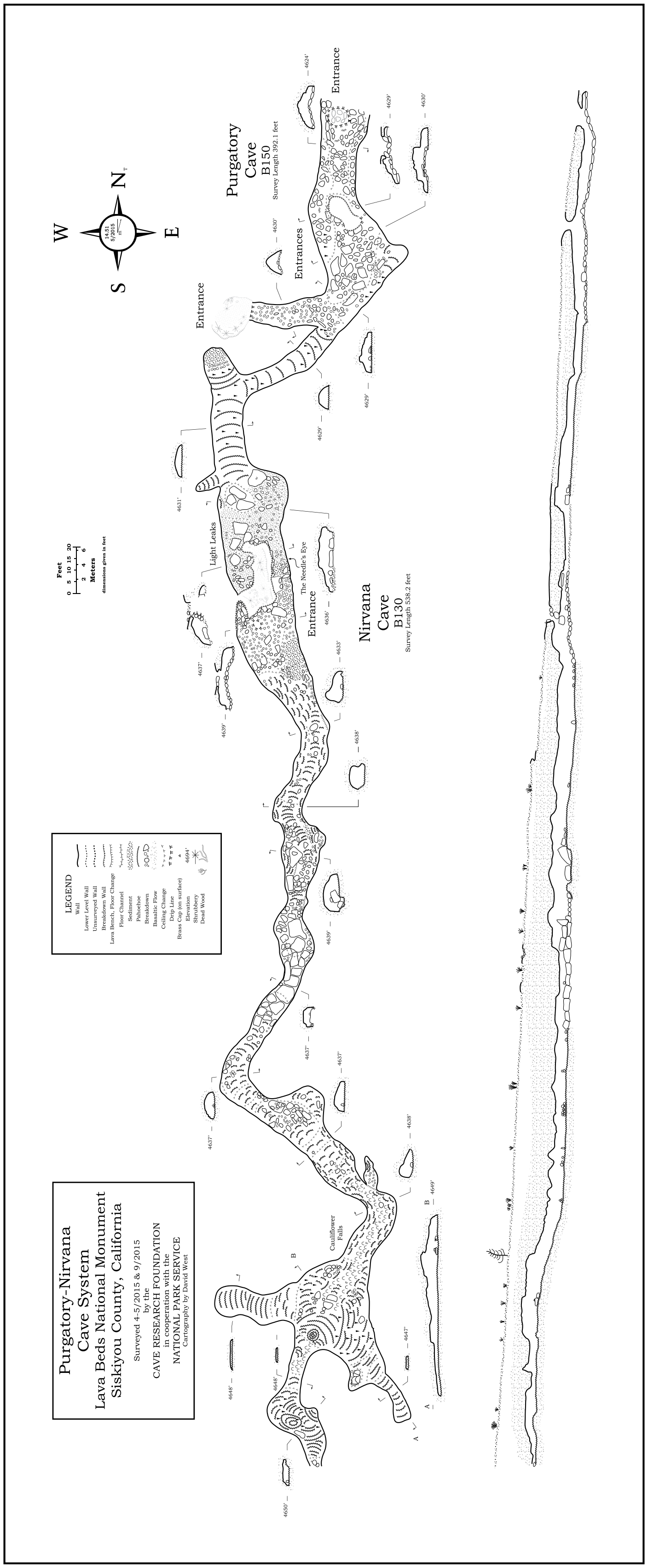

Rotunda Grotto
Lava Beds National Monument
Siskiyou County, California
B280
Surveyed 6/2014 & 10/2014
by the
CAVE RESEARCH FOUNDATION
in cooperation with the
NATIONAL PARK SERVICE
Survey Length 23.7 feet
Cartography by David West
LEGEND
Wall
Lower Level Wall
Unsurveyed Wall
Breakdown Wall
Lava Bench, Floor Change
Floor Channel
Sediment
Pahoehoe
Breakdown
Basaltic Flow
Ceiling Height
Ceiling Change
Drip Line
Airflow
Datum
Elevation
12
4733
N
W
E
S
Feet
0 5 10 15 20
2 4 6
Meters
dimensions given in feet
Entrance
4718
<.5
Datum
4733
4724
4718
Rotunda Grotto
Projected Profile
View Angle 85°


Roadside Cave
Lava Beds National Monument
Siskiyou County, California
#B???
Surveyed 7/25/2015 by
Karen Willmes and Dave West
of the
CAVE RESEARCH FOUNDATION
in cooperation with the
NATIONAL PARK SERVICE
Cartography by Dave West
Legend
Wall
Breakdown Wall
Drip Line
Ceiling Change
Lava Bench, Floor Change
Breakdown
Slopes
Sediment
Basaltic Flow
Elevation above Sea Level
4727'
4694'
4693'
4693'
4689'
4691'
4698'
Skylight
Light
Leaks
Entrance
N
W
E
S
Feet
0 5 10 15 20
2 4 6
Meters
Dimensions given in feet
Survey Length 104.9 feet
Profile View 299°



Pango Ndogo Cave
Lava Beds National Monument
Siskiyou County, California
#B140 Survey length 456.2 feet
Surveyed 4-5/2015 & 9/2015
by the
CAVE RESEARCH FOUNDATION
in cooperation with the
NATIONAL PARK SERVICE
Cartography by David West
LEGEND
Wall
Lower Level Wall
Unsurveyed Wall
Breakdown Wall
Lava Bench, Floor Change
Floor Channel
Sediment
Pahoehoe
Breakdown
Basaltic Flow
Ceiling Height
Ceiling Change
Drip Line
Airflow
Brass Cap (on surface)
Elevation
Shrubbery
Feet
0 5 10 15 20
Meters
2 4 6
dimensions given in feet
Entrance
Skylight
Entrance
Entrance
Projected Profile Looking West
Entrance
W
N
E
S
14.51
5/2015


Balcony-Sharks Mouth Cave System
Lava Beds National Monument
Siskiyou County, California
Surveyed 6/2014, 10/2014 & 4/2015
by the
CAVE RESEARCH FOUNDATION
in cooperation with the
NATIONAL PARK SERVICE
Cartography by David West
Shark's Mouth Cave
B120
Balcony Cave
B180
Entrance
Skylight
Grotto Entrance
Detail of Main Level
Profile Path Guide
Feet
Meters
LEGEND
Plan View
Wall
Lower Level Wall
Unsurveyed Wall
Breakdown Wall
Lava Bench, Floor Change
Floor Channel
Sediment
Pahoehoe
"Cauliflower"
Breakdown
Basaltic Flow
Ceiling Change
Drip Line
Coralloids
Lavacicles
Elevation Above Sea Level
Profile Views
Profiles Provide View Looking West
Bedrock Ceiling or Floor
Hidden Ceiling or Floor
Ledge West Wall
Ledge East Wall
Entrance Wall
N
S
E
W


Purgatory-Nirvana
Cave System
Lava Beds National Monument
Siskiyou County, California
Surveyed 4-5/2015 & 9/2015
by the
CAVE RESEARCH FOUNDATION
in cooperation with the
NATIONAL PARK SERVICE
Cartography by David West
LEGEND
Purgatory
Cave
B150
Survey Length 392.1 feet
Nirvana
Cave
B130
Survey Length 538.2 feet
Entrance
Entrances
Light Leaks
The Needle's Eye
Cauliflower
Falls
Feet
Meters
W
N
S
E

Cave Loop Resurvey Project 2014–15

Lava Beds National Monument

Liz Wolff

Principal Investigator

Labyrinth Cave

The Cave Loop Resurvey Project continued the surveys in Labyrinth Cave, completing the cave using eight cavers in four trips, 23 hours, 38 stations, with total footage added of 849.1 feet plus surface traverses. In the course of these surveys, two possible J. D. Howard paintings were found. One, the more scenic of the two, is a boulder at a passage junction painted to look like a dragon. This was done in red, yellow, and blue paints of the type and style used by Howard to identify caves. The other is in red in an upper level side passage on the floor of a low chamber and is difficult to read. This artwork could have been painted by Glaeser, as the location is obscure, which is often a characteristic of his paintings.

The dragon made an admirable station, easy to relocate and shoot into all passages. The passage down flow toward Mushpot Cave was carried into the point it became too tight and gnarly to continue, but light and voice connection was made to Mushpot. The smaller connection to a Mushpot side passage was made by voice also, but is too tight to get through. Up-flow from the dragon, the Lava Brook was surveyed under a lava fall / boulder jam for 18 feet until it too was blocked. Over the boulder jam in the final chamber, faint daylight could be seen in an upper level chamber that was too tight to get into. On the surface, that entrance was located and surveyed back to the ledge. These surveys, plus the final loops in the lowest part of the cave, brought the totals for Labyrinth Cave to 6223.7 feet in length and 156.7 feet in depth.

Seven caves had been found near the upper end of the Thunderbolt portion of Labyrinth Cave. Two are digs, so were not done, and one was not relocated. The other four were checked and surveyed in three days in October.

Thunderbolt Attic survey was completed on a frosty, starry night trip by three cavers, adding 19 feet to the March 2013 survey, bringing that cave to 84.2 feet long.

Blitzen, with a vertical tube entrance, tapped out to 66.6 feet in three hours by four cavers.

Donder came to 45.6 feet in length in two hours by four cavers. A very tight bush-constricted exit was negotiated by one caver to the detriment of his shirt.

Burst Y'r Bubble taped to 70.5 feet with some complexity in three+ hours by five cavers. It is named for the burst lava bubble that marks the entrance.

Garden Bridges

During the winter, while we were kept out of Labyrinth Cave by hibernating bats, surveys proceeded in the Garden Bridges. In February, Labryinthian Bridge was surveyed by one caver and one NPS person keeping the book to 67.95 feet, in one hour and three stations. They found two J. D. Howard paintings, one in blue on the floor and a very faded yellow one on the northern wall. The same day, joined by another caver, survey was started in Cave B getting 56.8 feet, in three hours and five stations, plus surface traverse. The same day, a crew of three began survey of Hidden Cave, getting 96.05 feet in nine stations in six hours, plus surface traverse.

In March, two cavers surveyed Chute Cave to 123.6 feet in eight stations in four hours, plus surface traverse. The same day, Backwash Cove was surveyed to 52.7 feet in five stations, two hours, plus surface traverse. Siamese Bridges were surveyed to 231.55 feet by two cavers in 15 stations, and six hours, plus surface traverse. Sharp Cathedral Room was discovered.

May saw a concentrated attack by six cavers on Hidden Cave. A total of 182.5 feet was added to the previous 96.05 feet bringing it to 278.55 feet, most of that is in the "hidden" lower level. Sixteen stations were set in 11 hours, plus an extensive surface traverse survey. Sharp Cathedral Room was surveyed to 31 feet, too short to be designated as a separate cave, by two cavers in two hours and three stations, plus surface traverse. Lone Bat Cave was surveyed to 73.5 feet, stopping at a fallen ceiling block that almost completely blocks the passage. Seven stations were set in three hours. Velcro Cave was discovered by the Lone Bat crew and surveyed to a length of 104.4 feet in two days in eight+ hours and seven stations. It was named for its main feature, the drag applied to caver bodies. The dilapidated arch was checked for possible passage and a small room found that is 21.4 feet long. Strong magnetics skewed the compass about 60 degrees in this area for the three cavers attempting to survey.

July, two cavers taught nine Student Conservation Association volunteers how to do a cave survey, with two of them brave enough to try keeping the book. Surface traverse was carried out from Siamese Bridges to Terrace Bridge to learn the mechanics of surveying; then, it was on to Tube in Tube Cave for some cave survey. Eight stations netted 155.4 feet of the main passage, with 84.7 additional feet in the lower tube, in three hours. Total cave length is 240.1 feet. A GPS survey (conducted in 3+ hours) was made by one caver to include all entrances, exits, bridges and arches to rectify problems with the magnetic surveys and correctly place all caves in their proper relationships to each other.

In September and October, Cave B survey was completed adding 179.5 feet to the 56.8 feet surveyed in February, for a survey total of 236.3 feet. Eleven stations were set in five hours by seven cavers in two trips, plus surface traverse.

In November, Midden Cave was surveyed by two cavers setting 10 stations in three hours to a length of 183.5 feet, plus surface traverse. Cave A was surveyed to 290.55 feet by two cavers setting 10 stations in nine hours, plus surface traverse. One shot was taken into Golden Dome Cave which connects to Cave A.

A surface traverse was run December 1 from Labyrinthian Bridge, Cave B, and Midden to the lower Tube in Tube Cave exit by three cavers (in just under one hour). All in all, the Garden Bridges saw 19 survey trips by an aggregate total of 42 cavers, three NPS people and nine SCAs in 2014, netting 1660.35 feet of cave in 109 stations, in 73 hours. Surface traverses totaled 1822.2 feet.

The gold in Golden Dome. *Dave West*

Ozarks Operations, 2014–2015

Overview

Scott House

CRF Ozark Operations continued to be very active during these two years, with even more field trips than ever despite WNS-related restrictions. During this two-year time over 560 trips were fielded. The approximate breakdown of field trip days by project is as follows:

- Ozark National Scenic Riverways cave management, biology, survey and inventory: 154
- Mark Twain National Forest cave survey, inventory, and gating: 190
- Buffalo National River cave survey, monitoring, and inventory: 109
- Missouri Department of Conservation: 22
- Missouri State Parks: 22
- St. Louis County Parks: 3
- U.S. Fish and Wildlife Service: 10
- Pioneer Forest: 10
- Perry County Area: 22
- Others: 49

Other projects included private lands, smaller agencies, small-scale gating projects, database support, and service trips.

Participants volunteered nearly 15,000 hours of time over 1800 field days, and drove 177,000 miles in support of our projects. A modest volunteer rate of $18/hour results in approximately $270,000 of field time value. At the standard reimbursement rate, the mileage amounts to at least

Scott Sutton looks out at the Buffalo National River on the hike to Sunset Cave.

another $95,000 of volunteered value. Adding a standard per diem rate to the field days would give us a field value of over $430,000 for these two years. Adding in a reasonable factor for office, drafting, and prep time would easily add another $65,000 of value, making our total contributed value to our agency partners very close to $500,000 in these two years. And that does not include the cost of personal gear.

Buffalo National River

(National Park Service)

Kayla Sapkota

The 2014–2015 period was one of exponential growth in both work accomplished and personnel involved. Due to WNS concerns on behalf of the NPS, CRF work in the Buffalo National River did not take place in January or February 2014, but picked up again soon after. Personnel involved in CRF activities quickly increased over the two-year period, allowing for more teams to be involved in the monthly expeditions.

Figures

- Total Mileage: 46,770
- Total People Days: 354
- Total Survey Footage: 13,402
- Total Hours: 3,035
- Total Trips: 109
- New Public Use Monitoring Records: 161
- New Faunal Records: 394
- New Maps Completed: 52
- New Caves Located: 12

Facilities

For the entire 2014 year and up until February 2015, operations were based out of a 1970s, modular house above the Steel Creek canoe put-in on the Buffalo National River. This facility was used as a base for several years running but became decommissioned in February 2015 due to a burst pipe causing prolonged flooding and water damage. Trips were still held, but were mostly operated on a day-trip basis through June 2015, when an alternate arrangement was provided.

Currently, CRF uses the "rock house," a neighboring facility to the previously flooded modular house. The rock house, later to be deemed the Steel Creek Research Center (SCRC), has a larger kitchen area, more square footage, a dedicated decontamination/laundry room, and greater area to store gear. The concern of sleeping space is

Kayla Sapkota sketches on rope in Waterfall Pit #1, Buffalo National River. *Kenny Akers*

a work-in-progress, with NPS recently providing oversized fold-up cots and sleeping pads, along with two new sets of bunkbeds. Ample space is available for camping in the front yard if need be.

Areas of Focus

Work focus continues to be based upon biological monitoring, public use monitoring, and cartographic survey, with special attention being given to bat survey and WNS monitoring. CRF volunteers receive continual small group training on biological identification and hosted Mike Slay, from the Nature Conservancy, to conduct a larger scale cave biology workshop with an accompanying field experience in December 2015. Additionally, pocket-sized biology ID cards are provided to teams in the field as needed.

An additional area of focus has been the training and equipping of new team leaders, sketchers, and cartographers. A cartography work-day was held in February 2014, and periodic one-on-one survey sessions are held on an as-needed basis. Because several caves in the Buffalo National River require vertical equipment to fully reach, some focus was given to equipping some new volunteers with basic vertical skills; future training is still needed, as the

Kyle Moore exits Caprock Cave #2, Buffalo National River.
Kayla Sapkota

addition of the vertical component in cave-related activities is not to be taken lightly.

At the same time, the 2014–2015 period was a prime time for growth in CRF volunteer ranks. New individuals regularly joined expeditions from surroundings grottos and institutions of higher education. New “recruits” were paired with “seasoned” team leaders to learn about the purpose and culture of the operations.

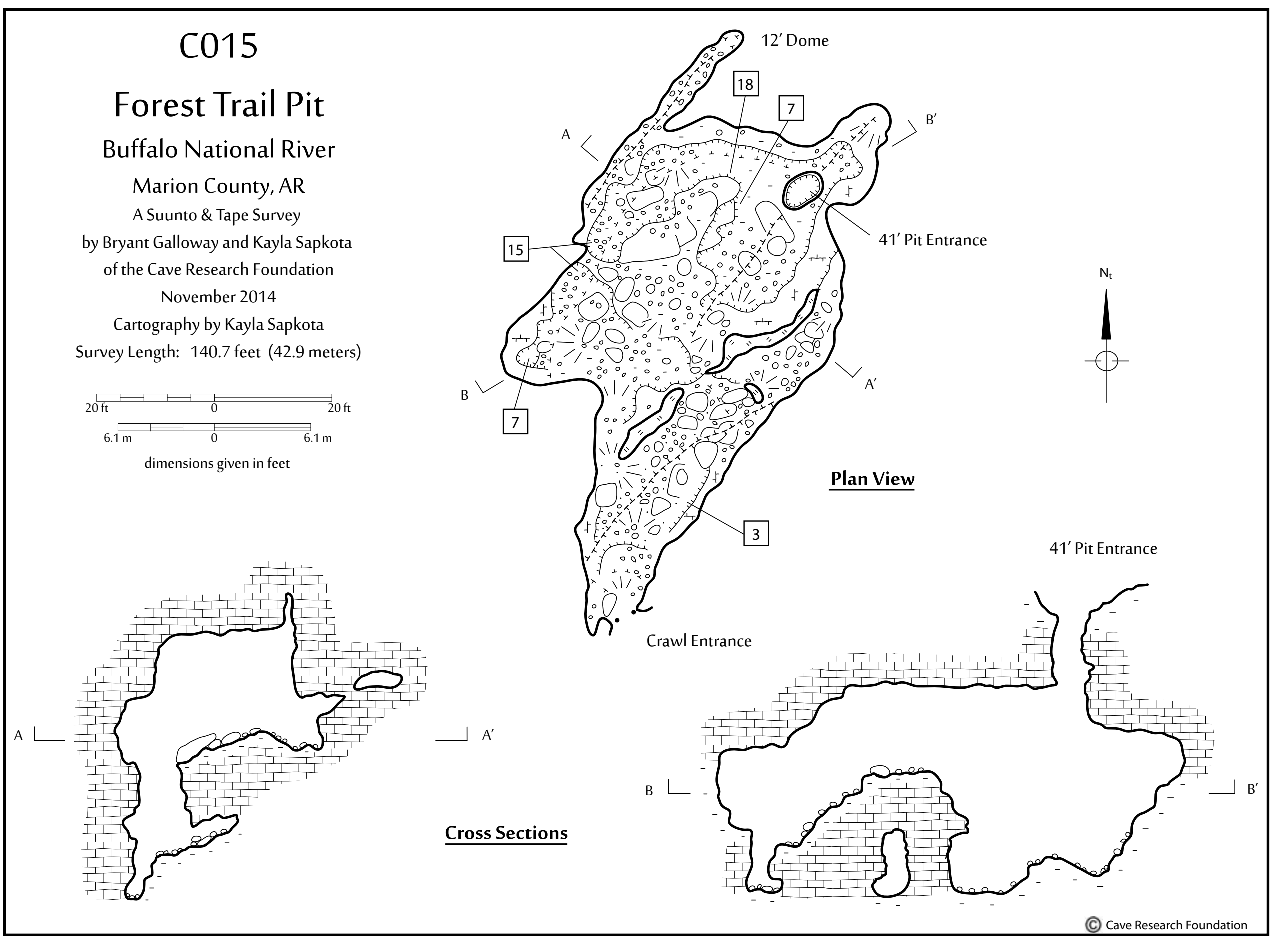
Field Trips

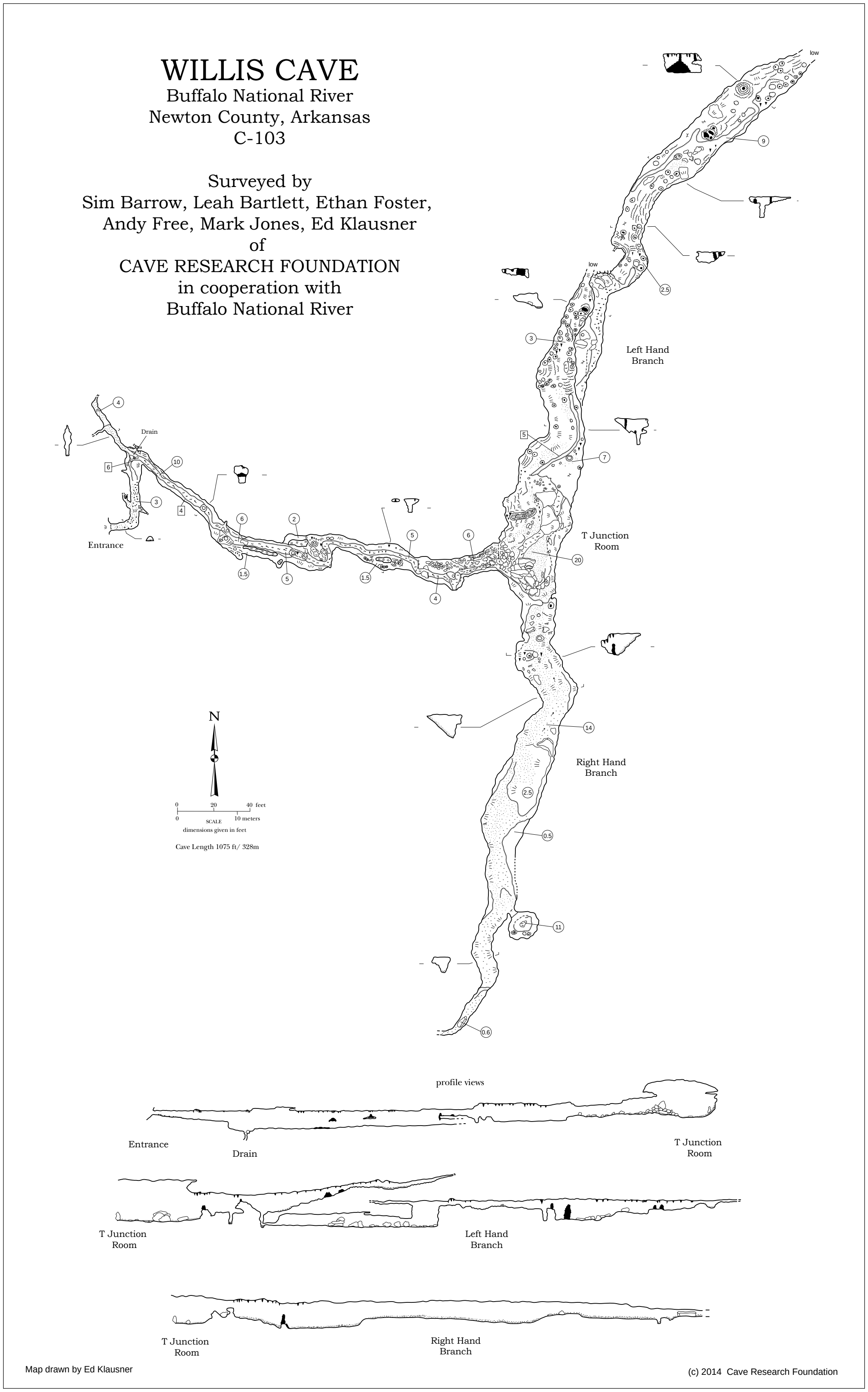
With the exception of early 2014, at least one expedition was held each month. Winter and cooler weather trips were focused on monitoring and ridgewalking, as physical exertion is much more bearable during times outside of Arkansas hot weather. As a result, twelve new caves were located during this period. In warmer months, known caves in need of survey and caves accessible by river became more attractive priorities; of course, biological monitoring and public use monitoring continued on all trips.

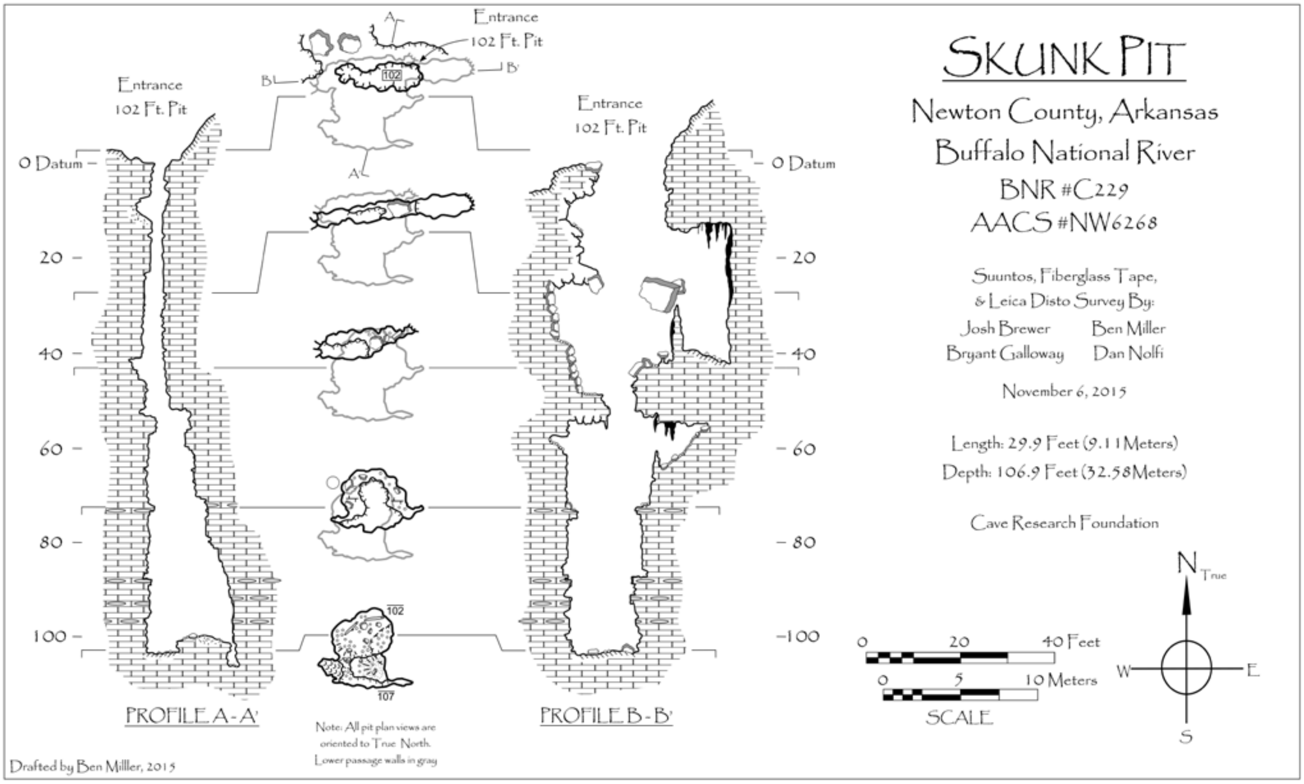
During both years, a large float monitoring expedition occurred, at which time multiple teams took to the river to visit those caves not accessible by land. In December of both years, a week-long expedition was held during which biological monitoring, public use monitoring, survey, cartography, and data management work were completed.

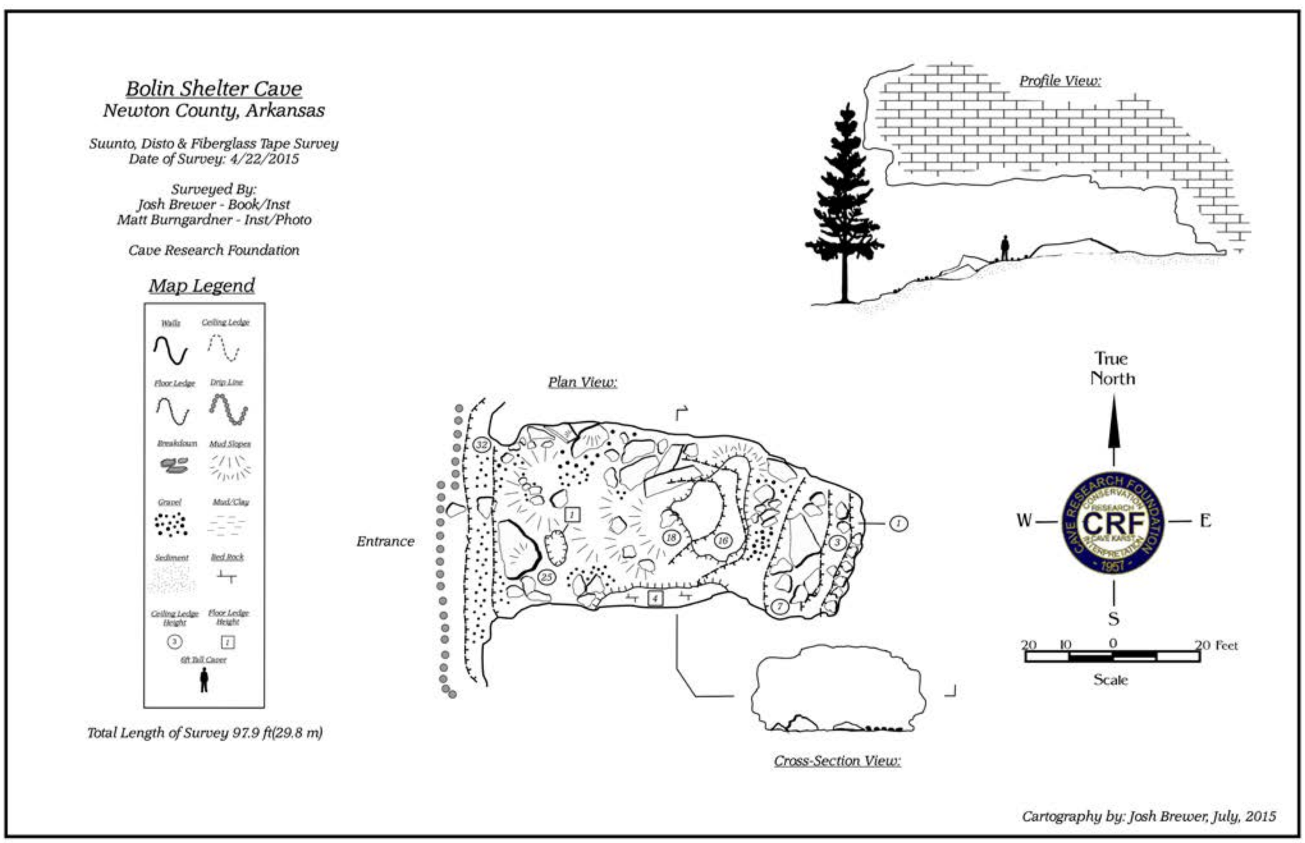
Future Work

Operations will continue to focus on biological monitoring, public use monitoring, and cartographic survey. Improvements upon the SCRC arrangements will continue to take place, with the hopeful addition of a dedicated, secure office space for files and technology. Expectations are that




WILLIS CAVE
Buffalo National River
Newton County, Arkansas
C-103
Surveyed by
Sim Barrow, Leah Bartlett, Ethan Foster,
Andy Free, Mark Jones, Ed Klausner
of
CAVE RESEARCH FOUNDATION
in cooperation with
Buffalo National River
low
Left Hand
Branch
Drain
Entrance
T Junction
Room
Right Hand
Branch
N
SCALE
dimensions given in feet
Cave Length 1075 ft/ 328m
profile views
Entrance
Drain
T Junction
Room
T Junction
Room
Left Hand
Branch
T Junction
Room
Right Hand
Branch
Map drawn by Ed Klausner
(c) 2014 Cave Research Foundation


SKUNK PIT
Newton County, Arkansas
Buffalo National River
BNR #C229
AACS #NW6268
Suuntos, Fiberglass Tape, & Leica Disto Survey By:
Josh Brewer
Ben Miller
Bryant Galloway
Dan Nolfi
November 6, 2015
Length: 29.9 Feet (9.11 Meters)
Depth: 106.9 Feet (32.58 Meters)
Cave Research Foundation
Entrance
102 Ft. Pit
0 Datum
PROFILE A - A'
PROFILE B - B'
Note: All pit plan views are oriented to True North. Lower passage walls in gray
SCALE
0 20 40 Feet
0 5 10 Meters
N True
W
E
S
Drafted by Ben Miller, 2015


Bolin Shelter Cave
Newton County, Arkansas
Suunto, Disto & Fiberglass Tape Survey
Date of Survey: 4/22/2015
Surveyed By:
Josh Brewer - Book/Inst
Matt Burngardner - Inst/Photo
Cave Research Foundation
Map Legend
Walls
Ceiling Ledge
Floor Ledge
Drip Line
Breakdown
Mud Slopes
Gravel
Mud/Clay
Sediment
Bed Rock
Ceiling Ledge Height
Floor Ledge Height
6ft Tall Caver
Total Length of Survey 97.9 ft(29.8 m)
Profile View:
Plan View:
Entrance
Cross-Section View:
True North
W
E
S
Scale
20 10 0 20 Feet
Cartography by: Josh Brewer, July, 2015

the size of future expeditions will continue to increase, calling for greater logistical efficiency, but sufficient seasoned volunteers are already greatly aiding in this positive trend of growth. The addition of historical faunal records will continue in the process of more thoroughly populating the Buffalo National River Cave database, which holds some 600 cave and karst features at currently.

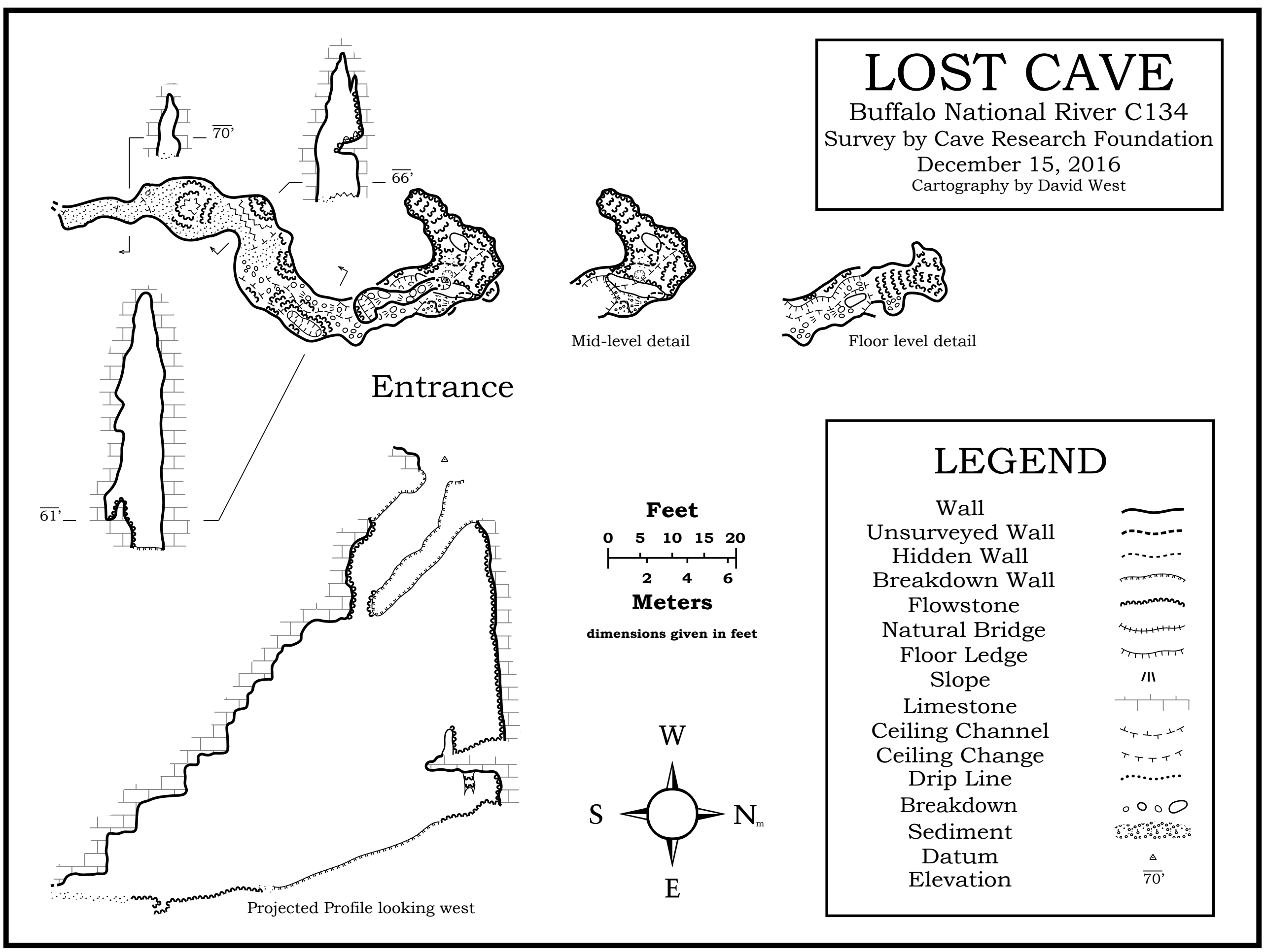
Carissa Shock admires a bat in Locust Cave, Buffalo National River. *Adrian James*

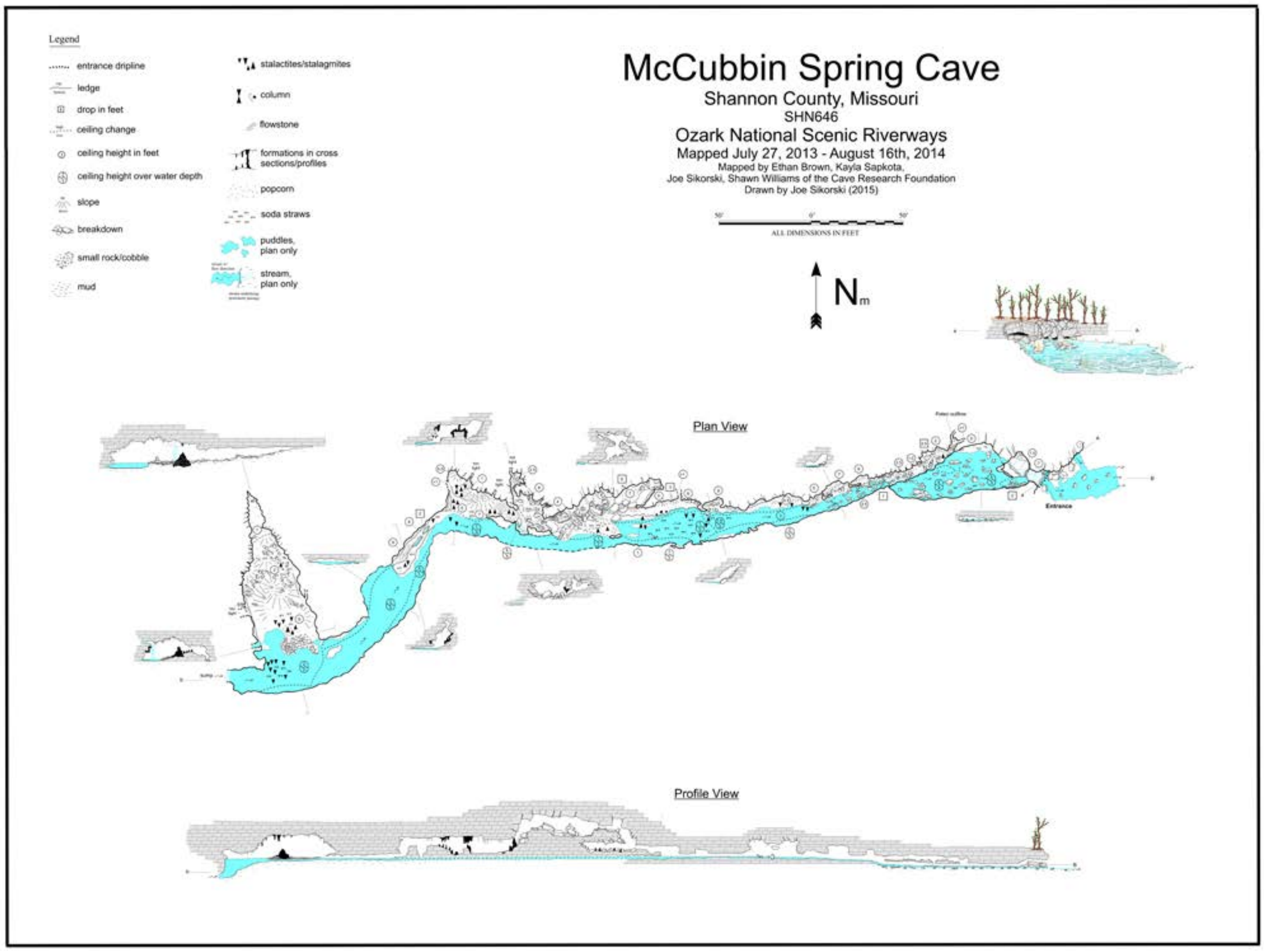
Ozark National Scenic Riverways

(National Park Service)

Scott House and Tony Schmitt

The Ozark National Scenic Riverways (OZAR) is a linear park along the Current and Jacks Fork Rivers in Missouri. OZAR projects accounted for a high proportion of CRF-Ozarks field trips; this was made possible by a contract for cave management services, including data acquisition. This highly successful program, headed up by Scott House, emphasized cave monitoring but included cave survey and inventory. Trips involved large numbers of CRF members from several states. Most of the trips are small but some, such as Martin Luther King or Missouri Speleological Survey meeting weekends, involved numerous people and parties. CRF helps maintain the Powder Mill Research





Karen Willmes, Scott House, and Dave West count bats in Branson Cave, Ozark NSR. *Matt Bumgardner*

Center, a former visitor center converted to office, storage, and bunk space; we also keep our cave gating materials at that locale. NPS support includes the research center, office space, cave equipment, computers, and all utilities.

OZAR Cave Surveying and Inventory

Surveying highlights include the continuing survey of Bealert Blowing Spring Cave, a long, wet virgin cave that keeps on going. Currently the surveyed length stands at 5500 feet. The survey of Ditch Cave, an important biology cave, was finished at 660 feet. Due to wet weather, surveying in 3000 foot-long Alphen Hollow Spring Cave has been on hold—this is a stream cave with numerous low-air spaces. The map of Sluiceway Cave, an important site on the upper Jacks Fork River was completed (and won an award at the NSS Convention). The survey of Wallace Cave, near Devils Well, was continued; the cave is now more than 2500 feet in length. The survey of McCubbin Spring Cave was completed. Mapping of Round Blue Hole Cave on the upper Jacks Fork River, was completed with 700 feet of survey. Lawrence Hollow Cave, on private land bordering the park was also surveyed.

Scott House leads Jeff Briggler of the Missouri Department of Conservation along with two Japanese herpetologists to look for salamanders in Round Spring Cave, Ozark NSR.
Shelly Colatskie, Missouri Department of Conservation

A biological survey of several long stream caves is continuing with trips to Ditch Cave, Alphen Spring, Sluiceway, Welch Spring, Bealert Blowing Spring, and Concolor Cave.

OZAR Cave Management, Monitoring, Gating, and Interpretation

Most of the trips led into the park were for cave management issues, including monitoring, gate maintenance, and sign installation. CRF also participated in Junior Ranger Days (a school day) and provided leadership for several university class trips into Round Spring Cave. Two more trips were taken into Round Spring Cave for visiting biologists (from Brazil and Japan).

Replacement interpretive signage was provided for three locations in the park. New posters on bats and cave management in the park were created. Bat bookmarks, for distribution to school students and others, were also created by CRF.

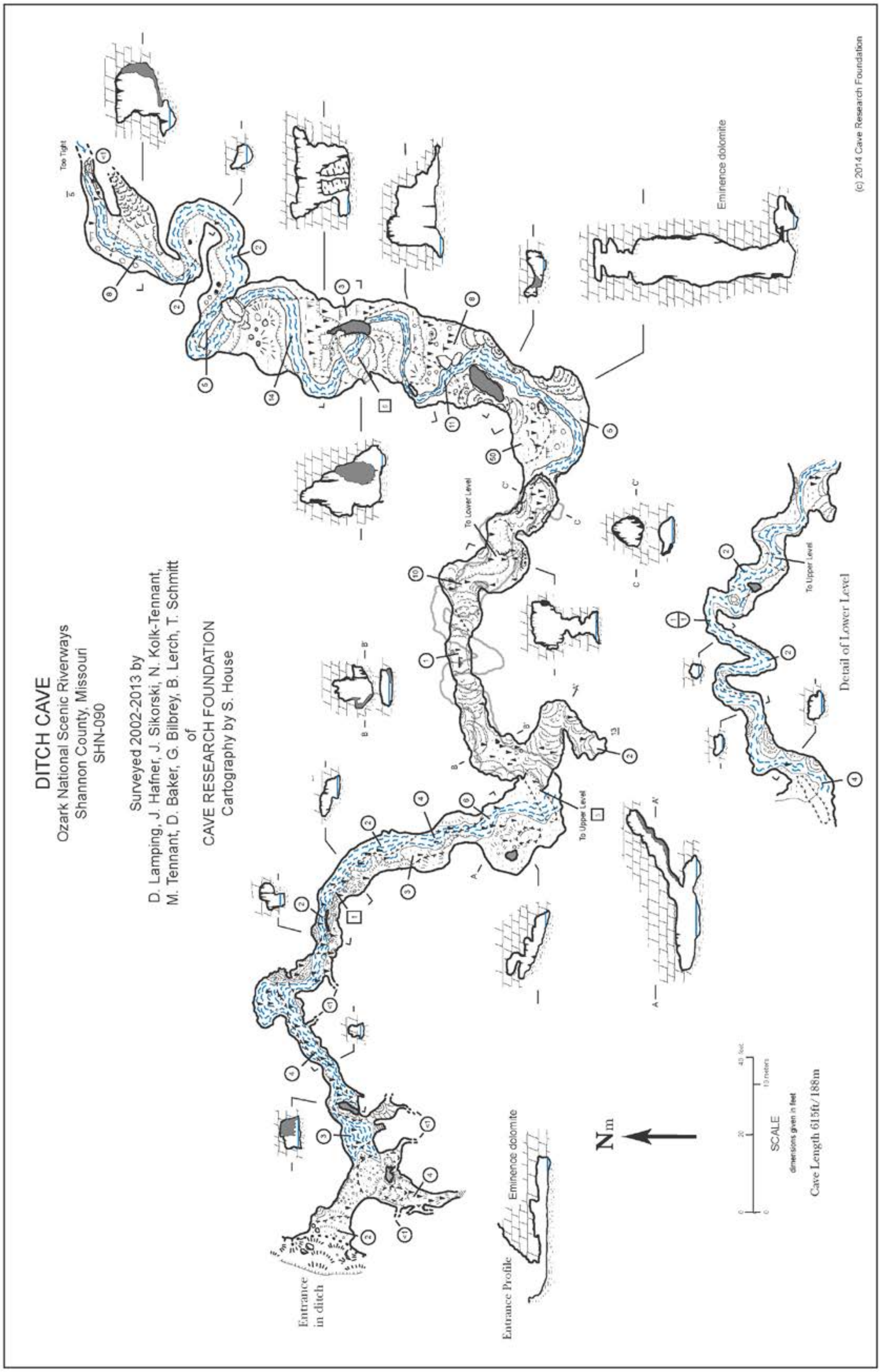
Numerous monitoring trips counted cave fauna and analyzed human impacts to the caves. A special emphasis was given to examine bats closely to monitor the continuing spread of White Nose Syndrome. Several days were spent on bat counts of priority hibernacula in cooperation with the Missouri Department of Conservation. Monitoring visits to caves totaled approximately 200 for these two calendar years.

Two caves were gated: Bear Cave on the upper Jacks Fork River in 2014, and Wallace Cave on the upper Current River in 2015. Gate repairs were done to several other caves.

Revisions were made to numerous cave locations. Additional reports were incorporated into the cave database as well. Cave management issues were also addressed and information was provided to the park for use in upcoming management plans, including the General Management

Jon Beard avoids the ice-mites while monitoring a cave in Ozark NSR. *Matt Bumgardner.*

Members of Springfield Plateau Grotto fix the trail in Round Spring Cave, Ozark NSR. *Matt Bumgardner.*


DITCH CAVE
Ozark National Scenic Riverways
Shannon County, Missouri
SHN-090
Surveyed 2002-2013 by
D. Lamping, J. Hafner, J. Sikorski, N. Kolk-Tennant,
M. Tennant, D. Baker, G. Bilbrey, B. Lerch, T. Schmitt
of
CAVE RESEARCH FOUNDATION
Cartography by S. House
Entrance in ditch
Entrance Profile
Eminence dolomite
To Upper Level
To Lower Level
Too Tight
Detail of Lower Level
Eminence dolomite
SCALE
dimensions given in feet
Cave Length 615ft/188m
(c) 2014 Cave Research Foundation

Plan and the Roads and Trails Plan. Cave monitoring and faunal records are now entered into the master Missouri Cave Database.

Mitigation of a vandalism incident occupied a team for days in June. This occurred on L-A-D Foundation land within the park boundaries and is discussed further below.

Devils Well Monitoring Trip

The Devils Well is a 100-foot pit that drops into a large underground lake with water depths of 80–135 feet. It serves as a window into the massive supply for Cave Spring about a mile away on the Current River. It is a day use area open to the public, with a very nice walkway down to the lip of the pit, complete with a high powered LED light hanging in the shaft, which turns on via a motion detector as you walk down the stairs. There are several interpretive signs explaining the geology, hydrology, and early exploration of the well. The Devils Well had not been entered since the Park Service purchased the land in 1973. CRF personnel included the in-cave team, Dan Lamping, Joe Sikorski, Bob Lerch, Mike Tennant, and Tony Schmitt. Rick Haley and Mark "Elvis" Andrich were the Pit Masters / Safety Team. Acting as surface support were Scott House, Don Dunham, and George Bilbrey.

The team arrived on site Wednesday, June 24, to set up camp and begin rigging the main line and haul line. Due to the infrastructure at the entrance more planning and thought went into the rigging than most cave trips. Everything was rigged by evening, and the rafts and other inflatables were staged on the upper platform. All of the team would wear wetsuits for the trip.

Jerry D. Vineyard, one of the original explorers and legendary Missouri caver, was on hand for the event. The project would mark the first descent of Devils Well in over 30 years, and the first descent using modern caving SRT techniques. The drop was 90 feet free to the lake. An inner tube with a tough canvas material was dangled below the harness. At water level the first person rappelled into the inner tube and then detached from the main line. Radio contact was then established (although tough to hear, the radios did work) and rafts were then lowered. The first man's job was to get the rafts under the other cavers as they descended.

Once in the lake two of the team took photographs, while two others looked for blind fish in the murky water (it had been raining heavily for days prior to the trip). One other person moved about the room, checking conditions and leads. It became clear very quickly that communicating in the Well was going to be difficult. The waterfall from the entrance shaft, plus at least two other waterfalls in the Well, made for a constant roar. Every word echoed throughout, making talking, unless within six feet of each other, very difficult.

Dan Lamping at the gate of Devils Well, Ozark NSR.
Scott House

Mike Tennant, Tony Schmitt, Jerry Vineyard, Dan Lamping, Scott House, Bob Lerch, and Joe Sikorski line up on the boardwalk at Devils Well, Ozark NSR. *Don Dunham.*

made the ascent without difficulty, although the waterfall covered the team as they ascended. The rest of the day was spent discussing findings with park staff, reporters, and onlookers.

More than anything this trip was a proof of concept venture. No one had ever descended the Well with SRT. Historical access was via a Bosun's chair and winch. We have now established it can be done, safely and efficiently. More trips are already being planned, with the ultimate goal of possible removing the platform, trash, and getting cave divers to further the knowledge of the Cave Spring / Devils Well system. While CRF already has a great working relationship with Ozark National Scenic Riverways, this further enhanced that relationship. The park staff on hand, which included the Public Information Officer / Acting Chief of Interpretation and the Chief of Resource Management, was pleased and impressed. We made the front page of newspapers in the state, including local newspapers plus the *St. Louis Post Dispatch*. The park featured the trip prominently on the park's Facebook page.

In the Devils Well. *Dan Lamping*

The only easily accessible side passage known as the muddy crawl-way was entered for about 50–80 feet. Access was via an old rotting platform with ladder made of wood. No historical reports mention this in the Well. It also had a light fixture, and some electric line that must have long ago gone to the surface. Sitting on the platform was an old metal clipboard, with the word "help" written on it, perhaps a former explorer's attempt at humor. About two hours were spent exploring and photographing the Well room which measures approximately 400 × 100 feet. All

Mark Twain National Forest

(U.S. Forest Service)

Mick Sutton

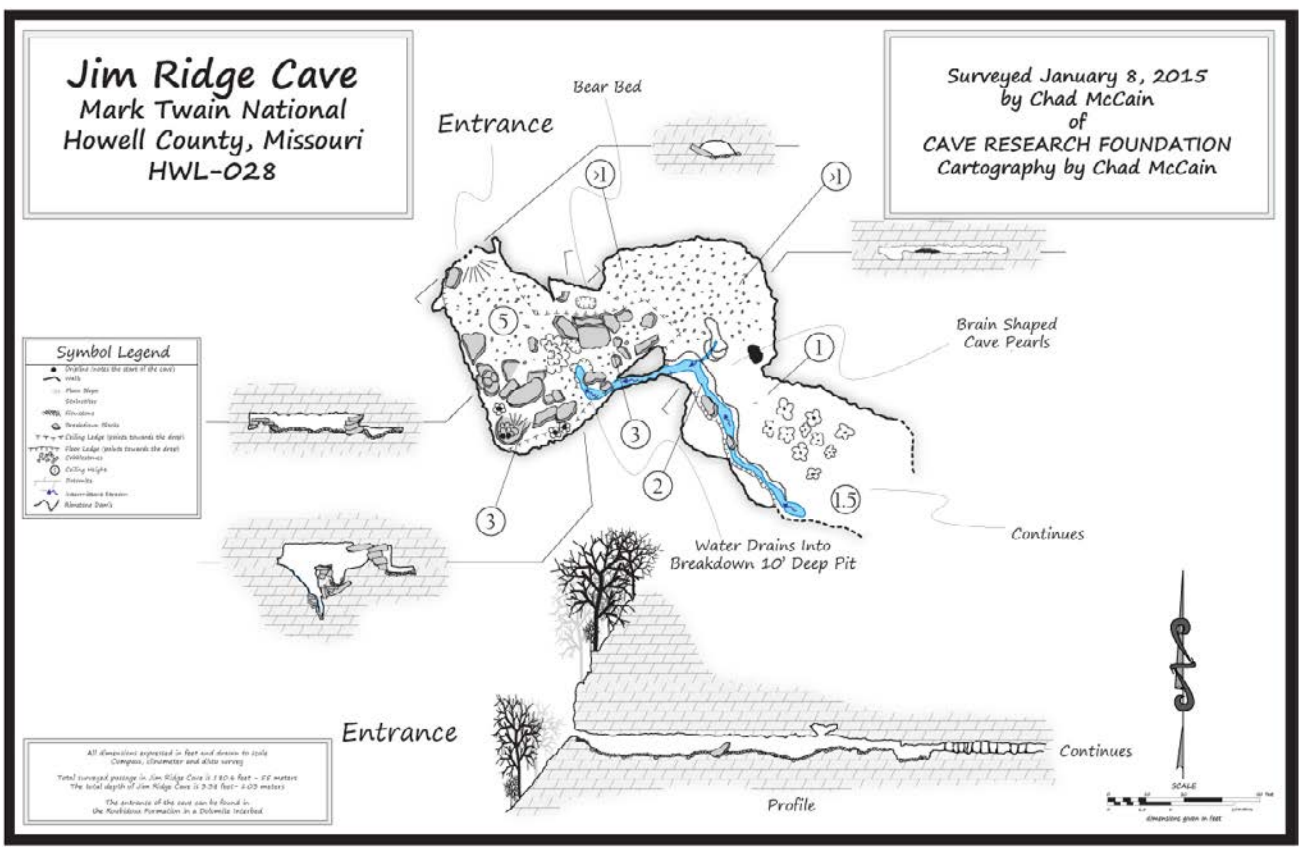
The amount of work being done on the Mark Twain National Forest has become so diverse and extensive, with such a wide range of participants, that it is sometimes difficult to keep up. One of the major focuses has been on bat surveys to monitor and track the spread of White Nose Syndrome. Unfortunately, the first record of WNS on the Mark Twain occurred in Bass Cave in the Potosi District and WNS observations gradually spread southwards and westwards, first to Cave Hollow Cave in Iron County then to other MTNF districts. Where comparisons could be made with previous counts, bat numbers were generally lower.

Another major focus was on cave gating and associated monitoring activities. These projects involved close collaboration between CRF, MTNF, C.A.I.R.N. and Americorps personnel. A group of caves in the Butler Hollow area of Barry County were historically mined for (supposedly) radium—a fascinating story, but the relevance is that, as mining sites, MTNF is obliged to gate them. Many trips were taken to assess the gating sites and draw up gate plans under the direction of Jim Cooley and to do archeological assessments under the direction of Craig Williams. Late in 2015 the two entrances of Radium Cave, the natural entrance and an artificial pit entrance, were gated. The Butler Hollow project also includes ridge-walking in the general area to locate and assess unrecorded caves, of which at least 12 were discovered and most of them mapped.

In the Fredericktown District, three mine entrances in the Silver Mines area on the St. Francois River were gated, following assessments of historic and prehistoric archeology. A breach in the Onyx Cave, Pulsaki County gate was repaired, and a small mine shaft on the Ava District was gated with a cupola gate. Secesh Cave (Carter County), an Indiana and northern bat cave, was assessed for what will be a difficult gating project if the decision is made to go ahead with this.

CRF continued to provide scoping assessments of private caves within or near MTNF project boundaries. CRF personnel in the person of Mike Tennant assisted Ozark

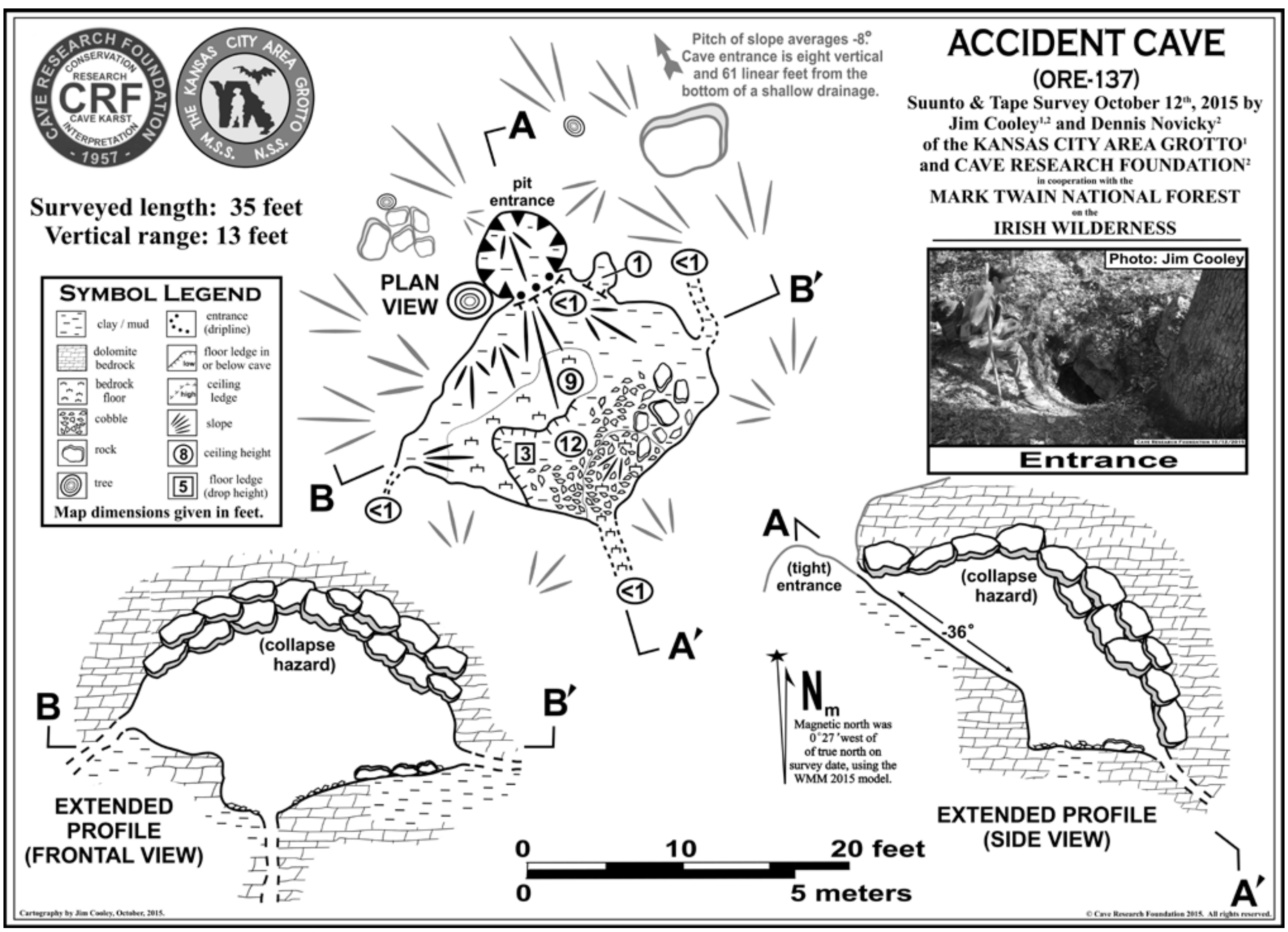
In a Mark Twain NF cave, Mark Jones begins sketching as Brandon Van Dalsem watches. *Richard Young.*



A camouflaged CRF caver blends in to a Mark Twain NF cave. *Jeff Crews*

Dan Lamping in Corral Cave, Mark Twain NF. *Tony Schmitt*

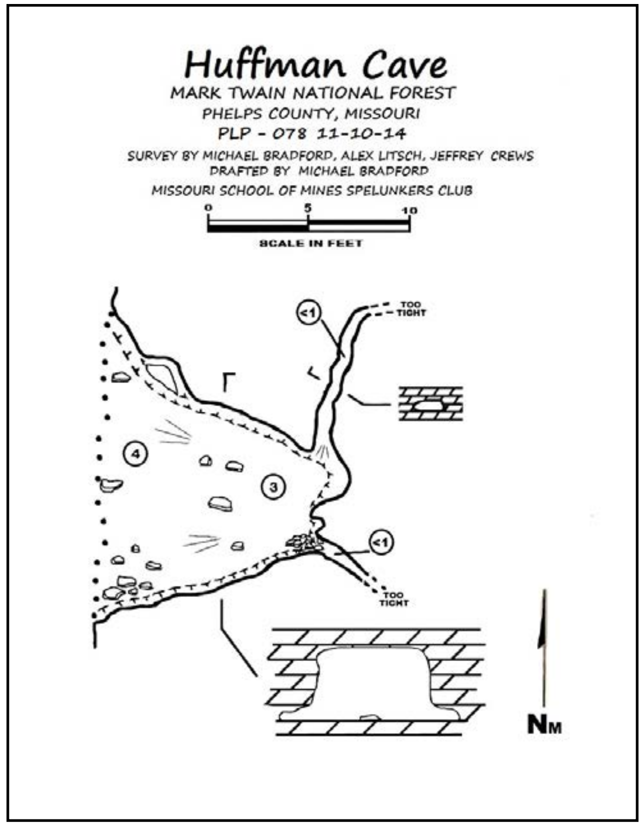
A pleased crew of CRF and Americorps workers pose on the new gate of Radium Cave, Mark Twain NF. *Jim Cooley*



Cave Diving Alliance divers in their attempted exploration of Stone Mill Spring on the Rolla District, but a mass of construction debris makes further progress impractical.

Elsewhere, almost every district on the Mark Twain was visited for mapping, bio-inventory, and monitoring trips. An impressive total of 95 previously unrecorded caves were documented during the two years, and 74 maps were drafted. All of the caves visited for other purposes were also monitored for biology and for use and abuse; additionally, a large number of caves were visited just for use and biology monitoring. Highlights included:

- Cane Bluff Cave #2 (Taney County)—the survey was successfully carried through an annoying tight spot into roomier territory.
- Countyral Cave (Washington County)—old map replaced and additional passage added for a total of 880 feet, with a wet lead continuing.
- Saltpeter and Big Brown Bat Caves (Madison County)—survey of two caves joined by an impassable voice connection completed for a total of 1400 feet. Gray bat clusters discovered in Big Brown Bat Cave, which is also an Indiana bat hibernaculum.
- Turtle Cave (Oregon County)—spotted skunk observation, a first cave record for this rare animal; survey completed, 200 feet.
- Hanley and Western Turkey Caves (Phelps County)—survey of this two-cave system completed for a total of 1040 feet.
- Mud Spring Cave (Howell County)—old undetailed map replaced, 840 feet.
- Hog Pen Cave (Christian County)—petroglyph of headless figure documented with 3D photography.
- Robert Taylor Memorial Cave (Christian



Someone has to do it. A CRF survey and monitoring crew moves from cave to cave on the North Fork River, Mark Twain NF. *Scott House.*

Richard Young examines cultural remains in a cave on Mark Twain NF. *Scott House*

County)—survey continued, with about 1000 feet mapped and more to go.

- North Fork River (Douglas and Ozark Counties)—a lot of effort went into completion of ongoing surveys, and locating, mapping, and assessing many new caves along the North Fork White River in the Willow Springs District. The most significant was hard-to-access Huffman Cave, mapped for 540 feet with good continuing leads.
- Irish Wilderness (Oregon County)—another focus of concentrated work on locating and mapping new caves, many of them tight and wet, with many survey and monitoring trips.

CRF has also helped publish several issues of *Missouri Speleology,* focusing on CRF project reports. The journal is edited by CRF member Don Dunham.

Berome Moore Cave

(Missouri Caves and Karst Conservancy)

The Berome Moore Cave system, one of four large systems in Perry County, Missouri, is owned by the Missouri Cave and Karst Conservancy and is managed by MMV Grotto of St. Louis. CRF is leading the resurvey effort of this large and important cave. A few loop blunders slowed field work down but there were still eleven trips during 2014–2015. The resurveyed length of Berome Moore is now at 5.7 miles.

Other Missouri Projects

Scott House

(With contributions from Tony Schmitt, Dan Lamping, and Jim Cooley)

Missouri Cave Database

(Missouri Speleological Survey)

The Missouri Cave Database is a project of the Missouri Speleological Survey. Cave Research Foundation provides support in the form of office space, computer hardware and software, along with personnel and financial support. The database is written in FileMaker Pro, currently kept in version 13, and today amounts to approximately 175mb in size.

The database contains records in several different tables that are related. The main table consists of approximately 7,000 records, representing distinct cave entrances. Some entrances connect to others, so the number does not exactly reflect the number of caves in Missouri. Another table incorporates individual cave faunal records which total over 22,000. A maps record table indexes over 4500 cave map sheets. A newer public use table documents over 2,200 monitoring trips to caves. Lastly, a reports table preserves over 12,000 text reports, including memos, emails, narrative descriptions, science reports, and trip reports.

The database contains records from state and federal agencies, who rely on the MSS to provide a consistent numbering scheme, as well as providing review and auditing of cave locations and names.

CRF members who have contributed heavily during 2014 and 2015 include Mick Sutton, Ken Grush, Ben Miller, Chad McCain, Jim Cooley, Jon Beard, Jeff Crews, Matt Bumgardner, Tony Schmitt, Richard Young, Dan Lamping, Paul Hauck, and Scott House.

CRF crew of Tony Schmitt and Richard Young draw a crowd of onlookers in downtown Perryville as they enter a city cave. *Scott House*

Perryville Karst Inventory

(City of Perryville)

The City of Perryville requested help inventorying their karst resources as part of a protection plan for the endangered Grotto Sculpin. CRF facilitated a total of ten trips to city-owned caves; these trips included biological surveying, mapping, relocation of caves, and management. Two small caves were mapped and in one larger cave, a map was begun.

Dan Lamping begins sketching in a Perryville cave.
Derik Holtmann

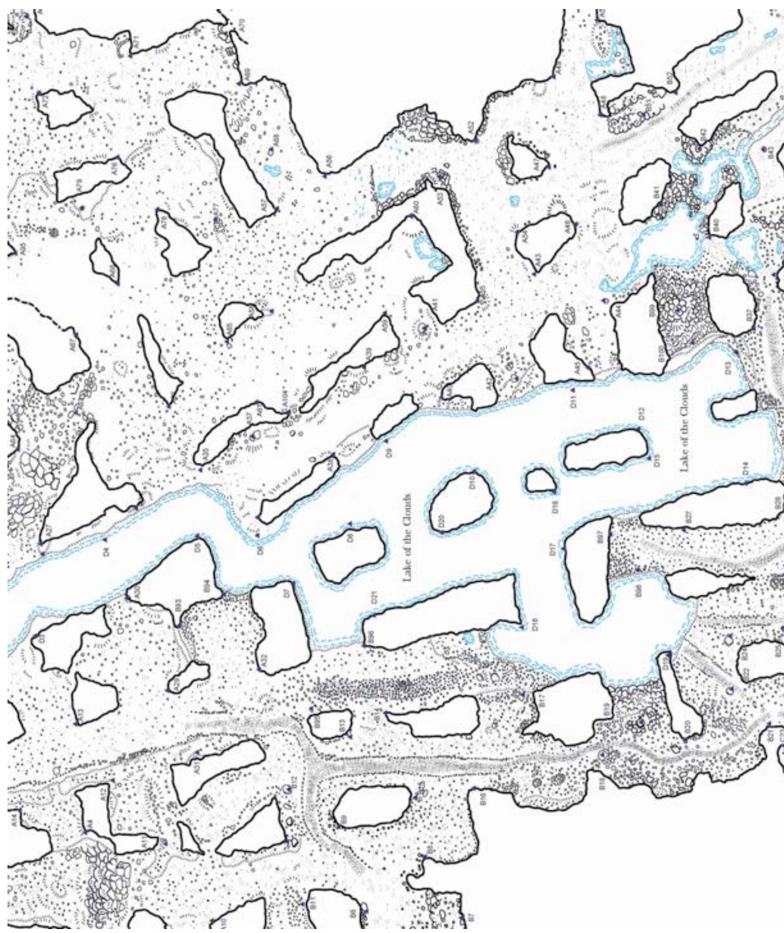
Paul Hauck and Andy Free endure the wet sections of Lime Kiln Mine near Hannibal, Missouri.
Kirsten Alvey-Mudd, Missouri Bat Census.

An MCKC/CRF crew poses at a community tree planting in Perryville, Missouri. *MCKC photo*

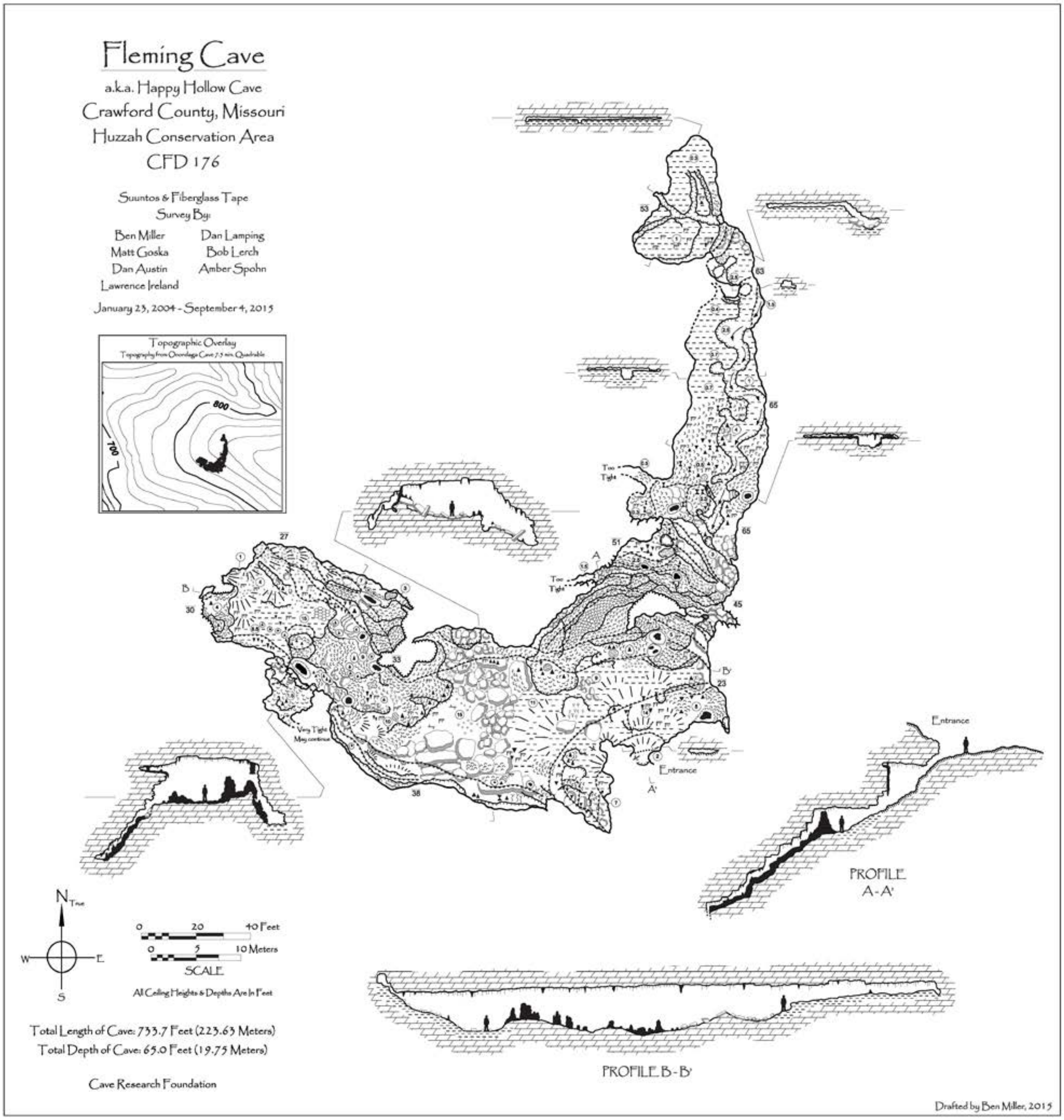
Lime Kiln Mine / Sodalis Nature Preserve
(U.S. Fish and Wildlife Service)

The survey of Lime Kiln Mine in Hannibal, Missouri, was continued with nine field trips during 2014–2015. This mine is currently the largest known hibernaculum for Indiana bats (M. sodalis). This was a continuation of an effort begun in 2012. Major funding originally came from the U.S. Fish and Wildlife Service through the Missouri Department of Conservation; beginning in 2014 the funding was continued by The Conservation Fund (TCF) which transferred title of the mine to the City of Hannibal as the Sodalis Nature Preserve.

Surveying in the mine is exacting but not exciting. Long hours are spent standing in water in "passage" that pretty much looks the same all over. The goal of the project is to create maps for biological (bat mapping), management (property extent), and in case of search-and-rescue needs (the mine is a total maze). Thus far, approximately 16 miles of survey have been put in. Field work is expected to continue in 2016.



Excerpt of Lime Kiln Mine map.


Fleming Cave
a.k.a. Happy Hollow Cave
Crawford County, Missouri
Huzzah Conservation Area
CFD 176
Suuntos & Fiberglass Tape
Survey By:
Ben Miller
Dan Lamping
Matt Goska
Bob Lerch
Dan Austin
Amber Spohn
Lawrence Ireland
January 23, 2004 - September 4, 2015
Topographic Overlay
800
700
Too Tight
Too Tight
Very Tight May continue
Entrance
Entrance
PROFILE A-A'
PROFILE B-B'
N True
W
E
S
0 20 40 Feet
0 5 10 Meters
SCALE
All Ceiling Heights & Depths Are In Feet
Total Length of Cave: 733.7 Feet (223.63 Meters)
Total Depth of Cave: 65.0 Feet (19.75 Meters)
Cave Research Foundation
Drafted by Ben Miller, 2015

Chad McCain, Paul Hauck, and Richard Young prepare to enter Crevice Cave, Perry County MO, after obtaining locational information from a Missouri Department of Conservation crew. *Scott House*

Conservation Areas Cave Survey, Monitoring, and Inventory
(Missouri Department of Conservation)

An unfunded Missouri Department of Conservation project continued with drafting on the first two of four sheets of the Powder Mill Creek Cave map. Special Use Permits were given out to aid in the continuation of survey, monitoring, and inventory projects on MDC conservation area (CA) lands. The Fish and Wildlife survey project described above was partially facilitated by MDC. Two large survey projects were continued. The first of these was the renewed survey of Lowell Cave on Fuson CA. That survey was finished at well over a mile in a series of determined trips. Survey in Shop Hollow Cave (joint project with Ozark Riverways) was continued and is now well over 6000 feet in length. A number of other MDC caves were monitored, usually in conjunction with MDC staff—most of these were around the Ozark Riverways. The map of Fleming Cave in Huzzah CA was completed.

Missouri State Parks
(Missouri Department of Natural Resources, Division of State Parks)

Missouri State Parks are administered through the Department of Natural Resources; monitoring and survey efforts were partially supported by a grant. Continuing our tradition of working with the Missouri State Parks, several trips were taken to sort out caves in certain areas, map some unsurveyed caves, and perform biological inventory. Monitoring and survey trips were taken to Roaring River State Park, St. Francois State Park, Battle of Carthage State

Joe Sikorski sketches deep in a large Ozark cave. *Derik Holtmann*

Joe Sikorski and Dan Lamping make sure their notes agree, deep within a cave on Missouri Department of Conservation land. *Derik Holtmann*

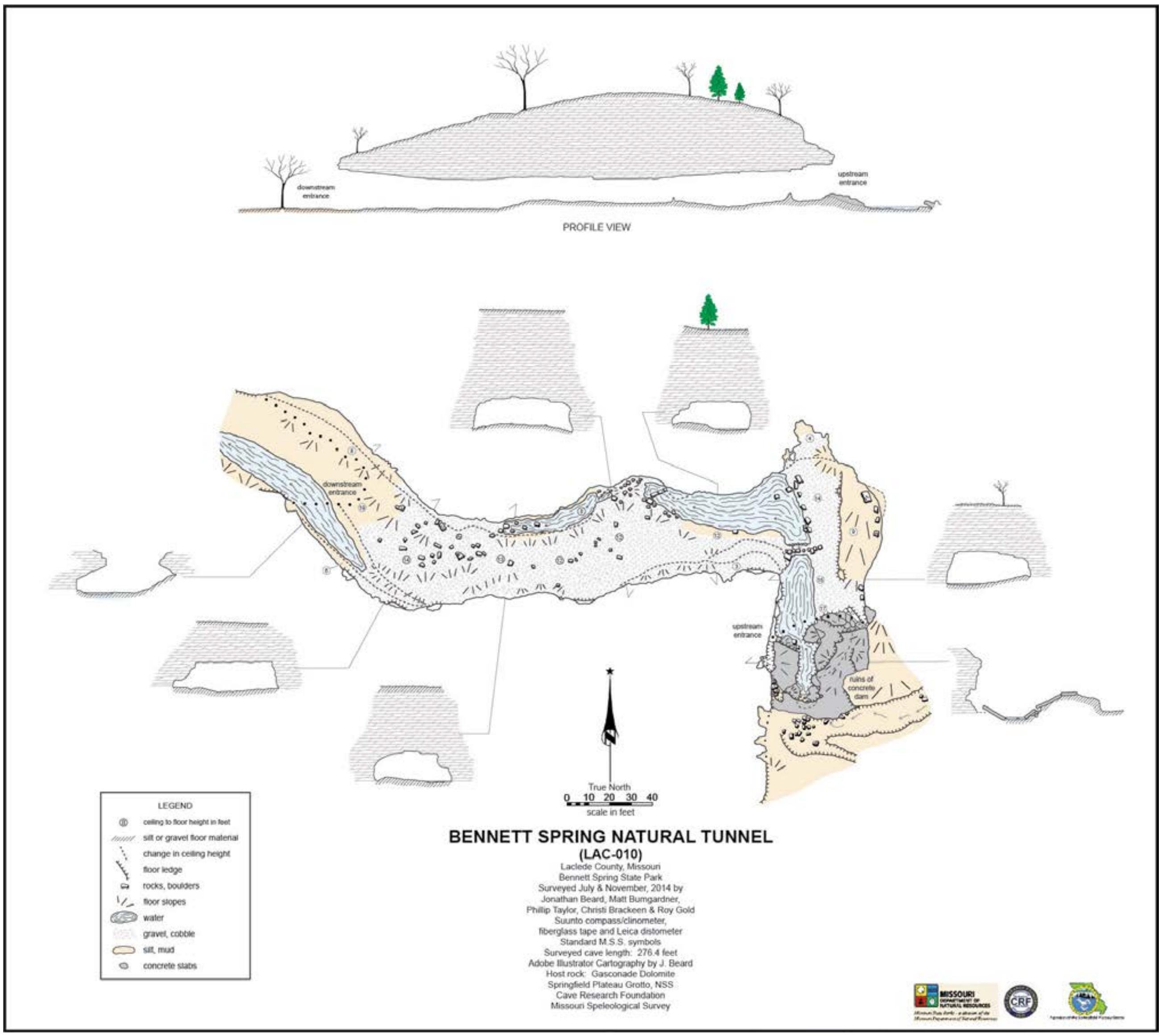
Historic Site, Lake of the Ozarks State Park, Onondaga Cave State Park, Bennett Springs State Park, Cuivre River State Park, and the newly created Echo Bluff State Park.

Pioneer Forest

(L-A-D Foundation)

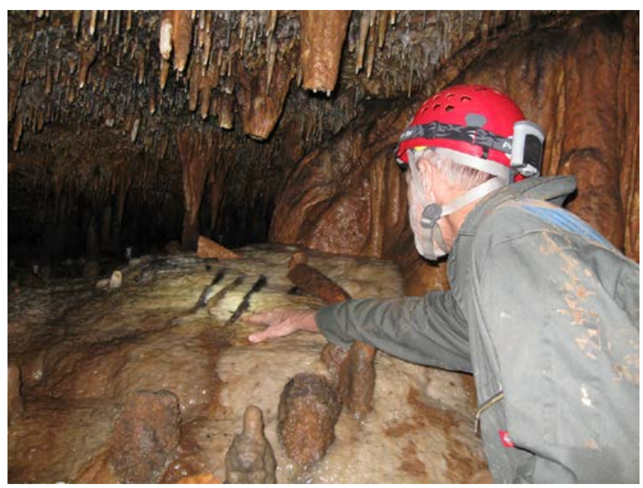
Missouri's largest private landowner owns more than 150 caves. CRF has supported occasional survey and inventory in them, while providing cave management consultation. Trips during 2014 and 2015 involved monitoring at such important caves as Cookstove Cave and Wind Cave, both important bat sites. A gate was repaired on Medlock Cave, located on L-A-D land within Ozark National Scenic Riverways. A new map of Holmes Hollow Cave was finished

A western slimy salamander guards fully developed eggs in a Pioneer Forest cave. *Derik Holtmann*



An enthusiastic CRF crew repairs a gate on a cave in Ozark NSR, but owned by L-A-D Foundation. *Scott House*

Shawn Williams and George Bilbrey prepare to measure a guano pile in a L-A-D Foundation cave. *Scott House*



Richard Young examines torch fragments encased in flowstone in a Pioneer Forest cave. *Scott House*

and mapping continued on several smaller caves, generally along the Blair Creek basin. Another cave, Thompson Creek Cave, was surveyed in a project also supported by the Ozark Riverways.

A new initiative seeks to update all Pioneer and L-A-D cave database records (not all L-A-D lands are within the Pioneer Forest). This update will take at least a year and will hopefully guide future work.

In 2015, a major service was performed by CRF members at Chalk Bluff along the Jacks Fork River, on L-A-D land within the Ozark National Scenic Riverways. A vandal (sadly a local off-duty serviceman) had spray-painted a large piece of the bluff. As part of the perpetrator's court resolution, he was required to pay restitution for cleaning the bluff. CRF stepped in and assembled a team that spent three days of work rappelling down the bluff with cleaning gear and, by hand, removing the graffiti. Much press attention resulted from this work, as the NPS put out news releases concerning the work. Numerous newspapers across the state reported this effort.

Greensfelder Park Caves Survey, Monitoring, and Inventory

(St. Louis County)

In the summer of 2015 an agreement was signed with St. Louis County parks to monitor, survey, and provide management considerations for caves on Greensfelder Park. Greensfelder Park is a 1734 acre site located in western St.

Alicia Wallace at the entrance of a Greensfelder Park cave, St. Louis County. *Tony Schmitt.*

Jim Cooley filling out a monitoring form. *Ken Grush*

Louis County that consists of steep forested hills. The park is known for its great mountain biking, equestrian trails, and proximity to the Six Flags amusement park. There are seven known caves in the park and numerous karst features within its boundaries. All of the known caves, except one, are vertical and require rope. Five of the caves are gated and have been closed to visitation for 20+ years. One cave is completely mis-located (cannot be found) while another cave is open for public visitation for a wild cave experience.

This project is just getting off the ground. 2015 was our first year of operations with St. Louis County. CRF and Meramec Valley Grotto ran four trips in late winter focusing on locating existing caves, updating GPS locations, and digging out gates. No actual trips into the caves occurred in 2015. We have cave trips scheduled for 2016. We hope to expand this project in the future to other St. Louis County Parks.

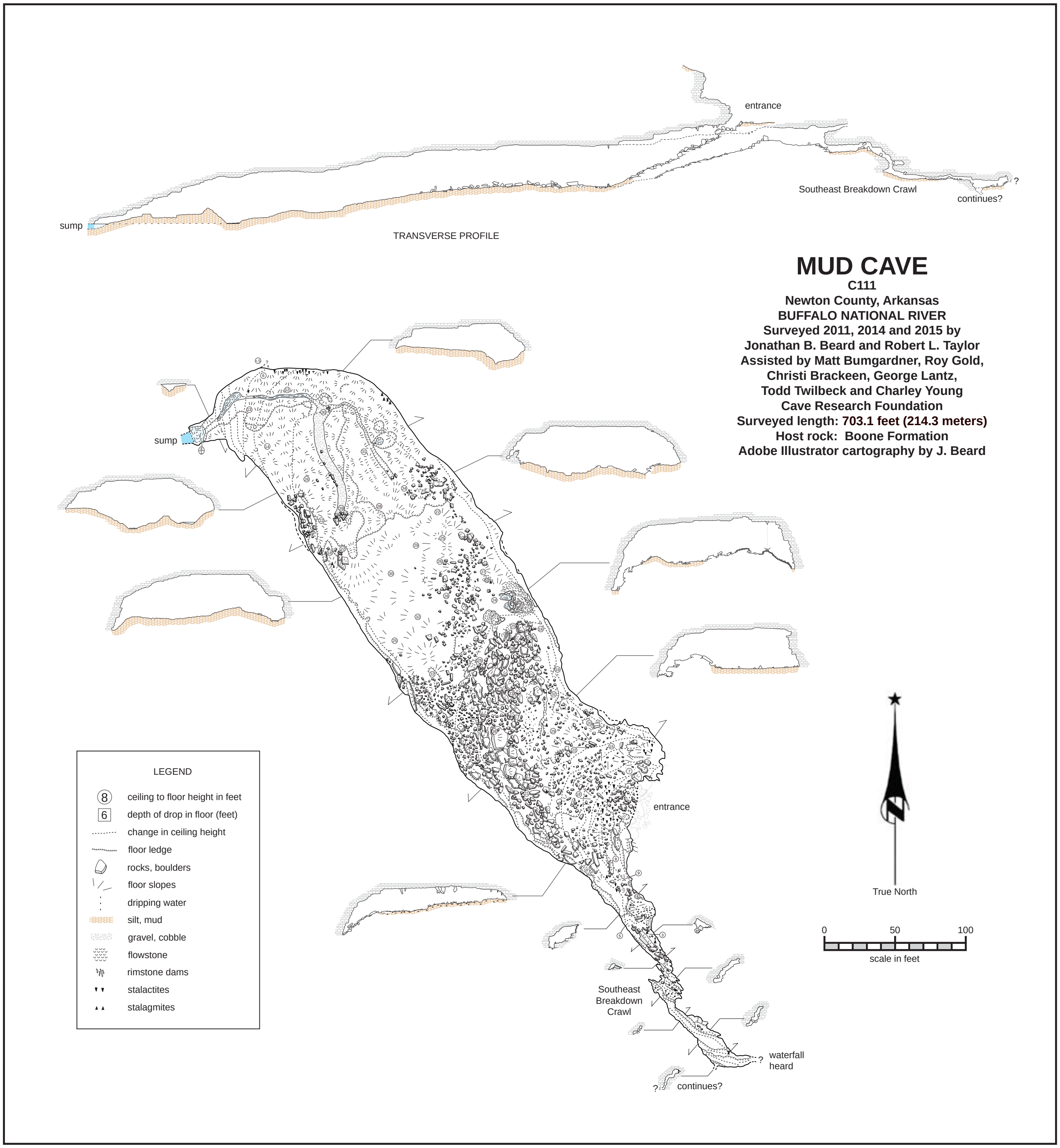
Elsewhere

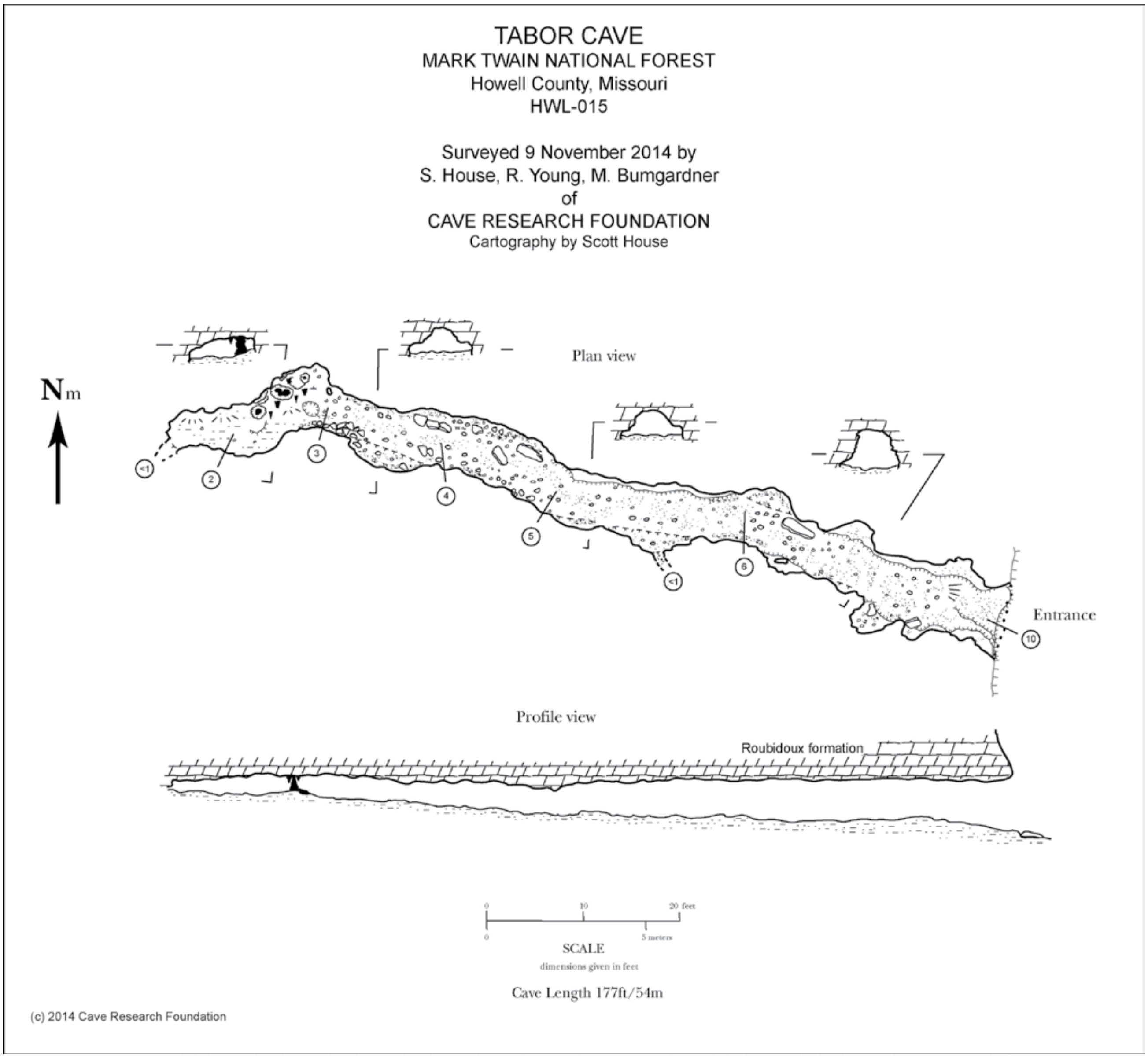
CRF personnel continued surveys at privately owned Lewis Cave (Ripley County, Missouri) and Big Mouth Cave (Oregon County, Missouri) in 2014 and 2015. Both are substantially important biological sites in extreme southern Missouri.

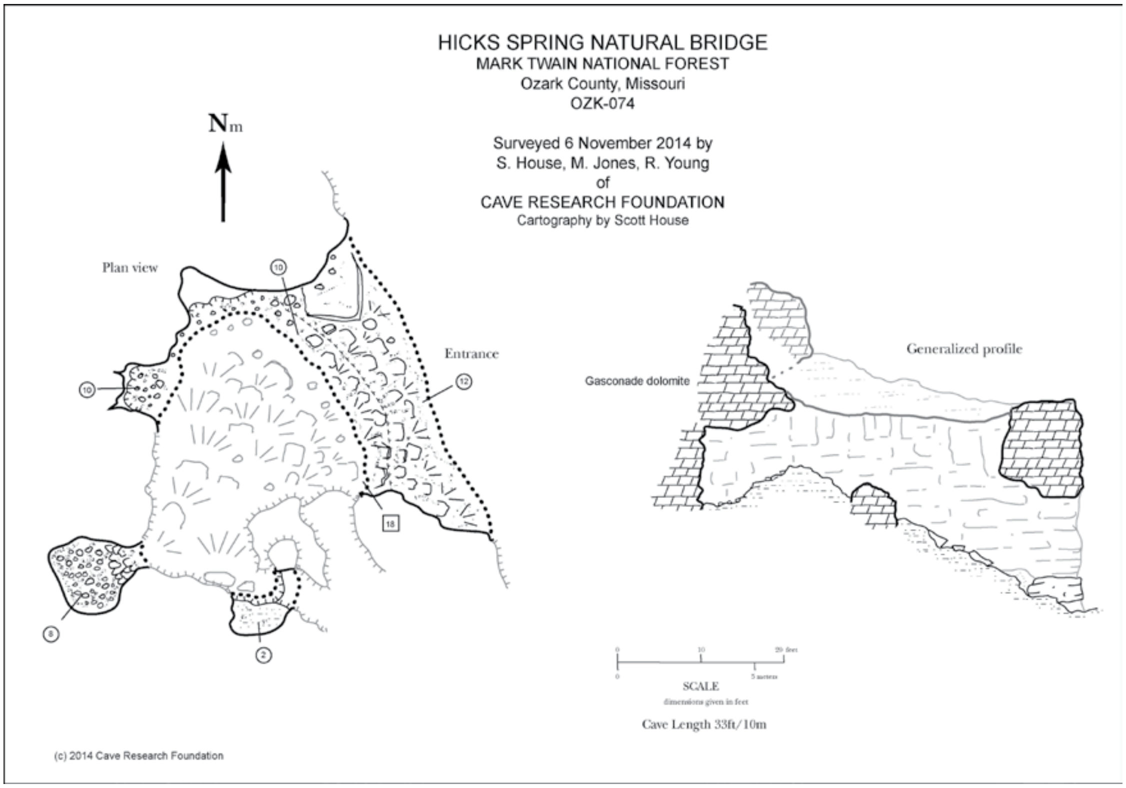
Numerous CRF personnel attended bat identification workshops at several locations. CRF members also attended bat coordination meetings to insure that efforts within Missouri were not duplicated. Training sessions were also held both inside and in the field for volunteer cave monitors.

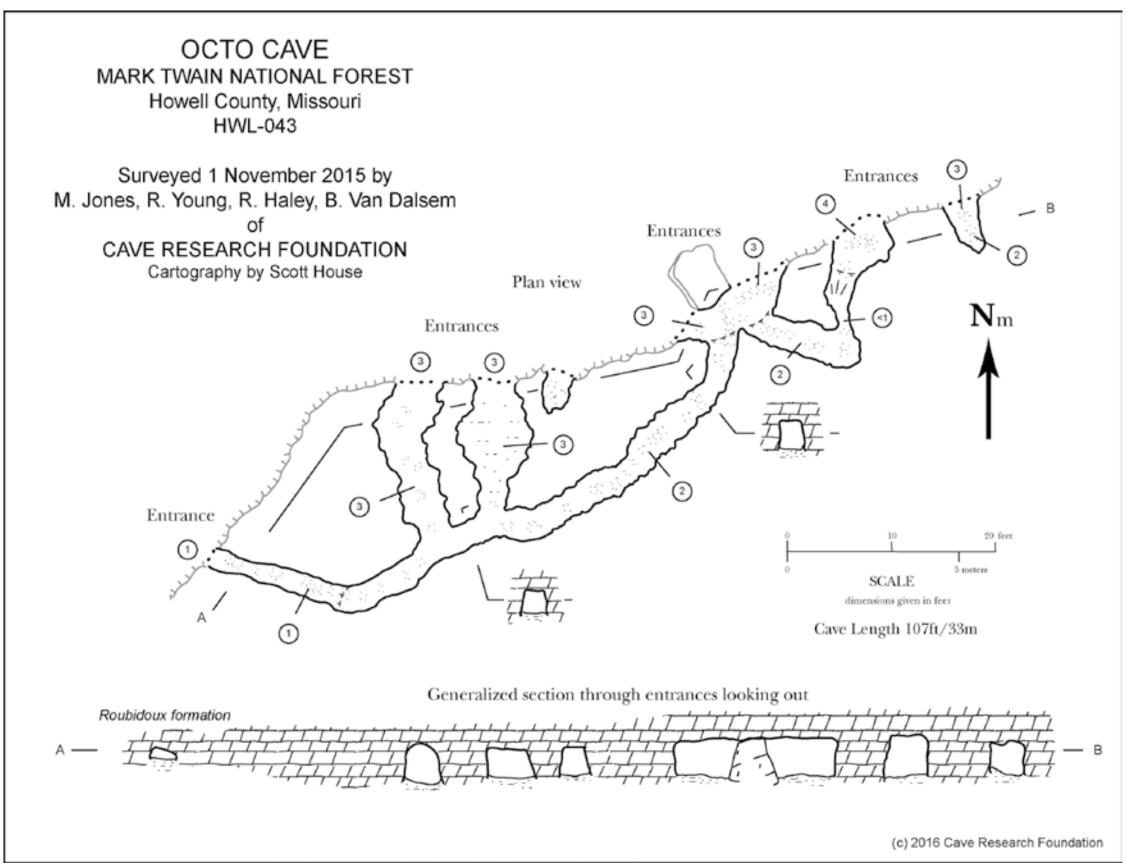
CRF members also worked on other privately-owned, agency lands or municipality properties including work in the city and county of Ste. Genevieve, work along state highway corridors, and bat surveys on private property.

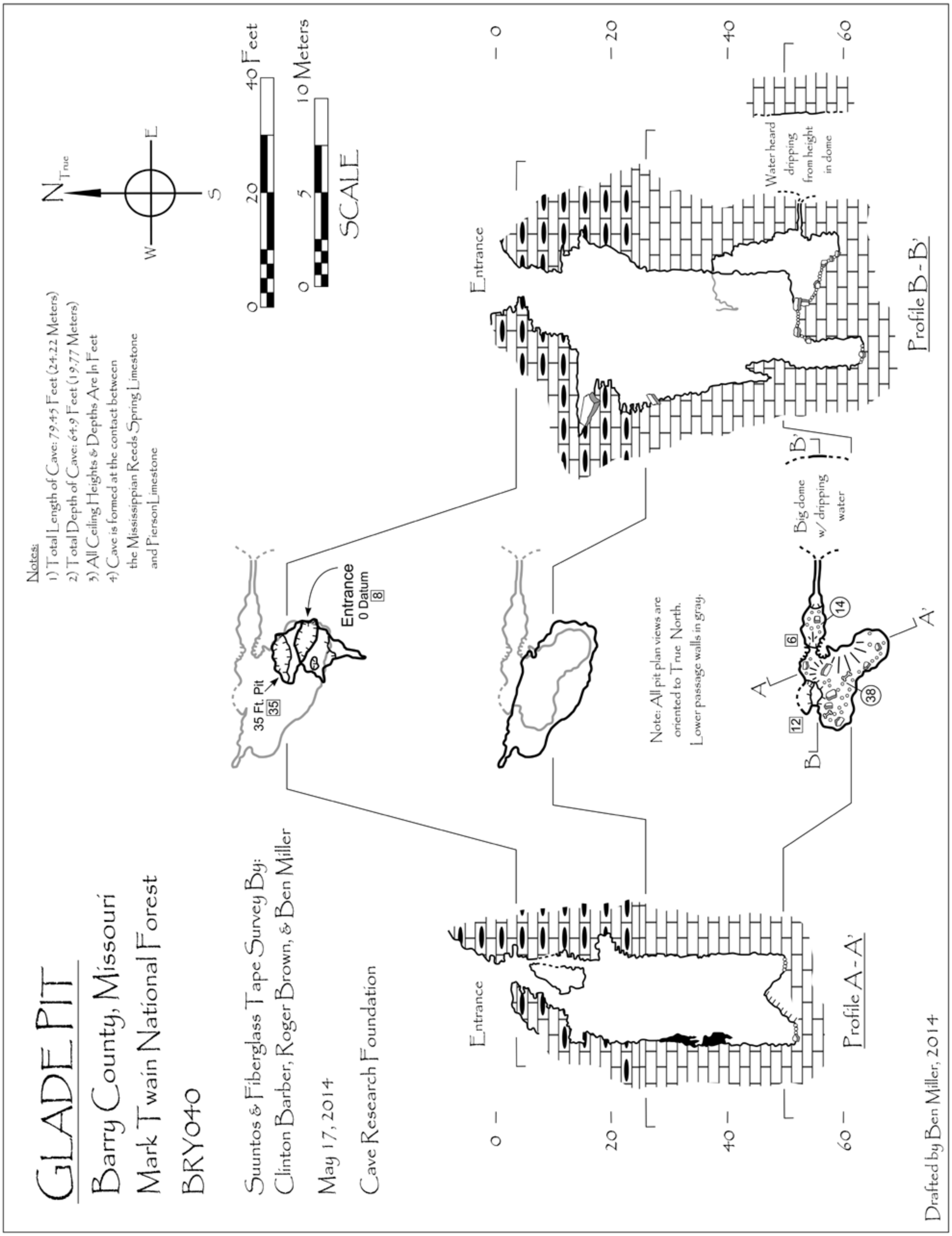
CRF members helped with the 2015 National Speleological Society convention in Waynesville, Missouri. Several presented papers, numerous CRF maps were displayed, and a number of members played behind-the-scenes roles in helping make the convention a success.


entrance
Southeast Breakdown Crawl
continues?
sump
TRANSVERSE PROFILE
MUD CAVE
C111
Newton County, Arkansas
BUFFALO NATIONAL RIVER
Surveyed 2011, 2014 and 2015 by
Jonathan B. Beard and Robert L. Taylor
Assisted by Matt Bumgardner, Roy Gold,
Christi Brackeen, George Lantz,
Todd Twilbeck and Charley Young
Cave Research Foundation
Surveyed length: 703.1 feet (214.3 meters)
Host rock: Boone Formation
Adobe Illustrator cartography by J. Beard
sump
entrance
LEGEND
ceiling to floor height in feet
depth of drop in floor (feet)
change in ceiling height
floor ledge
rocks, boulders
floor slopes
dripping water
silt, mud
gravel, cobble
flowstone
rimstone dams
stalactites
stalagmites
True North
0 50 100
scale in feet
Southeast Breakdown Crawl
waterfall heard
continues?

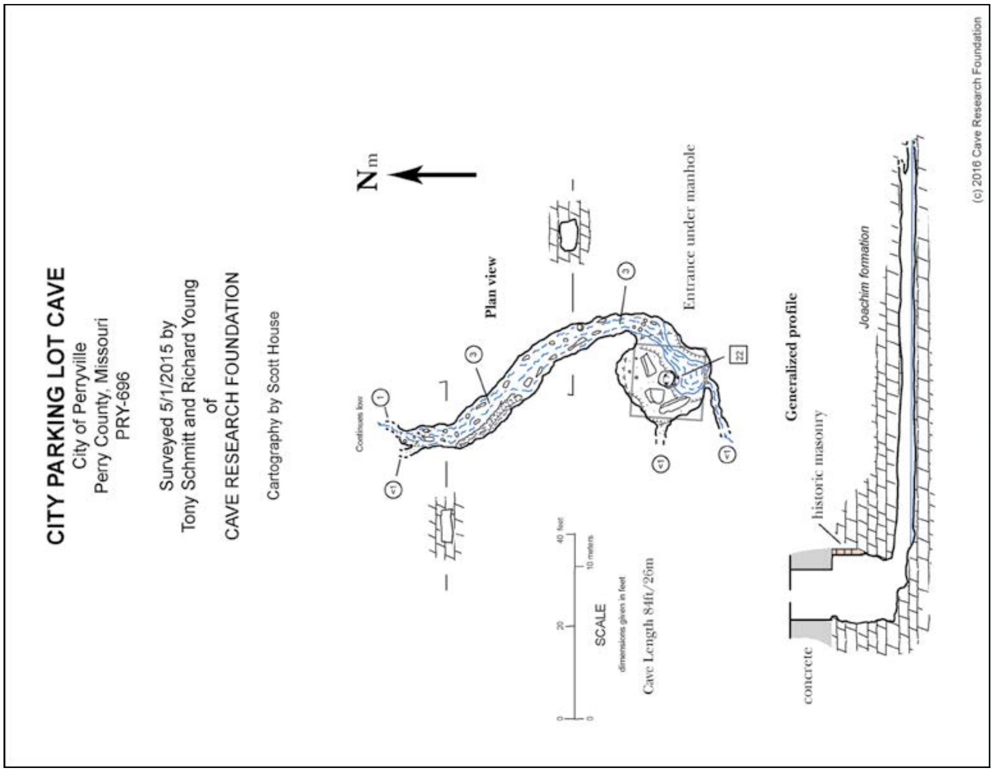

TABOR CAVE
MARK TWAIN NATIONAL FOREST
Howell County, Missouri
HWL-015
Surveyed 9 November 2014 by
S. House, R. Young, M. Bumgardner
of
CAVE RESEARCH FOUNDATION
Cartography by Scott House
Plan view
Nm
Entrance
Profile view
Roubidoux formation
SCALE
dimensions given in feet
Cave Length 177ft/54m
(c) 2014 Cave Research Foundation

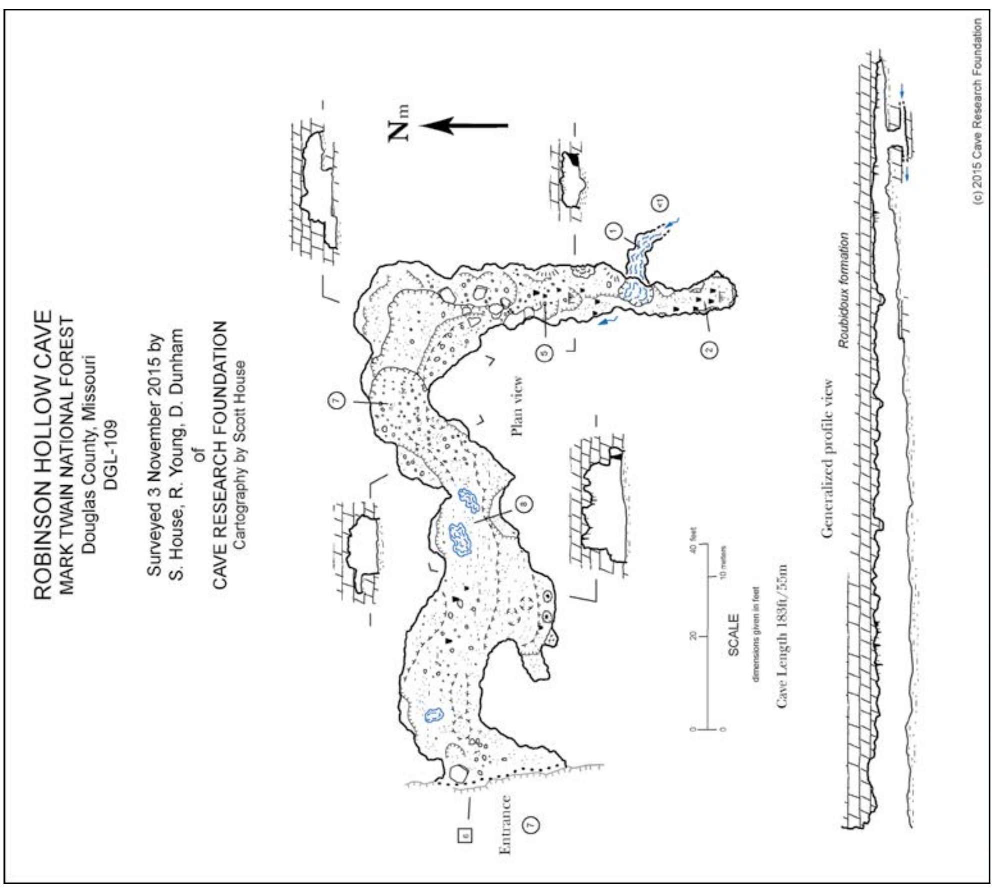

HICKS SPRING NATURAL BRIDGE
MARK TWAIN NATIONAL FOREST
Ozark County, Missouri
OZK-074
Surveyed 6 November 2014 by
S. House, M. Jones, R. Young
of
CAVE RESEARCH FOUNDATION
Cartography by Scott House
Nm
Plan view
Entrance
Generalized profile
Gasconade dolomite
SCALE
Cave Length 33ft/10m
(c) 2014 Cave Research Foundation

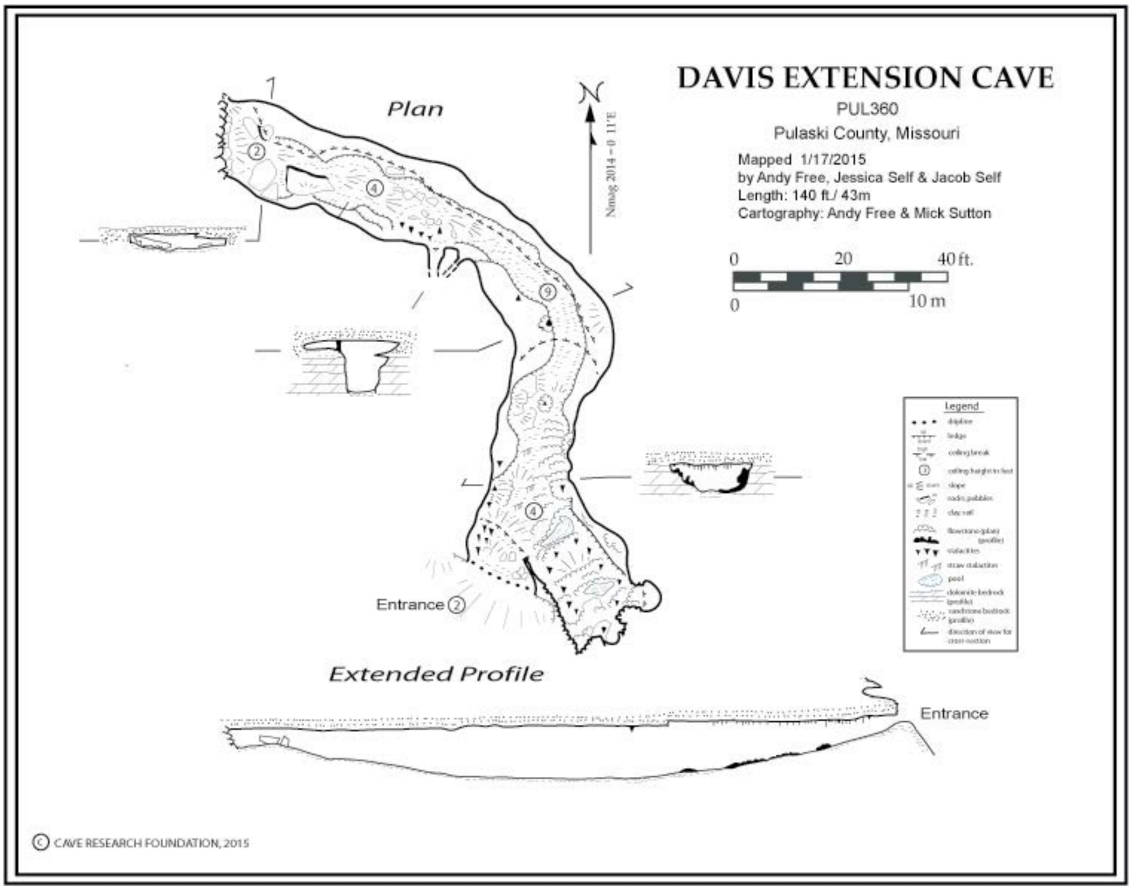

OCTO CAVE
MARK TWAIN NATIONAL FOREST
Howell County, Missouri
HWL-043
Surveyed 1 November 2015 by
M. Jones, R. Young, R. Haley, B. Van Dalsem
of
CAVE RESEARCH FOUNDATION
Cartography by Scott House
Plan view
Entrances
Entrances
Entrances
Entrance
Nm
A
B
SCALE
dimensions given in feet
Cave Length 107ft/33m
Generalized section through entrances looking out
Roubidoux formation
(c) 2016 Cave Research Foundation

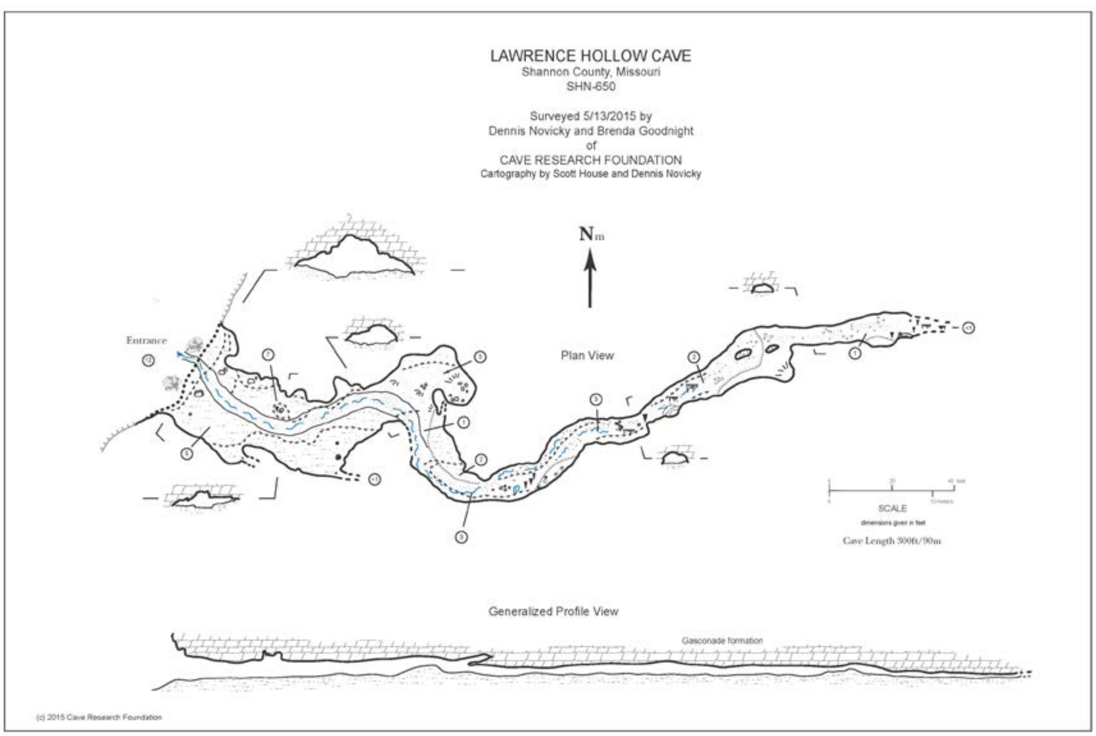


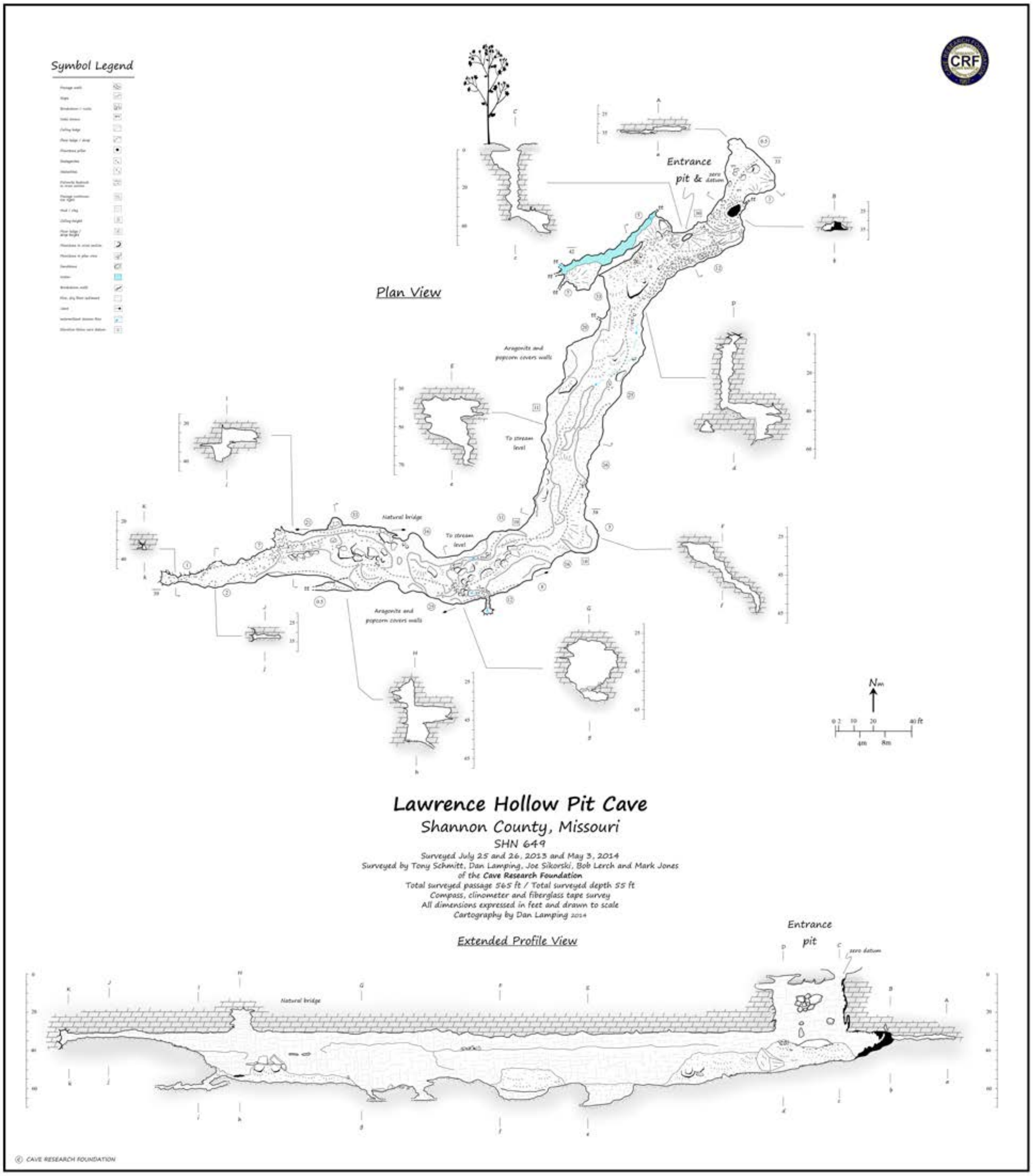
GLADE PIT
Barry County, Missouri
Mark Twain National Forest
BRY040
Suuntos & Fiberglass Tape Survey By:
Clinton Barber, Roger Brown, & Ben Miller
May 17, 2014
Cave Research Foundation
Drafted by Ben Miller, 2014
Notes:
1) Total Length of Cave: 79.45 Feet (24.22 Meters)
2) Total Depth of Cave: 64.9 Feet (19.77 Meters)
3) All Ceiling Heights & Depths Are In Feet
4) Cave is formed at the contact between the Mississippian Reeds Spring Limestone and Pierson Limestone
N True
W
E
S
0
20
40 Feet
0
5
10 Meters
SCALE
Entrance
0 Datum
8
35 Ft. Pit
35
Note: All pit plan views are oriented to True North. Lower passage walls in gray.
A
A'
B
B'
6
12
14
38
Big dome w/ dripping water
Water heard dripping from height in dome
Profile A - A'
Profile B - B'
0
20
40
60

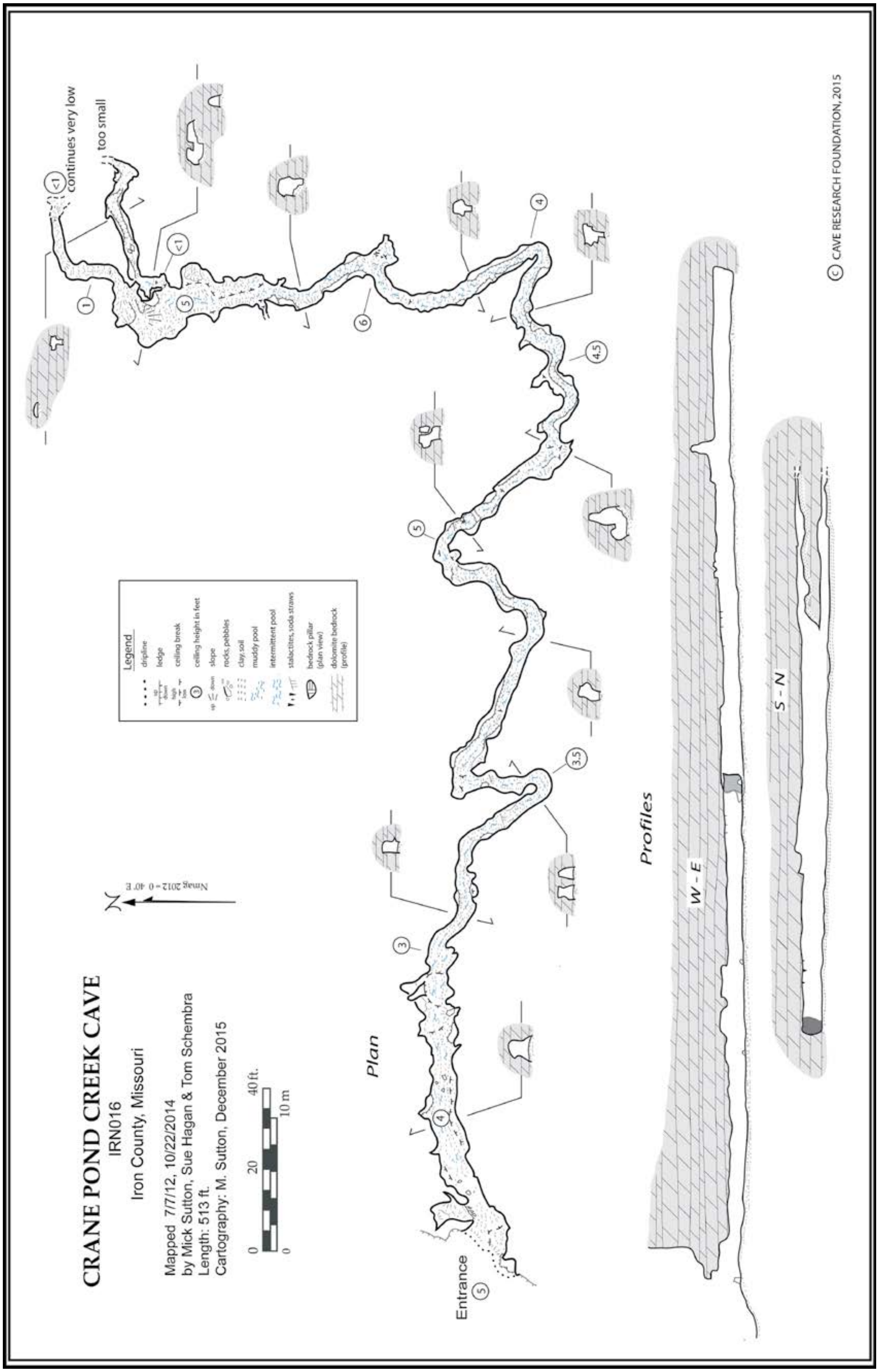

CITY PARKING LOT CAVE
City of Perryville
Perry County, Missouri
PRY-696
Surveyed 5/1/2015 by
Tony Schmitt and Richard Young
of
CAVE RESEARCH FOUNDATION
Cartography by Scott House
Nm
Plan view
Continues low
Entrance under manhole
SCALE
dimensions given in feet
Cave Length 84ft/26m
Generalized profile
historic masonry
concrete
Joachim formation
(c) 2016 Cave Research Foundation


ROBINSON HOLLOW CAVE
MARK TWAIN NATIONAL FOREST
Douglas County, Missouri
DGL-109
Surveyed 3 November 2015 by
S. House, R. Young, D. Dunham
of
CAVE RESEARCH FOUNDATION
Cartography by Scott House
Nm
Plan view
Entrance
SCALE
dimensions given in feet
Cave Length 183ft/55m
Generalized profile view
Roubidoux formation
(c) 2015 Cave Research Foundation


DAVIS EXTENSION CAVE
PUL360
Pulaski County, Missouri
Mapped 1/17/2015
by Andy Free, Jessica Self & Jacob Self
Length: 140 ft./ 43m
Cartography: Andy Free & Mick Sutton
Plan
0 20 40 ft.
0 10 m
Legend
Entrance
Extended Profile
Entrance
© CAVE RESEARCH FOUNDATION, 2015


LAWRENCE HOLLOW CAVE
Shannon County, Missouri
SHN-650
Surveyed 5/13/2015 by
Dennis Novicky and Brenda Goodnight
of
CAVE RESEARCH FOUNDATION
Cartography by Scott House and Dennis Novicky
Nm
Entrance
Plan View
SCALE
dimensions given in feet
Cave Length 300ft/90m
Generalized Profile View
Gasconade formation
(c) 2015 Cave Research Foundation


Symbol Legend
Plan View
Entrance pit & zero datum
Aragonite and popcorn covers walls
To stream level
Natural bridge
To stream level
Aragonite and popcorn covers walls
Lawrence Hollow Pit Cave
Shannon County, Missouri
SHN 649
Surveyed July 25 and 26, 2013 and May 3, 2014
Surveyed by Tony Schmitt, Dan Lamping, Joe Sikorski, Bob Lerch and Mark Jones
of the Cave Research Foundation
Total surveyed passage 565 ft / Total surveyed depth 55 ft
Compass, clinometer and fiberglass tape survey
All dimensions expressed in feet and drawn to scale
Cartography by Dan Lamping 2014
Extended Profile View
Entrance pit
zero datum
Natural bridge
© CAVE RESEARCH FOUNDATION


CRANE POND CREEK CAVE
IRN016
Iron County, Missouri
Mapped 7/7/12, 10/22/2014
by Mick Sutton, Sue Hagan & Tom Schembra
Length: 513 ft.
Cartography: M. Sutton, December 2015
40 ft.
10 m
Plan
Profiles
W - E
S - N
Entrance
continues very low
too small
Legend
dripline
ledge
ceiling break
ceiling height in feet
slope
rocks, pebbles
clay, soil
muddy pool
intermittent pool
stalactites, soda straws
bedrock pillar (plan view)
dolomite bedrock (profile)
© CAVE RESEARCH FOUNDATION, 2015

Sequoia–Kings Canyon Operations Area Summary

September 30, 2014

John Tinsley

Manager, CRF-SEKI Operations

CRF operations at SEKI continued this year much as in past years, but with the added onus of responding to the draft Wilderness Stewardship Plan / Environmental Impact Statement (EIS), in which the NPS at SEKI advanced a preferred alternative of abating the Redwood Canyon cabin / field station, an alarming prospect, as the cabin has been the heart and soul of SEKI operations since 1981. The science efforts center about principal investigator (PI) Jed Mosenfelder's cartography RP at Lilburn Cave, and PI Jessica Oster and Corey Lawrence's geochemical study of the epikarst and modeling of carbon cycling there. Fofo Gonzalez is our newest PI, and he is mapping the early speleogenetic attributes of the Lilburn Cave system. Other traditional studies including monitoring Big Spring hydrology, making a surface karst map of the Redwood Canyon Karst, Sedimentology of Redwood Canyon Karst, and Structural Geology of Lilburn Cave remain to be resurrected.

Personnel Changes

A significant change in leadership is afoot. John Tinsley is stepping down as SEKI Ops Manager in favor of Rodolfo (Fofo) Gonzalez and Jennifer Hopper. Tinsley isn't going away and will continue as Science Officer for SEKI, continuing to recruit PIs. But with or without the cabin, the SEKI operation will benefit immeasurably from new energetic leadership. Tinsley has run the SEKI ops since 1983, and demonstrably, it shows.

Fofo Gonzalez is an engineer and is president of his own company that manufactures different sorts of containers for storing/shipping various kinds of lettuce and other produce from farm to market. Appropriate minor differences in composition make for significantly greater shelf life of produce. He is an expedition-grade caver who has participated in J2 expeditions and other major explorations in his native Mexico. He's also the project's finest musician (guitar).

Jen Hopper coordinates the outdoor recreation program for University of California at Riverside. She is also a J2 expedition caver, among other explorational triumphs. She has been instrumental in recruiting new blood for CRF at SEKI and has been leading expeditions in Lilburn for three years. Fofo and Jen come as a team, with complementary traits and skills. I give them my highest endorsement and urge the BOD to approve this change in SEKI project leadership.

Project Summaries

1. Jed Mosenfelder (University of Minnesota): cartography. A number of small breakthroughs and drought-driven low water levels have facilitated extending the Lilburn Cave survey this year. Present total surveyed length of Lilburn Cave is 21.8 miles.
2. Jessica Oster (Vanderbilt University) and Corey Lawrence (USGS): isotope geochemistry and carbon cycling in epikarst of Sierra Nevada. This was not a good year for hydrologic sampling for this study, as all Lilburn's drips dried up, owing to year 3 of drought. However, Jessica and Corey completed a revision to their NSF proposal and submitted it. If they are awarded this grant, it will make Dan Doctor's 2005 $146K grant look like small potatoes. This proposal was turned down last year, but they are hopeful that having addressed the reviewers' concerns, the proposal will draw funding this year.
3. Marek Cichanski (DeAnza College): structural geology and Lilburn Cave. This study is potentially a most interesting contribution. It needs to be revived for next year.
4. Fofo Gonzalez, CRF: phreatic passage development at Lilburn Cave. This study newly approved in 2014 examines the upper parts of Lilburn's many canyons and maps the location of phreatic tube development, which constitutes primordial Lilburn Cave. We should gain great insights into the earliest history of this intriguing cave system. Results will be published as a layer added to the Lilburn Atlas, showing the location and extent of phreatic tubes.
5. Elaine Scott: Mineral King Caves. This cartographic and inventory study of multiple caves in Sierran high country has been making slow progress, and would benefit from careful targeting of objectives

in future years. Accessible only for a few months of the year owing to snow, drought years are the best time to find and survey passages that are plugged by snow and ice in wetter years. There are no promised deadlines, owing to the iffy nature of access. Much ridgewalking potential remains, and strong hikers are essential for solid progress as we work out from the Mineral King trailhead.

6. Other studies: monitoring of stage at Big Spring (Hopper), sedimentology of the Redwood Canyon karst (Tinsley), map showing karst features of Redwood Canyon (Tinsley), ebb-and-flow potentiated air flow changes at Lilburn Cave (Hurtt) are studies that have some history or which need to be revived and re-shaped. Gonzalez, Hopper, Tinsley, and Hurtt are working on these. We have had a turnover of our scientists. Ben Tobin finished his PhD and has moved on to work for NPS at Grand Canyon. Corey Lawrence has accepted a permanent appointment with the USGS in Denver and will be leaving Menlo Park after the first of the year. Jessica Oster is well into her second year as professor of geochemistry at Vanderbilt University and won't be coming back to Lilburn frequently, unless the NSF grant comes through. So we have much reconstruction of the science to do at SEKI. There is ample ridge-walking with great potential to be had in several areas. With vigorous leadership, the potential is great for SEKI operations to continue to flourish.

Draft Wilderness Stewardship Plan / EIS for SEKI vis a vis Redwood Canyon cabin

This issue has exhausted Tinsley during the past year or so, and the outcome is not yet resolved. The draft NPS-preferred alternative is to abate the cabin, aka Redwood Canyon Field Station, within two years of finalizing the Wilderness Stewardship Plan. The draft WSP/EIS went out for public comment in latest June, and comment period closed on August 25. Joel Despain and John Tinsley orchestrated a response from the caving community. Tinsley prepared a multi-page list of "talking points" and facts about the cabin, with instructions to NOT copy/paste that language, but to write one's own response in your own words. Despain coordinated a nationwide email campaign and made many suggestions. The response was totally gratifying. I haven't seen all the responses, but many did share their responses with me. I know that we definitely got the NPS's attention on this one, as they are re-evaluating their preferred alternative. The NPS brass hiked into Redwood Canyon to see the cabin earlier this week to learn first-hand what it is that they are proposing to abate. These bureaucratic trains are tough to turn around, and there is no guarantee that NPS will alter its position, but they will have to respond to a clear public response urging "keep things as they are at present". So finally we are getting a hearing from Superintendent Woody Smeck, a step that simply was not happening under his predecessor. We should learn the outcome before the end of the first quarter of 2015.

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

2015 Annual Report

Jennifer Hopper and Fofo Gonzalez

Managers, CRF-SEKI Operations

General Observations

This, our first year as project managers, has been full of events that have affected the level of participation and quantifiable results in our area of operation. In April of 2015, the National Park Service issued the Wilderness Stewardship Plan and Final Environmental Impact Statement, which we had been expecting for a couple of years. The results were better than expected, but there is now a counter that resets every third year, which could decide the fate of the fieldhouse for Lilburn Cave.

The drought in California has brought water levels to the lowest point in recent memory. As a result, the mountain stream that is used for supplying drinking and cooking water did not run at all this year. We depleted our emergency reservoir and canceled several expeditions because of the lack of water. We decided to learn to live with the low water situation and resumed the scheduled trips, asking people to bring their own water. The added weight is proving to be a challenge for several joint venturers and the participation levels have declined.

A massive fire in the Sierra National Forest that started in July is still burning (150,000 acres, 95% containment as of this report). The fire at one point threatened to spread into Redwood Canyon, and at least one expedition was canceled due to this.

The exploration project in Lilburn Cave is moving at a very slow pace due to the type of leads left in the cave and the fact that it has been several years since a major breakthrough in the cave. Experienced Lilburn cavers are preferring to join other caving areas or trips.

Wilderness Stewardship Plan

In April of 2015, the Wilderness Stewardship Plan and Final Environmental Impact Statement was published by the National Park Service. The main concern regarding our project was the situation of the cabin in Redwood Canyon, since, being a structure, there was a possibility for the removal of the cabin, due to its location in a wilderness area. Results are better than expected, with the cabin being allowed to stay. However, the current plan calls for a revision every three years to assess the need to have a cabin in the wilderness to support research in the cave.

Some major changes will happen in the immediate area next to the cabin. The reservoir will be allowed to remain, but not the water system or reserve barrels. The outer structures will have to be removed. The picnic tables will be missed but won't affect the operation in a substantial way. Losing the wood shed will be a burden, and we don't know if we will be able to stockpile wood, which would then be exposed to the elements.

The major loss will be the outhouse, and we are discussing with the park the benefits of having a single enclosed place for human waste, instead of the proposal by the park to use cat holes that would disseminate human waste through the forest in a much wider manner. Of course, the park could ask us to carry human waste out, which could also negatively affect participation in the future.

The park expects to be sued on the plan, and in that case the legal proceedings will delay implementation of the plan, so we could be a couple of years away from the official starting date of the document, and the infrastructure reduction would take place within a year of that.

Cave Management

There are now stricter qualification guidelines for cavers attending Lilburn. In the past, some people with no caving experience caved with us, and some went who had not been vetted by other Lilburn regulars. We did not have any rescue or injuries due to this, but we want to avoid creating a possibility now that the park service is keeping a closer eye on our activities.

There is now a tighter control over who joins our email distribution list, to prevent the dissemination of information to people who are not active Lilburn cavers. The communication platform for the group has been modernized. There are systems in place that allow for a faster and more effective communication. Furthermore, it allows for sharing of larger files and visuals, which help in the transmission of information between members.

Cave Data Management

The Chief Cartographer, Dr. Jed Mosenfelder, updated the cave atlas with the latest survey information. Our goal is to create an up-to-date document that we can share with the park and can serve as a moment frozen in time of how the cave stands as of 2015. There is now a laptop that will be used for record keeping, which will make filing reports faster and will allow for easier searches for specific information like reports for a certain area or in a determined time period. The information for the project is also kept in Google Drive now, which allows for faster sharing of information and to have controlled access to the different parts of the file. That is, not everyone should be allowed to see the personal information of new joint venturers, but medical records should be easy to access in case of emergency.

There is a transition in place of projects that were started in the past, for example a project to locate and monitor sinkholes, to bring continuity to these, especially given the current drought, which could prove a good window of opportunity to check sinkholes for possible openings into subterranean voids.

Cartography

The total length of passages surveyed in 2014 was 342.6 feet, for a total length of the cave of 21.81 miles. For 2015, the total length surveyed is 390.19 feet. Some of these feet are survey on existing passage, so the total cave length will have to be calculated. The main goal and also the main challenge in cartography is to expand the group of people working on the cave map. Having a single person responsible for all updates on the cave map has proven very ineffective due to the magnitude of the responsibility and the limited time that is normally available for any single person to work on it.

We have enlisted the help of people with good knowledge of computer systems to aid in finding a method that will allow for multiple people to work on a map without causing an issue by having different copies of a cave map, each with their own set of updates.

Educational and Cooperative Efforts

- Create a touch table of rocks for children.
- Install dataloggers at Big Springs to monitor temperature.

Plans for the Future

CRF will continue to have a higher degree of cooperation with the park in forwarding our mutual goals. There are several areas in the park that have not been researched, and existing caves other than Lilburn have a high potential for projects, even for continuing leads that were never explored. The CRF should be involved in more areas of the park, not just Lilburn Cave and Mineral King.

Cartography Report for Carlsbad Cavern 2014

Ed Klausner

Two trips were taken to Carlsbad Caverns National Park in 2014 to finish the survey of the Big Room (including Spirit World and Middle Earth). In addition, several leads were surveyed in Lower Cave.

In 2013, Derek Bristol, Roger Harris, Garrett Jorgensen, and Kevin Manley began the resurvey and lead checking of Spirit World, first discovered in 1985. It was tied into the Big Room survey below later in the year by Stan Allison, Abby Tobin, Gosia Allison-Kosior and Shawn Thomas. On Halloween of 2013, Derek Bristol and Shawn Thomas continued the resurvey of Spirit World and discovered Halloween Hall. Derek Bristol, Shawn Thomas, and Garrett Jorgensen finished the survey of Halloween Hall in February of 2014. Halloween Hall added 407 feet of new survey to the total survey length of Carlsbad Cavern. Figure 1 shows this area in plan and Figure 2 shows this in profile.

Kathy Lankford let the effort to resurvey Middle Earth from 1999 to 2003, leaving a number of small or hard to reach leads. In 2014, four lead-checking and surveying trips were taken into Middle Earth. One of the leads noted as

Figure 1. Spirit World and Halloween Hall.

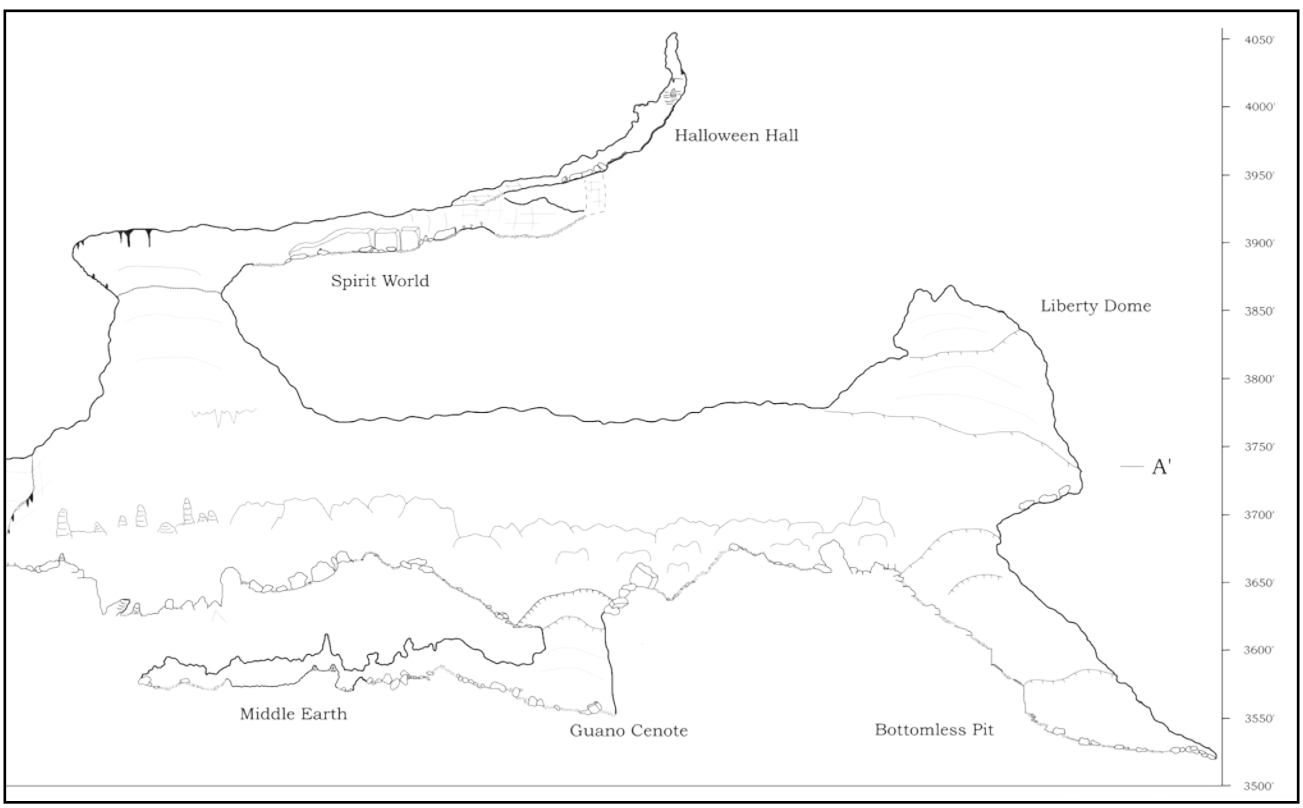


Figure 2. Profile of Spirit World and Halloween Hall.

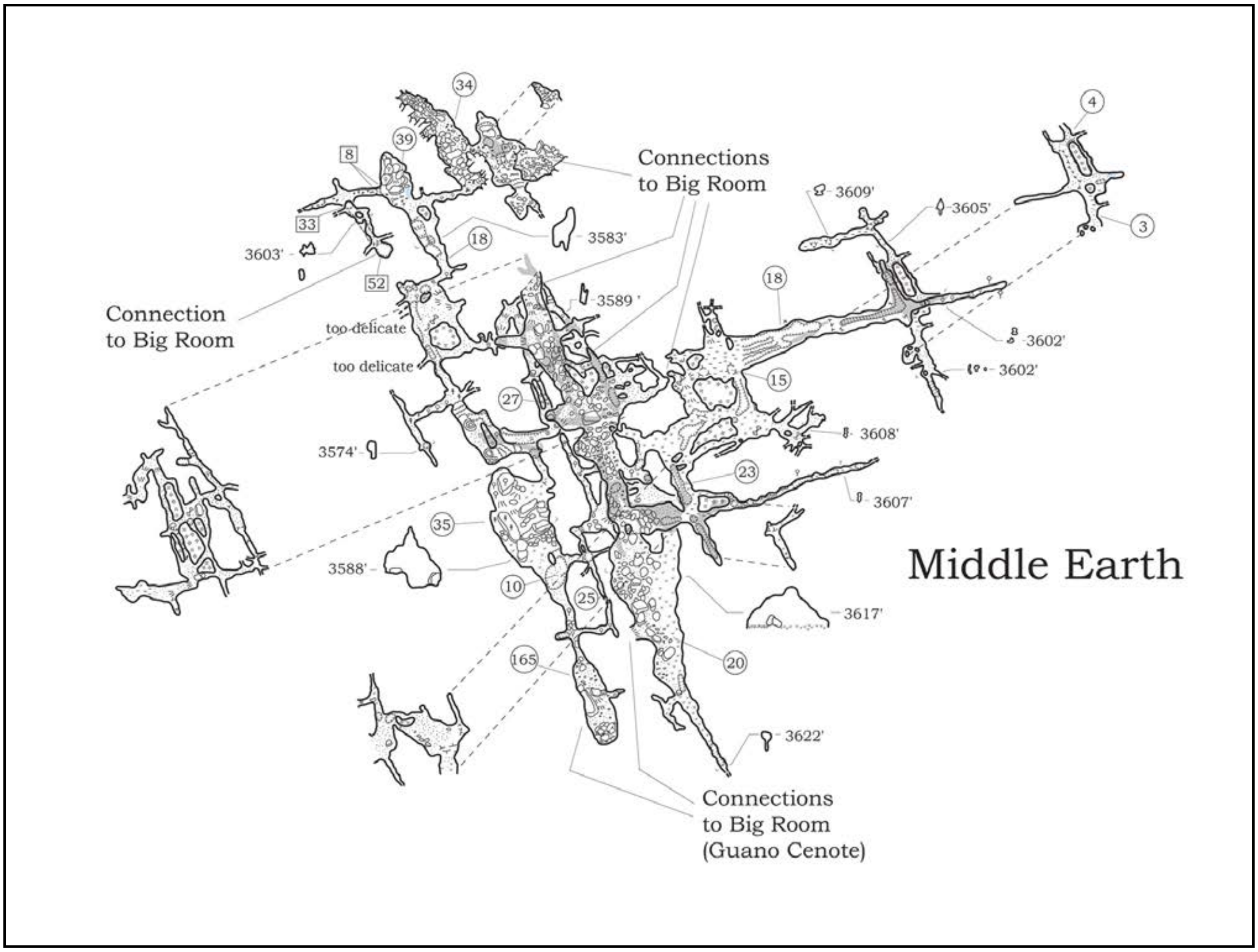


Figure 3. Middle Earth.

being a tight spot, led to 301 feet of new passage (not virgin) and another connection to the Big Room. Figure 3 shows Middle Earth, and Figure 4 shows the newly surveyed area on the north side of Middle Earth.

In Lower Cave, seven survey trips were taken to survey leads in Talcum Passage plus a number of side passages off the main tour route. Chris Beck and I left a survey station in a short section of Talcum Passage (also known as Middle Talcum Passage) that we hoped would be visible from Upper Talcum Passage. It would be very difficult to reach Upper Talcum Passage from this survey station, so we approached if from the corkscrew route to Mabel's Room and then along the length of Upper Talcum Passage. This tie was completed by Shawn Thomas, Chris Beck, Mark Jones, and me in 2014. In addition, several leads were checked in Lower Cave and some led to additional survey, most just a few survey shots. The majority of these leads were in the Central Boneyard area of Lower Cave.

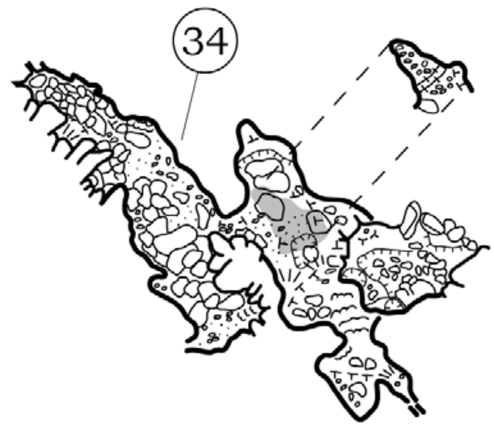


Figure 4. A portion of Middle Earth.

Slaughter Canyon Cave, Carlsbad Caverns National Park

Dave West

2014

Continuing our work from 2013, we returned in February 2014 and began surveying horizontal leads and assessing high leads, while obtaining needed cross-sections and profile detail.

The 2008 survey sketchers had not annotated the presence of guano deposits, so these were searched out and identified in four general locations: two in the main passage, one in Fossil Avenue, and one in the Tom Tucker Room. Two areas were re-surveyed. Six leads were surveyed, and four leads were eliminated as un-enterable or were simply sketched. An additional seven cross-sections were obtained, and additional profile detail obtained in ten areas. Sketching details were added in three areas. Two pits were assessed, and it was determined they would require additional survey. An additional lead was identified, but time was not adequate to survey it, and it remained for the next visit. Fourteen high leads were assessed for access requirements. It was determined that a thirty-two-foot ladder would be adequate to reach most, if not all of the high leads.

We returned to Carlsbad in September. A ladder and stabilizers had been purchased and delivered to the park. Unfortunately, we arrived as Carlsbad was flooding, and the park was closed. We spent one night in a Carlsbad motel before Pat Seiser graciously adopted us for three days while the park recovered from the flooding. We spent our time assisting her with the demolition of the roofing over her patio, for which she was planning a rehab project. When the park finally reopened, we had only two and a half days remaining before our scheduled departure. The road to the cave was still flooded at first, but the following day, with four wheel drive, was at least marginally passable. The first day was spent marveling at the amount of water in the cave. The Christmas Tree area was a lake, as was the Wall of China. Water entering the cave was audible in a few places but generally could not seen for more than the point where it entered at the ceiling to where it disappeared in the floor a few feet away. We resurveyed a portion of the main passage where two sketchers' details did not match well; completed survey of an additional four leads, and obtained additional profile detail in Mole's Run. Yet another lead was identified for later survey. The next day was spent assembling and carrying the thirty-two-foot ladder up to Slaughter Canyon. It was stored out of sight of the tours in an area off the Tom Tucker Room. We then

China Wall Lake. *Chris Beck*

Christmas Tree Lake. *Chris Beck*

Ed Klausner and Karen Willmes admire the Guardian Towers. *Chris Beck*

Elizabeth Miller checks a lead. *Mark Jones*

Tree Room and a connecting passage between the Mushroom and Toad's Palace, which had been included on the old trail map. The third was an undocumented passage at the beginning of Mole's Run, apparently a continuation of the 83-foot connector to the Tom Tucker Room.

A shallow pit in breakdown near the Sentinel had somehow been overlooked by earlier surveys and was free climbed. It led to an undocumented low 25-foot-by-35-foot chamber. A 20-foot deep pit, located in the passage that overlooks the guano mining area, was rigged and surveyed. It had 65 feet of undocumented down-sloping passage at the bottom that paralleled the higher passage above it and a 14-foot crawl that overlooked a parallel lower passage. The last pit to be surveyed is in Santa's Basement, below the Christmas Tree Room. This 20-foot drop led to about 140 feet of decorated passage. A single horizontal lead was observed and surveyed in Fossil Avenue but quickly became too small and decorated to continue.

But we ran out of time. High leads remain in the Subterranean Disaster passage that could not be reached with the ladder. One of these is a ledge at one of the highest points in the cave. The high lead at the end of the Monarch passage was left rigged so a crew might return and lasso a large stalagmite to reach a still higher lead that looks intriguing. A ladder lead remains in Santa's Basement that heads away from known cave. Neither Ed Klausner nor I fit into a lead at the end of Mole's Run that is known to loop around to the far end of the Pool Room, so it will be necessary to either bring along a still thinner sketcher or access the area through the water in the Pool Room.

The survey length now stands at 20,371 feet (3.858 miles). We plan to return at our first opportunity.

(Participants—Dave West, Karen Willmes, Mark Jones, Dawn Ryan, Ed Klausner, Elizabeth Miller, Dwight Livingston, Pat Seiser.)

attempted to photo-document the water in the cave, discovering that the viewing area for the Monarch was also completely under water.

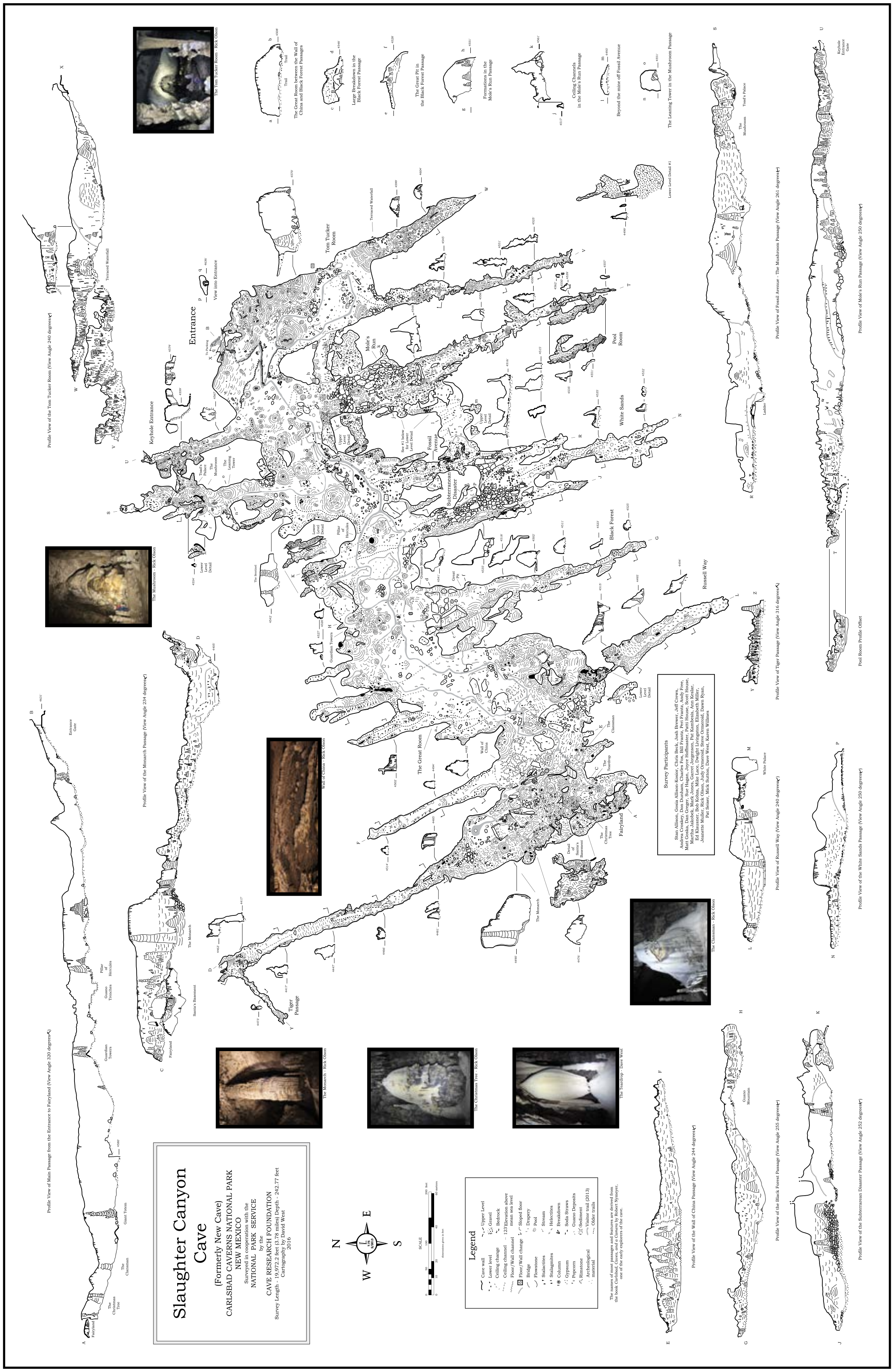
(February participants—Dave West, Karen Willmes, Mark Jones, Jeanette Muller, Chris Beck, Elizabeth Miller. September participants—Dave West, Karen Willmes, Mark Jones, Chris Beck, Elizabeth Miller, Ed Klausner.)

2015

Continuing our work from 2014, we returned in April 2015 with a ladder already in place in the cave. We began investigating high leads and two pits that required rigging, plus one in breakdown that was easily free-climbed. The goal was to finish the map, and everyone focused on Slaughter Canyon this visit.

Dwight Livingston and Mark Jones formed the core of Ladder Company Number One, which proceeded to carry the ladder from high lead to high lead throughout our visit. Almost everyone in the group accompanied them for at least one day. In all, twenty-six high leads were checked utilizing the ladder, with many being simply sketched in, and many others taking a single shot to define. Most of the leads checked in this manner were virgin, with a passage connecting the Tom Tucker Room and Mole's Run yielding 83 feet of survey. Two high leads off the Monarch passage added another 114 feet. Most impressive was a lead in the White Palace, producing 456 feet of survey, of which 309 feet were virgin, and added Russell Way as another major side passage to the known cave.

An additional three "high" leads were free-climbed and surveyed. These included Fairyland, an undocumented and highly decorated area accessed from the Christmas


Slaughter Canyon Cave
(Formerly New Cave)
CARLSBAD CAVERNS NATIONAL PARK
NEW MEXICO
Surveyed in cooperation with the
NATIONAL PARK SERVICE
by the
CAVE RESEARCH FOUNDATION
Survey Length - 19,972.2 feet (3.78 miles) Depth - 242.77 feet
Cartography by David West
2016

Restoration at Carlsbad Cavern

William Tucker

Due to circumstances beyond our control, and not due to lack of wanting or trying, we only had two Cave Research Foundation expeditions to Carlsbad Caverns for restoration work in 2015. The first was on Presidents Day weekend (February 14–16) which 12 volunteers attended. The second was a longer, field camp, expedition in June (June 9–13) with 4 volunteers. On Presidents Day weekend 2015, 12 CRF volunteers met at Carlsbad Caverns National Park for a weekend of restoration work in the Big Room of Carlsbad Caverns itself. We were attempting to make progress at a site that we call "Marker 39." It is located next to the visitor trail at number 39 on the self-guided tour.

Before, during and after restoration of one of the smaller pool basins at Marker 39.

Marker 39 is a series of heavily impacted, cascading pools. The pools had been filled, nearly to the brim with sediments from the original dirt trail, debris, and years of neglect. Our task was to restore this area to its natural state.

On previous expeditions, we had successfully removed a noticeable, tracked trail, leading upslope across a flowstone to an alcove. We had cleaned the edges of the pools where a surprising amount of nice shelf stone was found that was previously not known to exist. We had used inflatable child's wading pools to pump all of the water from the largest pool while we cleaned the basin before returning the settled water. On this trip, we were concentrating on the next pools in the cascading series which were much smaller in volume but no less important.

As is advisable, we first cleaned the edges of the pool before tackling the basin itself. We then used food grade plastic buckets to temporarily store the water while we cleaned the basin. The settled water was returned to the pool basin at the end of the weekend.

In June of 2015, a small group of volunteers accomplished an extraordinary and noticeable amount of restoration work.

Removing coins from pools along the visitor trails.

In addition to continuing work at Marker 39, we performed a number of necessary restoration tasks.

We spent two full days continuing our effort at Marker 39. We were concentrating on dry sediments below the cascading pools. The technique was to carefully loosen the sediments with dental picks, tooth brushes, whisk brooms and other equipment, then to scoop the sediments into containers using spoons and dust pans. In places where we deemed it acceptable, we used a shop vac, after hours (so as to not disturb the visitor experience). Good progress was made.

The detailed, seemingly never-ending, drag-on stage has been reached. It seems that the last 10 percent of a large restoration project takes 90 percent of the time. One day was spent removing coins from pools along the visitor trails. This is a necessary task. If the coins are not removed, they become an attraction for visitors to toss in even more coins. The Rangers at Carlsbad Caverns attempt to remove coins as they can, but there are always dozens that the Park Rangers are unable to remove that CRF volunteers are left to tackle. We inevitably find trash and other bits of modern detritus to remove as well.

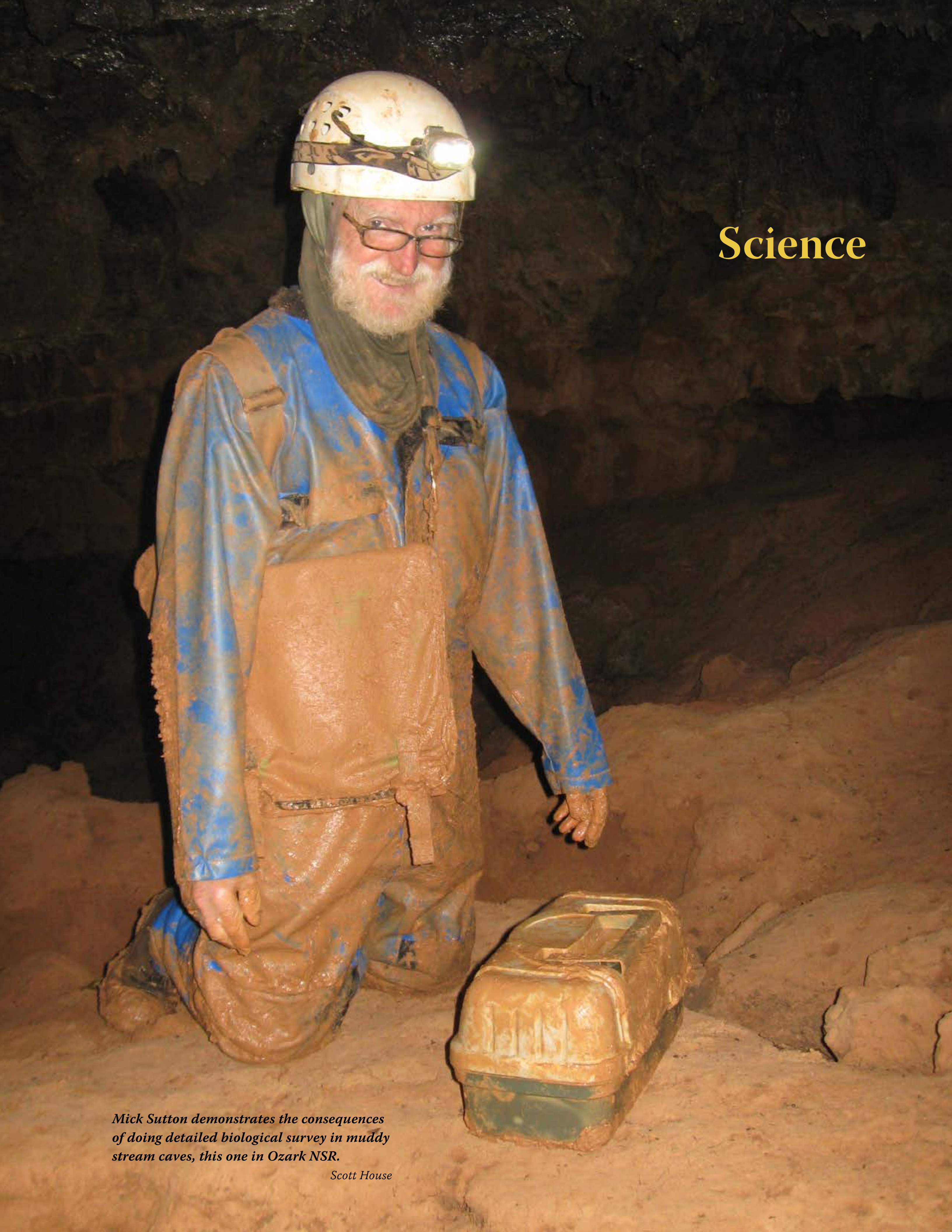
One day was spent cleaning the nylon bridges in Lower Cave. These bridges were put into place, with the help of CRF, years ago to protect the cave pearl nests from tracked sediments as the trails in Lower Cave are dirt. After a time, the bridges become coated with tracked sediments; and, these sediments threated to end up in the cave pearl nests and pools if not removed. So, each June, we make it a point to clean the bridges so that these sediments stay out of these protected areas. This year, our efforts were noticed by one of the Rangers who sent this note to us and the Cave Resources Office:

"Just a thanks to the CRF crew. I was in Lower Cave today and the bridges were so clean and shiny, I almost did not want to step on them. Wow, I did not know those bridges were white. THANKS CRF!!!!"

In all, though there were only two expeditions and fewer volunteers than normal, good and necessary restoration work was performed by CRF volunteers at Carlsbad Caverns in 2015.

Cleaning the bridges in Lower Cave to protect the cave pearls.

Science



Mick Sutton demonstrates the consequences of doing detailed biological survey in muddy stream caves, this one in Ozark NSR.
Scott House

Philip M. Smith Graduate Research Grant for Cave and Karst Research

George Crothers

Grant Program Chair

In 2015, the graduate student research grant was named in honor of Philip M. Smith (1932–2014), CRF's founding president. From the 1950s through the 1960s, Smith was deeply involved in caving, helping to found the Central Ohio Grotto of the National Speleological Society and taking part in the NSS C3 expedition in Floyd Collins Crystal Cave, Kentucky. In the early 1950s, there were few American scientists pursuing cave-related research, but advances in exploration like the C3 expedition, showed immense potential for sustained exploration and study. CRF was formed to help provide this support, largely modeled on similar organizational support for the International Geophysical Year, in which Smith was then deeply involved. Smith went on to become a national and international leader in science, technology, and public policy for five decades. He is best known for his work on polar research programs with the National Academy of Sciences, National Research Council, and the National Science Foundation, and served three U.S. presidents—Nixon, Ford, and Carter—on issues of science policy. From its inception, CRF has always placed importance on multidisciplinary, integrated research. Inspired by Phil Smith's lifelong support for science, and his early influence on the organization of CRF, the graduate research grant program is dedicated in his memory.

In 2014, eleven proposals were submitted to the grant program, and four were selected for funding at a total of $10,000. Abstracts of the funded proposals appear below. Extended field reports of all four projects may be found in this Annual Report under their respective disciplines. In 2015, fifteen proposals were submitted and five were funded for a total of $12,000. Abstracts appear below. Field reports for these projects will appear in the 2016 Annual Report.

Congratulations to all of the recipients. CRF continues to receive many high quality proposals, but unfortunately we can fund only a portion of the proposals submitted. The young scholars recognized here represent the best of the best. We look forward to their contributions to cave and karst science for many years to come.

2014 Grant Recipients

Ashley M. Bandy ($3,000)

Department of Earth and Environmental Sciences
University of Kentucky

Mobility of Stable Isotope-Labeled* Escherichia coli *in Karst Terrains

Abstract—Currently, bacterial transport in karst aquifers is not well understood. Bacterial contamination of karst aquifers is a large concern across the globe. Groundwater tracers typically used in karst systems include fluorescent dyes and latex microspheres. These tracers do not exhibit surface properties and transport behaviors mimicking those of bacteria and pathogens, and therefore are not good proxies for risk assessment involving microorganisms. The proposed project will expand upon a proof-of-concept study tagging nonpathogenic *Escherichia coli* (*E. coli*) with stable isotopes (^{15}N and ^{13}C) to use as a tracer in a karst basin. A trace will be conducted using labeled *E. coli* in conjunction with fluorescent dyes and latex microspheres in the Cane Run karst aquifer in central Kentucky and through epikarst above Cave Spring Caverns near Bowling Green, Kentucky. It is hypothesized that dyes, microspheres, and bacteria tracers will show differential transport times in the Cane Run / Royal Spring basin under normal flow conditions, with microorganisms arriving at the spring prior to microspheres or conservative dyes. For the epikarst trace above Cave Spring Caverns, the *E. coli* isolate that exhibits higher attachment efficiency in saturated granular columns is expected to have higher attenuation and emerge from the epikarst after the isolate that exhibits lower attachment efficiency. These two types of *E. coli* will have different transport times than microspheres or dyes and may take many storm events before they are flushed through the epikarst. Isotope analysis will be used in conjunction with genetic markers to monitor breakthrough of tracer bacteria.

David Brankovits ($3,000)

Marine Biology Interdisciplinary Program
Texas A&M University at Galveston

A Biogeochemical Investigation of a Methane-Dependent Anchialine Cave Ecosystem

Abstract—Energy limited flooded coastal cave systems are likely to utilize similar processes as those occurring in chemosynthesis-based oceanic ecosystems. Preliminary data from my dissertation research suggests methane may be the primary source of carbon and energy for a unique subsurface ecosystem in the tropics. I propose advanced molecular biological, lipid biomarker, and stable isotope techniques to test this premise. I will examine the following hypotheses in a coastal cave system in the Yucatan Peninsula in Mexico: (1) methane is seeping into the aquifer from overlying soils and is being consumed by methanotrophic ("methane-eating") microbes in the water column of a subterranean estuary; (2) methanotrophic bacteria inhabiting the groundwater are being consumed by the unique cave-adapted invertebrate community; (3) methanotrophic bacteria contribute significant chemosynthetically-produced organic matter to higher levels of the food web (i.e., cave-adapted shrimps).

The proposed study will provide a comprehensive biogeochemical description of carbon cycling and the fate of methane in the water column of a coastal cave system in the Yucatan Peninsula. Characterizing the microbial community, biogeochemical pathways, and carbon flow will expand our understanding on the ecology of anchialine caves. This study will significantly increase the knowledge on chemosynthetically-based ecosystems and the importance of methane for certain subterranean food webs. Moreover, demonstrating that an underground ecosystem is fueled by methane (powerful greenhouse gas) will have potential implications in studying globally relevant biogeochemical processes (e.g., methane sinks) for environmental purposes.

Brian M. Carlson ($3,000)

Department of Biological Sciences
University of Cincinnati

Creating High-Density GBS-Based Linkage Mapping Resources for Use in Astyanax mexicanus, the Blind Mexican Cavefish

Abstract—The ability to conduct genome-level studies aimed at illuminating the genetic underpinnings of traits of interest has led to significant advances in our understanding of a wide variety of interesting and ecologically relevant traits. In the past, however, the cost of sequencing-intensive methodologies has made such studies difficult or impossible for those working in non-model and emerging model systems. In such cases, alternate approaches such as the construction and use of linkage maps have proven both necessary and valuable. The blind Mexican cavefish, *Astyanax mexicanus*, is an emerging model fish system consisting of a derived cave morphotype and an extant surface morphotype. Here, I propose the use of cost-efficient next-generation sequencing technologies to generate the data necessary to create high-density linkage maps for use in this species, which has become the model of choice for many researchers interested in the evolutionary consequences of cave colonization. Additionally, I propose strategies that will allow researchers to leverage genomic resources for a related model fish species, as well as early drafts of genomic resources for *Astyanax mexicanus* itself, to determine the genes and genomic intervals associated with the anonymous markers from which these linkage maps are constructed.

John Wall ($1,000)

Department of Marine, Earth & Atmospheric Sciences
North Carolina State University

High-Resolution Morphometric Analysis of Sinkholes and Depressions within Karst Geology

Abstract—The proliferation of Light Detection and Ranging (LiDAR) surveys conducted at the county and state levels over the past decade provides increasingly high-resolution topographic data that can be used to quantify the geomorphology of karst terrains. Current methods to map sinkholes and depressions within karst geology typically employ coarse resolution topographic data. From this coarse data closed-contours are manually digitized which is time intensive. We will show that sinkholes and depressions can be delineated accurately using semi-automated methods operating on high-resolution Digital Elevation Models (DEM). This will be done by using standard Geospatial Information System (GIS) hydrologic tools to fill depressions within the DEM. The initial DEM will then be subtracted from the filled DEM resulting in detected depressions or sinkholes. These results will then be compared to the state inventories. Results will be used to test proposed scaling relationships for the size and distribution of sinkholes and depressions. The resulting catalog of sinkholes and depressions can then be used for hazard and risk assessment, cultural resource management, and ecological habitat identification.

2015 Grant Recipients

Justin N. Carlson ($2,500)

Department of Anthropology
University of Kentucky

Assessing Human Activities, Sediment Deposition, and Pedogenesis at Crumps Cave Vestibule and Sink, Warren County, Kentucky

Abstract—This project will study in Crumps Cave, Kentucky, will support collection of archaeological and geoarchaeological data as part of my dissertation project to refine the chronology of occupation, determine the range of prehistoric activities, and assess the geomorphological and pedological history of cave and sinkhole sites in the south-central Kentucky karst. More specifically, this research seeks to document evidence of anthropogenic forest impacts by fire and its timing in relation to intensive cave use in central Kentucky. The Late Archaic–Early Woodland transition (ca. 3500–2500 BP) in central Kentucky is a critical period for changes in land use, adoption of new subsistence technologies, and socio-economic reorganization. The proposed work at Crumps Cave is significant to cave and karst studies in three ways: (1) developing a model of hunter-gatherer and early horticultural utilization of holokarst terrains; (2) contributing to contemporary forest management literature by considering long-term history of karstic barrens and cedar glades ecosystems; and (3) elucidating the Holocene history of geogenic, biogenic, and anthropogenic sediment deposition in Crumps Cave sink and vestibule, and the effects of prehistoric human land use on cave systems.

Mara L. Cashay ($2,500)

Department of Biology
Appalachian State University

Impact of Exogenous Nutrients on Mn-Oxidizing Microbial Consortia among Caves of the Southern Appalachian Mountains

Abstract—Manganese-oxidizing microbes are common in a variety of environments, including cave and karst systems and can act as indicators of water quality and/or bioremediators in their natural habitats. The microbial ecology of Mn oxide deposits is not well understood, and even less is known about the factors that stimulate Mn-oxidizing microbes *in situ*. Previous studies suggest that biological Mn oxidation is carbon limited. Preliminary results from the proposed research, however, have shown that fungal growth can be stimulated *without* inducing biotic Mn oxidation the addition of simple sugars (i.e. glucose and malt extract), as well as complex carbohydrates (i.e. wood, cotton and cellulose). This lack of simple correlation between Mn oxidation and additional exogenous carbon suggests that other environmental factors need to be considered in order to define the biotic role of Mn oxidation within cave systems. The aim of this study is to identify the range of factors that stimulate biotic Mn-oxidizing activity *in situ* and to identify how anthropogenic impacts may alter biogeochemical cycling and contaminant trapping within these ecosystems. This work has far reaching implications for water quality within karst aquifers that house a significant portion of the drinking water for the eastern United States.

Aaron Covey ($3,000)

Department of Earth and Environmental Sciences
Vanderbilt University

Quantifying Parameters of Climate Variability on Soil and Speleothem Carbon Isotopes: Coupling Modern Cave Monitoring with Multicomponent Reactive Transport Model

Abstract—Speleothem carbon isotope values (δ13C) have potential to record past variability in hydroclimate, vegetation, and soils. Yet, these data are often not interpreted in a paleoclimate context due to the multiple and complex environmental factors controlling δ13C. Radiocarbon (14C) can provide insight into water-soil/rock interaction in the epikarst, but it is also complicated by input from multiple subsurface carbon pools. By using a reactive transport model that has been ground-truthed with observations of modern systems, the factors controlling drip water carbon isotope systematics can be constrained, providing the basis needed to build an interpretive framework for speleothem δ13C and 14C records.

I propose to couple monitoring of a modern cave system with a thermodynamically and kinetically driven multiphase reactive transport model, CrunchFlow. Monitoring of surface temperature and precipitation, soil temperature and moisture gradients, and cave temperature and pCO2 will set the initial boundary conditions for the model. Monthly δ13C and seasonal 14C samples in soil (gas and water) and cave (air and drip water) will constrain the factors controlling drip water δ13C and 14C, providing data for a best-fit model of the soil-epikarst environment. Once the model has been parameterized, I will conduct a series of experiments to determine how changes in temperature, precipitation, seasonality, vegetation, and soil thickness influence δ13C and 14C of drip water over varying timescales. These model simulations will help determine the fundamental factors that control δ13C in drip waters and should thus provide an innovative and powerful tool for future interpretations of speleothem δ13C records.

Charles D. R. Stephen ($1,500)

Department of Biological Sciences
Auburn University

Reassessment of the Cave Pseudoscorpion* Hesperochernes mirabilis *(Pseudoscorpiones: Chernetidae)

Abstract—The karst regions of Tennessee, Alabama, and Georgia are well known as a biodiversity hotspot for cave life. Pseudoscorpions represent some of the best examples of this phenomenon, but their true diversity throughout the Appalachian karst has likely been underestimated. Few people are working on the group worldwide, and there are no active workers based in North America. Our knowledge of Appalachian cave pseudoscorpions is restricted to species lists, species descriptions, and unsupported hypotheses of the genealogical relationships between species. In most Appalachian troglobitic pseudoscorpions, the distribution of an entire species is restricted to a single cave system. The biggest exception to this pattern is *Hesperochernes mirabilis*. This species is known from at least 145 caves located from Alabama to Ohio and on either side of significant geographic barriers to dispersal. It may represent a complex of several species, of which some may be rare and deserving of protection. Alternatively, it may represent an extreme example of phoresy (or "hitching rides"), in which it is tracking the distribution of larger animals. Using phylogenetics, I will identify the boundaries of populations and test their genetic connectivity. If analyses support the hypothesis that *H. mirabilis* is a species complex, the species will be redefined, and distinct lineages will be described as new species. Results from this work will affect either the conservation status of currently unprotected *H. mirabilis* populations and the caves they inhabit, or provide compelling evidence for the impact that migrant mammals have on the genetic diversity of cave-inhabiting arthropods.

Gilles Tagne ($2,500)

Department of Geological Sciences
Ball State University

Using Geochemical and Isotopic Data to Partition Sources of Groundwater in Epigenic Karst Aquifers

Abstract—This research comprises two related objectives in the study of epigenic karst aquifers: (1) to better constrain the flux of carbon through a detailed study of inorganic and organic carbon, including the temporal variation, reaction pathways, and relation to overlying land use; and (2) to examine the source and transport of sulfur and the impact of this sulfur upon water-rock interactions.

- The ***focus*** is upon the *critical zone* that extends from the land surface to the base of the zone of active groundwater circulation and includes the soil, the epikarst, and underlying conduits.
- The ***scope*** includes karst aquifers in Paleozoic carbonates of southeast Kentucky with a record of prior investigation and differing land use.
- The ***vision*** is to use results from this study to contribute to a greater understanding of the critical zone, deeper groundwater, and the impact of changing land use on karst aquifers.

This study juxtaposes two primary geochemical pathways for carbonate dissolution in karst aquifers, carbonic acid conveyed by meteoric recharge and the oxidation of reduced sulfur entrained into groundwater flow. I will attempt to quantify the magnitude of each pathway and additionally assess the influence of petroleum-associated brines from deeper groundwater upon on the chemistry of these karst aquifers. This study will contribute to a mixing model to partition contributions of surface and deeper sources to nutrient and carbon flux in karst aquifers. It will also provide new insights in the geochemistry of karst waters in area impacted by agriculture and historic oil exploration.

Mobility of Stable Isotope-Labeled *Echerichia coli* in Karst Terrains

Ashley M. Bandy

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Bacterial contamination of karst aquifers is a large concern across the globe. Currently, bacterial transport in karst aquifers is not well understood. Groundwater tracers typically used in karst systems include fluorescent dyes and latex microspheres. However, these tracers do not exhibit surface properties and transport behaviors mimicking those of bacteria and pathogens, and therefore are not good proxies for risk assessment involving microorganisms. This study compared movement and attenuation of two isolates of nonpathogenic *Escherichia coli* (*E. coli*) to that of rhodamine WT dye and 1-μm diameter fluorescent microspheres within epikarst above Crumps Cave (Smiths Grove, KY) and in an aquifer within the Cane Run / Royal Spring basin (near Lexington, KY) (Figure 1).

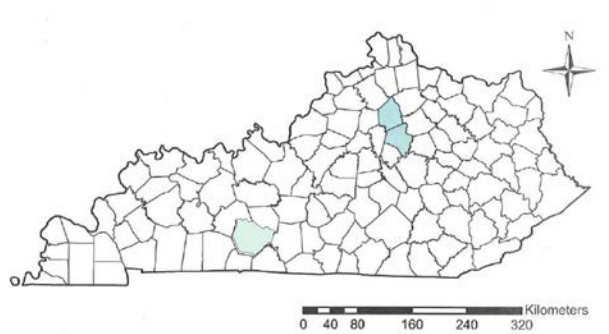

Figure 1. Map of Kentucky showing the study sites. The epikarst study was conducted above Crumps Cave, in Smiths Grove, Warren County. The aquifer trace was conducted in the Cane Run / Royal Spring basin, located in Scott and Fayette counties.

Two isolates of *E. coli* with differing attachment efficiency (Cook et al. 2011) were labeled with stable isotopes (^{15}N or ^{13}C) following the methods of Ward (2008) and Warden (2010). These isolates were used for their specific genetic markers. The isolate with the higher attachment efficiency contained the *iha* gene, while the isolate with lower attachment efficiency contained the *kps* gene. Isolates were sent to the Penn State *E. coli* Reference Center for testing and found to be non-virulent. Those results confirm molecular analyses conducted by Cook and colleagues at the United States Department of Agriculture (USDA).

Injection of tracers for the epikarst study occurred during a storm event on May 16, 2015. Approximately 3×10^{11} of each isolate of bacteria, 130.9 g rhodamine WT, and 5×10^{10} microspheres were injected in a hole augered to the top of the epikarst above Crumps Cave. Samples were collected at designated time intervals from Waterfall 1 within the cave. Samples were taken manually or with ISCO automated samplers, depending on the sampling resolution. Charcoal receptors were placed at other locations within the cave for qualitative dye detection.

Tracers for the aquifer study were injected during baseflow on October 16, 2015. Approximately 1×10^{11} of each isolate of bacteria, 357 g rhodamine WT, and 1.37×10^{13} microspheres were injected into a sinkhole at the Kentucky Horse Park and flushed with approximately 250 gallons of water from Royal Spring. Samples were collected at two locations at designated time intervals. Samples taken from the conduit well within the Horse Park were collected using a bailer. Samples taken from Royal Spring were collected using ISCO automated samplers.

Samples were analyzed for quantities of dye, microspheres, and bacteria. Dye analysis was performed on a spectrofluorometer at the Kentucky Geological Survey. For microsphere quantification, aliquots of sample were filtered onto black gridded cellulose nitrate filters with 0.45 μm nominal pore size. Filters were placed on glass slides with cover slips and manually counted on an epifluorescent microscope using the CFP filter. Bacterial analyses have been conducted using quantitative polymerase chain reaction (qPCR) at the USDA Agricultural Research Service lab in Bowling Green, KY for samples from the epikarst study. Isotope analyses have not yet been conducted, but will hopefully be conducted prior to May.

For the epikarst trace at Crumps Cave, breakthrough curves show differential tracer behavior within the epikarst (Figures 2 and 3). Dye arrived at the sampling location ~40 minutes prior to latex microspheres and 160 minutes prior to either bacterial isolate. The dye concentration peaked at 4.5 hours post-injection (PI). A secondary peak was observed during the second storm event approximately 270 hours PI. Total dye recovery was 1.25%. Among the bacterial isolates, differences were observed in arrival times, with the isolate containing the *iha* gene arriving two hours after the isolate containing the *kps* gene. Microsphere concentrations peaked during the second storm event (270.75 hours PI) and had a total recovery of 0.25%. The *kps* isolate of *E. coli* had a first arrival similar to the microspheres but

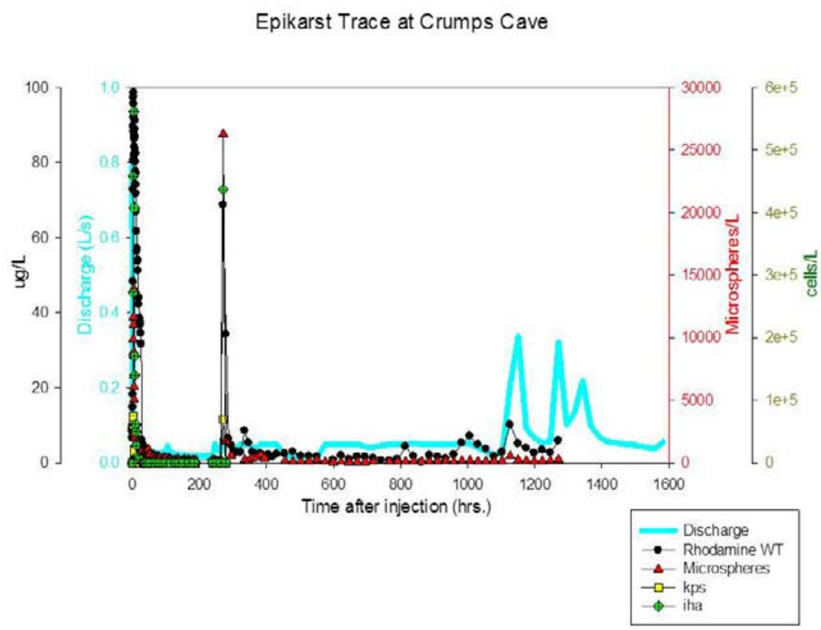

Figure 2. Plot of discharge and tracer concentrations throughout the sampling period for the epikarst study. Tracers exhibit resuspension during subsequent storm events.

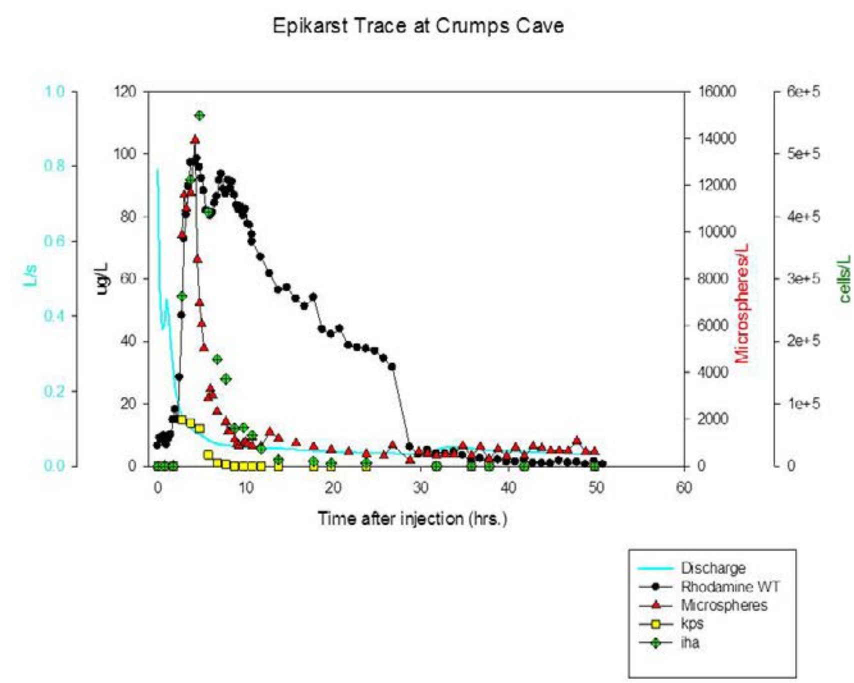

Figure 3. Fine scale resolution of discharge and tracer concentration during the epikarst trace. Note the broad shape of the dye peak as compared to the particulate tracers and the difference in arrival times for the two isolates of bacteria.

a peak concentration at 2.75 hrs. Recovery of the *kps* isolate was 0.17%. The *iha* isolate of *E. coli* had a peak concentration during the second storm event with a secondary peak at 4.75 hr PI. Total recovery of the *iha* isolate was 0.29%. The lag of several hours between the hydrograph peak and bacterial peaks was also seen in a French karst aquifer trace by Personné et al. (1998). Comparison of arrivals of dyes and particulate tracers do not agree with results from Sinreich et al. (2009), in which particles had shorter transport times and higher recoveries than dye.

Analyses are still being conducted for the aquifer trace, but preliminary results show slight differences in arrival times (leading edges) of dye and microspheres. Timing of peak concentrations differs slightly at the Horse Park sampling site, but is similar at Royal Spring, which is approximately 6.5 km from the injection site. As of early December, microsphere recovery for the aquifer trace was approximately 0.1% (10^{12} of 10^{13} microspheres recovered). Preliminary results from the aquifer study suggest similarities with Goeppert and Goldscheider (2011), who found that fluorescent dye and 1-μm microspheres had similar arrival times and concentration peaks in an aquifer trace conducted over a distance of 1 km.

Information gleaned from the traces will improve our understanding of transport and attenuation behavior of bacteria related to more common tracers such as fluorescent dyes and latex microspheres. During the epikarst trace, differences in transport were observed between dye, latex microspheres, and bacteria. Dye exhibited the broadest breakthrough curve, and microspheres had more prolonged tailing than the bacteria. Microspheres appear to undergo slight episodes of resuspension, unlike bacteria, under the conditions at this study site, similar to findings by Ward (2008). Field data on survival and transport of agricultural isolates of *E. coli* can be applied to improve transport models and used by regulatory agencies for making decisions to prevent bacterial contamination of water resources in karst terrains.

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A Biogeochemical Investigation of a Methane-Fueled Anchialine Cave Ecosystem

David Brankovits

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Figure 1. Research in an anchialine cave: obtaining physicochemical profiles above the halocline (blurry water bottom of the picture). Diver: David Brankovits. Photo: Rogelio Mier.

The graduate research grant provided by CRF has significantly contributed to the advancement of my PhD dissertation project by allowing me to do measurements in and collect samples from flooded coastal cave systems within density stratified coastal aquifers (*anchialine* caves) in the Yucatan Peninsula, Mexico (Figure 1). The collected samples were used to investigate methane dynamics and key biogeochemical processes that are vital in sustaining the subterranean ecosystem in anchialine caves. The Caribbean coast of the Yucatan contains the largest accumulation of anchialine caves in the world, including the Ox Bel Ha cave system, one of the longest continuously flooded cave system (> 240 km; QRSS 2015). Using advanced scientific cave diving techniques, we collected water and invertebrate fauna samples at four sampling sites along the Ox Bel Ha cave and tested the following specific hypotheses:

(H_1) Methane is present in the studied anchialine caves and it is oxidized within the brackish water (mixing zone), especially near the anoxic-hypoxic interface, of the cave system. Concentration and selected isotopic profiles of electron donors (methane, ammonium and dissolved organic carbon), electron acceptors (nitrate, nitrite, sulfate and oxygen) and conservative tracers (salinity and chloride) were used to delineate the active biogeochemical pathways (i.e., methanotrophy, nitrification, sulfate reduction) in the water column of the cave system. Based on that analysis, the contribution of methane to the energy and carbon balance of the ecosystem was determined as well as the significance of other processes were tested.

(H_2) Methane oxidation is mediated by methanotrophic bacteria that inhabit the anchialine caves. We used organic geochemical and molecular genetic techniques to characterize the microbial community from the environment, the gut content and adipose (lipid) tissue of cave-adapted shrimps. Lipid analysis provided chemotaxonomic information about the most active life forms. The ongoing next-generation sequencing analyses will allow us the characterization of the entire archaeal and bacterial community.

(H_3) Methane provides carbon and energy to higher trophic levels of the food web via methanotrophic bacteria. We analyzed the carbon isotope content of bulk tissue and fatty acids extracted from cave-adapted shrimps to test if the microbial-derived food source was present and incorporated into the biomass of cave-adapted shrimps.

Preliminary data provided compelling evidence that methane is an important source of carbon and energy for the anchialine food web (Brankovits et al. 2014). Methane concentrations ranging from 4,018 nM to 10,894 nM in fresh and anoxic water near the ceiling of the caves suggest *in situ* production and/or an input from overlying anoxic soils of the tropical forest and mangroves. Rapid and non-linear methane depletion with increasing salinity (and depth) suggests consumption of methane above the halocline. The $\delta^{13}C$ values of high-concentration methane samples ($\delta^{13}C_{mean}$ = -66.7‰) suggest a microbial source (Whiticar, 1999) near the ceiling. In contrast, the lower-concentration methane in the brackish and saline water is relatively enriched in ^{13}C ($\delta^{13}C_{mean}$ = -48‰) indicating that methane oxidation is an active process in the brackish portion of the water column. Similar to methane, DOC concentrations are highest near the ceiling (DOC_{mean} = 756µM) and decrease to an average value of 140 µM in the brackish water, which implies that heterotrophic microbes are also active. $\delta^{13}C$ values of the DOC (ranging between -30‰ to -26‰) in fresh and brackish suggest a terrestrial source whereas saline groundwater values (ranging between -27‰ to -21‰) are consistent with a mixture of terrestrial and marine sources.

Stable isotopic and lipid measurements of the microbes and metazoans allowed us to identify ecologically relevant carbon sources. As an example, a cross-plot of stable carbon and deuterium isotopes from tissue of atyid shrimp from the genus *Typhlatya* demonstrate that ^{13}C- and D-depleted organic material, which is derived from methane, is an important source of food (Figure 2). These isotopic values are not expected in an ecosystem where the primary energy source is plant-derived. Similar isotopic values have been observed in macrofauna from deep ocean where methane and its oxidation product CO_2, are strongly depleted in ^{13}C (e. g., Niemann et al., 2013). Furthermore, the presence of ^{13}C-depleted fatty acids (e.g., C16:1ω7c, 10Me-C14:0, C16:1ω5, cyC17:0ω5,6 with $\delta^{13}C$-values as low as -54.1‰) extracted from the cave-adapted shrimps provide evidence that methanotrophic bacteria were a substantial fraction of their diet. These lipids are typically not found in crustaceans, but are synthesized by methanotrophic and/or sulfate-reducing bacteria in other methane-dominated environments such as deep-sea cold seeps (Niemann et al. 2013). Taken together, this geochemical evidence suggests that microbes living in the water column of the caves recycle reduced compounds, such as methane and DOC, and, thus, provide important food source for the cave-adapted crustaceans (Figure 3). The composition and genetic potential of the microbial consortia mediating methane cycling in these systems is presently unknown. We have extracted microbial DNA from environmental samples for molecular microbial community analysis that will help identify the microbes that live in the water column of the studied anchialine caves.

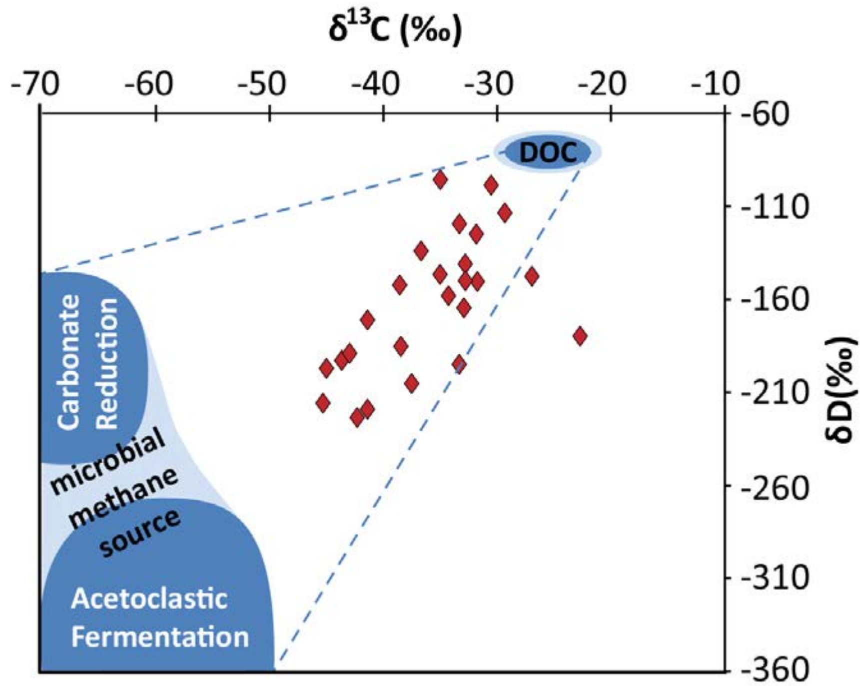

Figure 2. Carbon and hydrogen stable isotopic values for cave shrimps (red) and available organic matter sources (blue fields). Shrimps feed on sources that utilize methane carbon or dissolved organic carbon. Proximity of shrimps to source reflects relative dependence on that source.

Results are currently being processed and written up into multiple manuscripts that will be published in peer-reviewed journals. I presented my research with great success at multiple scientific meetings in the US and internationally (Brankovits et al. 2014, 2015a, 2015b).

In summary, CRF's support in the form of a graduate student grant greatly contributed to the success of my PhD dissertation project. CRF funds were used to cover field expenses in 2014 and 2015. The main results of the study, which provide evidence that methane is an important source of carbon and energy for the anchialine food web, were successfully disseminated in multiple conferences. Moreover, manuscripts are in preparation. These findings have the potential to reframe the carbon cycle and ecosystem dynamics for an isolated, yet widespread habitat within the Earth's interior.

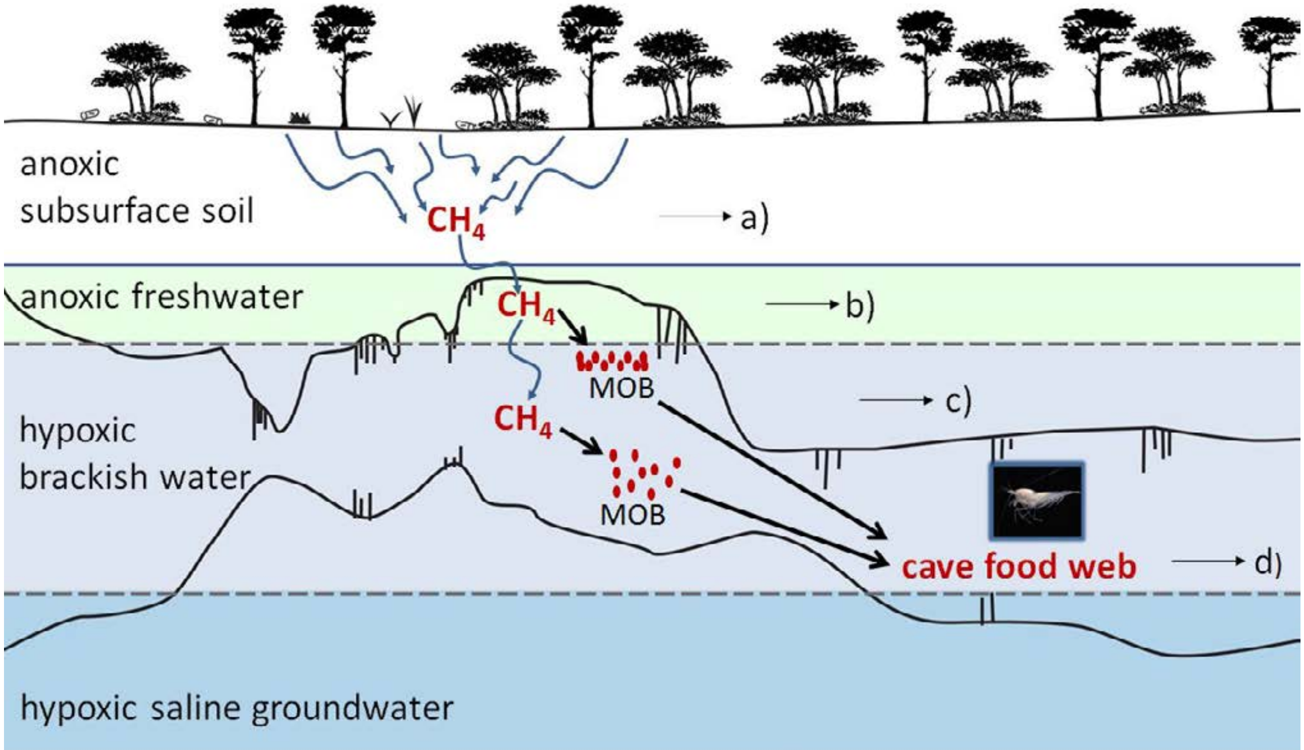

Figure 3. **(a)** ***Methane (CH_4) generated in subsurface anoxic soil from organic matter derived from surface vegetation is transported into the groundwater.*** **(b)** ***CH_4 accumulated in anoxic portions of the cave/groundwater is constantly oxidized at the shallow halocline by methane oxidizing bacteria (MOB).*** **(c)** ***CH_4 periodically transported into hypoxic portions of the cave system by rainfall induced mixing is consumed by MOB.*** **(d)** ***CH_4 present in the caves provides carbon and energy to the cave-adapted food web via trophic interactions of MOB and filter-feeding cave-adapted shrimps (Brankovits et al. 2014).***

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Developing Improved Linkage Mapping Resources for Use in the Blind Mexican Tetra, *Astyanax mexicanus*

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Abstract

Astyanax mexicanus, commonly known as the blind Mexican tetra, consists of 30+ cavefish populations in the Sierra de El Abra region of northeastern Mexico, as well as an extant surface form. The persistence of the surface form and the ability to generate viable hybrid offspring has made *Astyanax* a valuable model in which to investigate the evolutionary and developmental processes leading to the suite of regressive and constructive changes observed in these and other cave organisms (Jeffery 2001; Jeffery 2009). In the past, genetic mapping studies have identified candidate genes mediating a variety of these traits, such as retinal degeneration (O'Quin et al. 2013), rib number, eye size (Gross et al. 2008), albinism (*Oca2*) (Protas et al. 2006), and the brown phenotype (*Mc1r*) (Gross et al. 2009). In order to facilitate future genetic studies and allow for the detection of genetic loci with smaller effects, the goal of this project was to improve upon existing linkage mapping resources in this species by developing an accurate, high-density *Astyanax* linkage map using a genotyping-by-sequencing (GBS) based approach.

Methods

Briefly, genomic DNA was isolated from fin clips of surface, cave (Pachón) and F_1 hybrid (surface × Pachón) individuals (n = 4 each), as well as each member of two F_2 hybrid populations (n = 129; n = 41). Resulting DNA samples were prepped and sent to the Institute for Genomic Diversity (Cornell University) for processing. The resulting 7956 GBS markers (consisting of anonymous 64 bp sequences, each including a single nucleotide polymorphism or "SNP") were screened for suitability and a total of 3003 markers were selected for mapping. JoinMap (v. 4.1; Kyazma) was then used to group and subsequently map GBS markers based on the genotypic data from the F_2 individuals. Identification of anonymous markers was accomplished by using the BLASTN algorithm to compare each marker sequence against a number of genomic and transcriptomic resources.

Results and Discussion

Linkage Map

In its finalized form, the linkage map produced (Figure 1) contains a total of 2235 GBS markers with a mean intermarker distance of 1.052 cM. These markers are spread out over 25 distinct linkage groups (*Astyanax* has 25 chromosomes) with a combined length of 2110.7 cM.

Comparison with the *Astyanax mexicanus* Genome

BLASTN alignments against draft *Astyanax* genome resources enabled the identification of putative positions for 93.6% (n = 2091) of the 2235 markers. Genomic scaffolds from the draft *Astyanax* genome can be considered "anchored" to this map if they include the putative locations of one or more of these markers. Between 12 (linkage groups 8 and 22) and 55 (linkage group 15) scaffolds were anchored to each linkage group in this fashion, with a map-wide mean of 27.64 scaffolds per linkage group. Individual scaffolds included the putative locations for between 1 and 33 GBS markers, with each scaffold harboring an average of 3.50 markers per anchored scaffold. In total, connections were established between this map and 598 unique scaffolds. This represents only a small percentage (5.57%) of the 10,735 scaffolds comprising the current draft of the *Astyanax* genome, however the ~815 Mb of genome sequence included in these 598 scaffolds represents ~84.5% of the total length of the current genome assembly. Further, the anchored scaffolds contain 15,980 protein-coding genes, representing 69.4% of the protein-coding genes annotated in the current draft of the genome. Finally, in instances where individual genomic scaffolds harbor two or more GBS markers, those markers co-localize to the same linkage group 87.3% of the time, suggesting that this map accurately reflects the true genomic positions of the markers used to construct this map.

Comparison with the *Danio rerio* Genome

Given that the *Astyanax* genome is still in the draft phase (McGaugh et al. 2014), this map was also anchored to

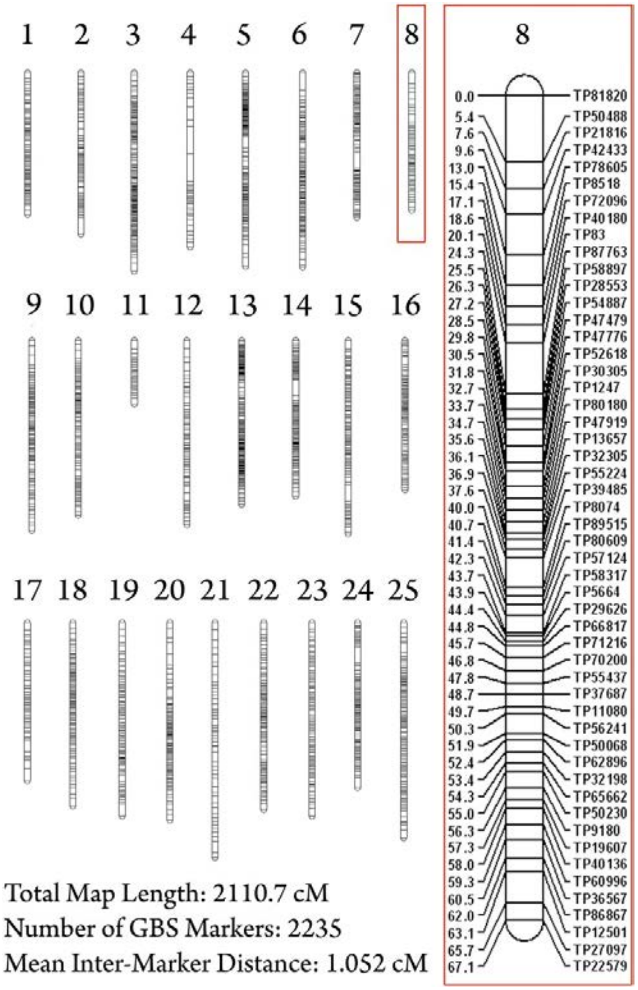

Figure 1. A high-density GBS-based linkage map for the Mexican cave tetra,* Astyanax mexicanus. *This linkage map consists of 2235 markers in 25 linkage groups (*A. mexicanus *karyotype number = 25), spanning a total distance of 2110.7 cM (mean inter-marker distance = 1.052 cM).* Astyanax *linkage group 8 (red box) illustrates typical marker density observed in most groups. This group consists of 52 GBS markers spanning 67.061 cM with a mean inter-marker distance of 1.315 cM. From Carlson* et al. *2015.

zebrafish (*Danio rerio*), the closest model organism with a finished grade genome. Despite the fact that these species diverged ~150 million years ago (Briggs 2005), previous work in *Astyanax* suggests that significant genome-level similarity persists between them (Gross et al. 2008; O'Quin et al. 2013). Direct alignment of GBS marker sequences with the *Danio* genome was relatively unsuccessful, returning results for only 1.2% (n = 26) of the 2235 markers included in this linkage map. However, success rates were much higher when using *Astyanax* genomic (26.5%) or transcriptomic (13.3%) sequences as an intermediary, thereby increasing the length of the sequences being aligned. In total, sequences similar to 35.1% (n = 784) of the markers in this linkage map were identified in the *Danio* genome (Figure 2). Loci from all 25 *Danio* chromosomes were represented in this analysis, with each chromosome linked to the *Astyanax* map by anywhere between 14 and 52 GBS markers (mean = 30.84 syntenic links per chromosome). In many instances, sequences similar to large groups of markers from a single linkage group are found together on the same *Danio* chromosome; these represent ancient syntenic blocks shared between these species.

Comparison with Previous Maps

At the time that this map was constructed, two previous publications included both linkage maps for use in *Astyanax* and an analysis of synteny between those maps and the *Danio rerio* genome: Gross et al. (2008), which included a map based on microsatellite markers, and O'Quin et al. (2013), which included a map based on both microsatellite and RAD-seq data. Although of similar length to these previous maps, the map presented here represents a dramatic increase in marker number (+559% compared with that of Gross et al. 2008; +320% compared with that of O'Quin et al. 2013) and marker density (+473% compared with that of Gross et al. 2008; +279% compared with that of O'Quin et al. 2013). Accordingly, a substantially higher number of links can be demonstrated between the current map and the *Astyanax* genome (+263% compared with that of Gross et al. 2008; +171% compared with that of O'Quin et al. 2013) and between the current map and the *Danio rerio* genome (+506% compared with that of Gross et al. 2008; +453% compared with that of O'Quin et al. 2013). Further, while the current map reflects all of the major points of synteny between *Astyanax* and *Danio* demonstrated in earlier analyses, it also includes an increased number of links between *Astyanax* linkage groups and *Danio* chromosomes poorly represented in previous work. For example, Gross et al. (2008) identified no links between their map and *Danio rerio* chromosome 11. In contrast, this map includes 36 links to chromosome 11. Similarly, *Danio* chromosomes 17 and 19 are each represented only once in the map produced by O'Quin et al. (2013). Here, substantial links have been established between these chromosomes and linkage groups 9 (n = 21) and 23 (n = 15), respectively. Finally, comparison of the *Astyanax* genomic scaffolds anchored to the linkage groups presented in all three maps indicates that the linkage groups in the current map represent genomic intervals similar to those included in prior maps; however, this map achieves a higher level of detail and resolution than previous mapping resources.

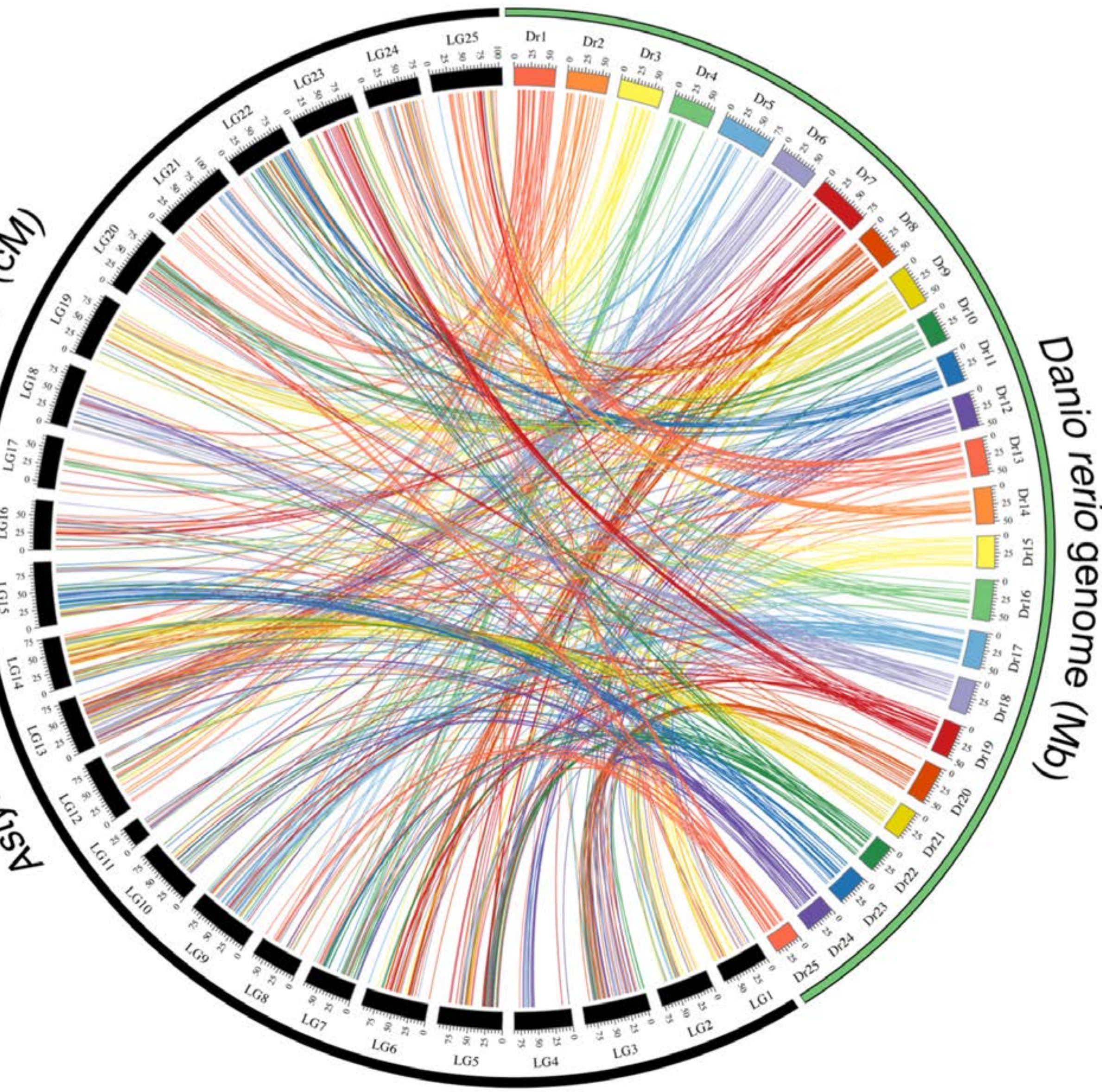

Figure 2. Whole-genome synteny between* Astyanax *and* Danio*. Syntenic links between the current GBS-based* Astyanax *linkage map and the* Danio *genome were visualized using Circos. Each line represents a connection between the position of a particular marker in our linkage map (black; scale in cM) and a homologous sequence in* Danio *(various colors; scale in Mb). Adapted from Carlson* et al. *2015.

Implications

Beyond the scope of the work discussed here and the ongoing studies heavily dependent upon it, it is hoped that 1) collaborative efforts will be successful in using this linkage map to inform the assembly of future drafts of the *Astyanax* genome, 2) the public availability of this map and the associated marker sequences will accelerate the *Astyanax* research community's search for genetic loci mediating cave-associated traits, and 3) that the effective and cost-efficient GBS-based approach described here will prove to be a useful framework for others seeking to develop high-density linkage mapping resources in other species of ecological, evolutionary or biomedical importance.

Impact of CRF Grant Funding

The work funded by this Cave Research Foundation Graduate Student Research Grant has resulted in a first-authored publication by the recipient (Carlson et al. 2015), which describes the work summarized here in greater detail; at least one additional publication heavily reliant on this work is forthcoming. Additionally, this project provided mentored research opportunities for four talented undergraduates, three from the University of Cincinnati and one from DePauw University. All of these students presented their research in public forums and one of them is listed as the second author on Carlson et al. (2015).

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High-resolution Morphometric Analysis of Sinkholes and Depressions within Karst Geology

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Closed depressions are topographic features having no lateral surface flow or external drainage. In karst landscapes, closed depressions are associated primarily with sinkholes, sinking streams and cave openings, which form by collapse or subsidence following the dissolution of carbonate or evaporate rocks. Geologic units susceptible to karst development cover roughly 25% of the continents (Veni et al., 2001), and these areas are home to a similar percentage of global population (Ford and Williams, 2007). Within the contiguous United States, nearly 20% of the landscape is underlain by karst-susceptible geologic units (Weary and Doctor, 2014). These inventories are used by federal, state, and local agencies for hazard mitigation (e.g. Galve et al., 2009; Galve et al., 2011), hydrologic modeling

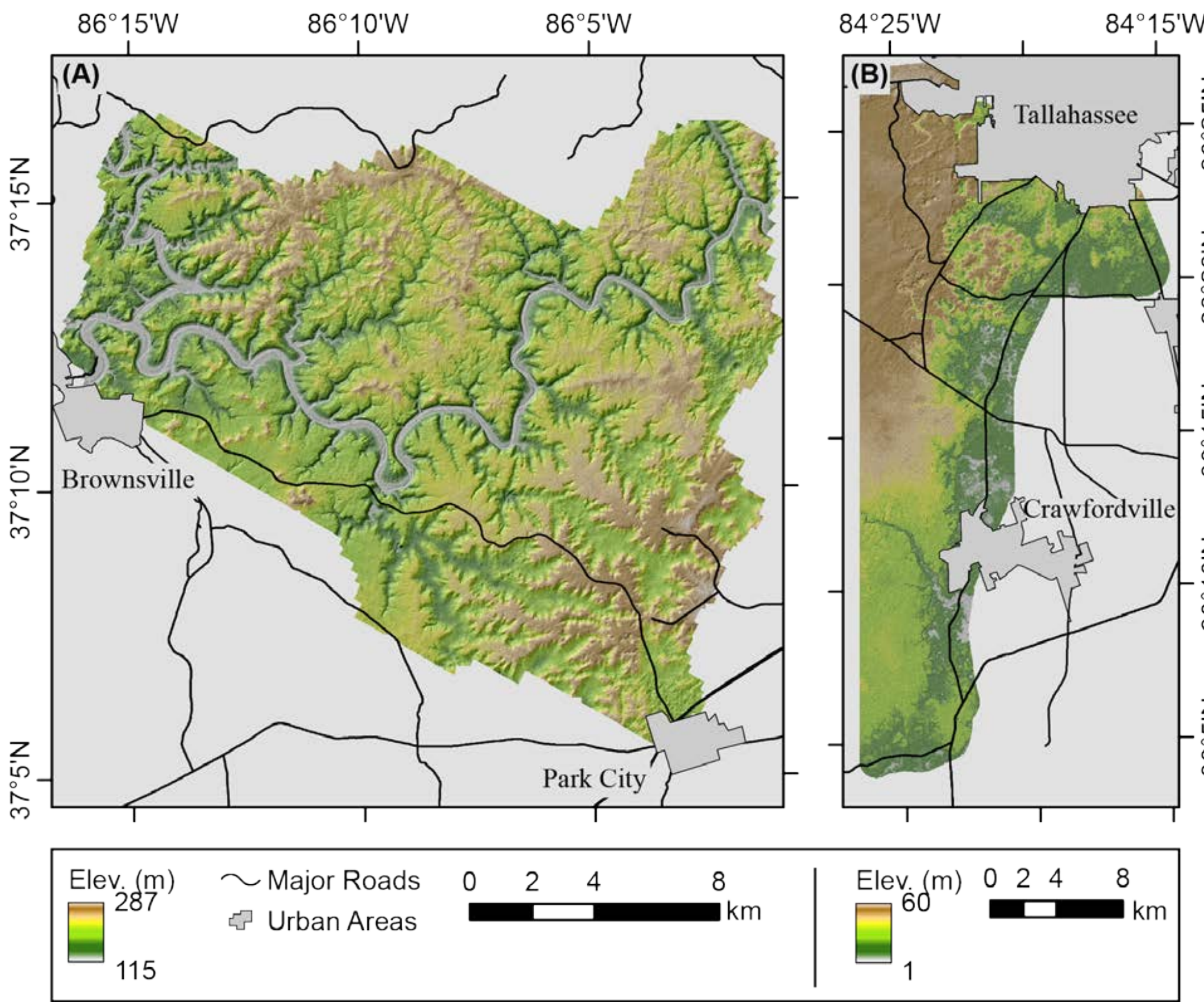

Figure 1. Digital elevation models created from light detection and ranging data for* (A) *Mammoth Cave National Park, Kentucky, and* (B) *Apalachicola National Forest, Florida, which were used in this study.

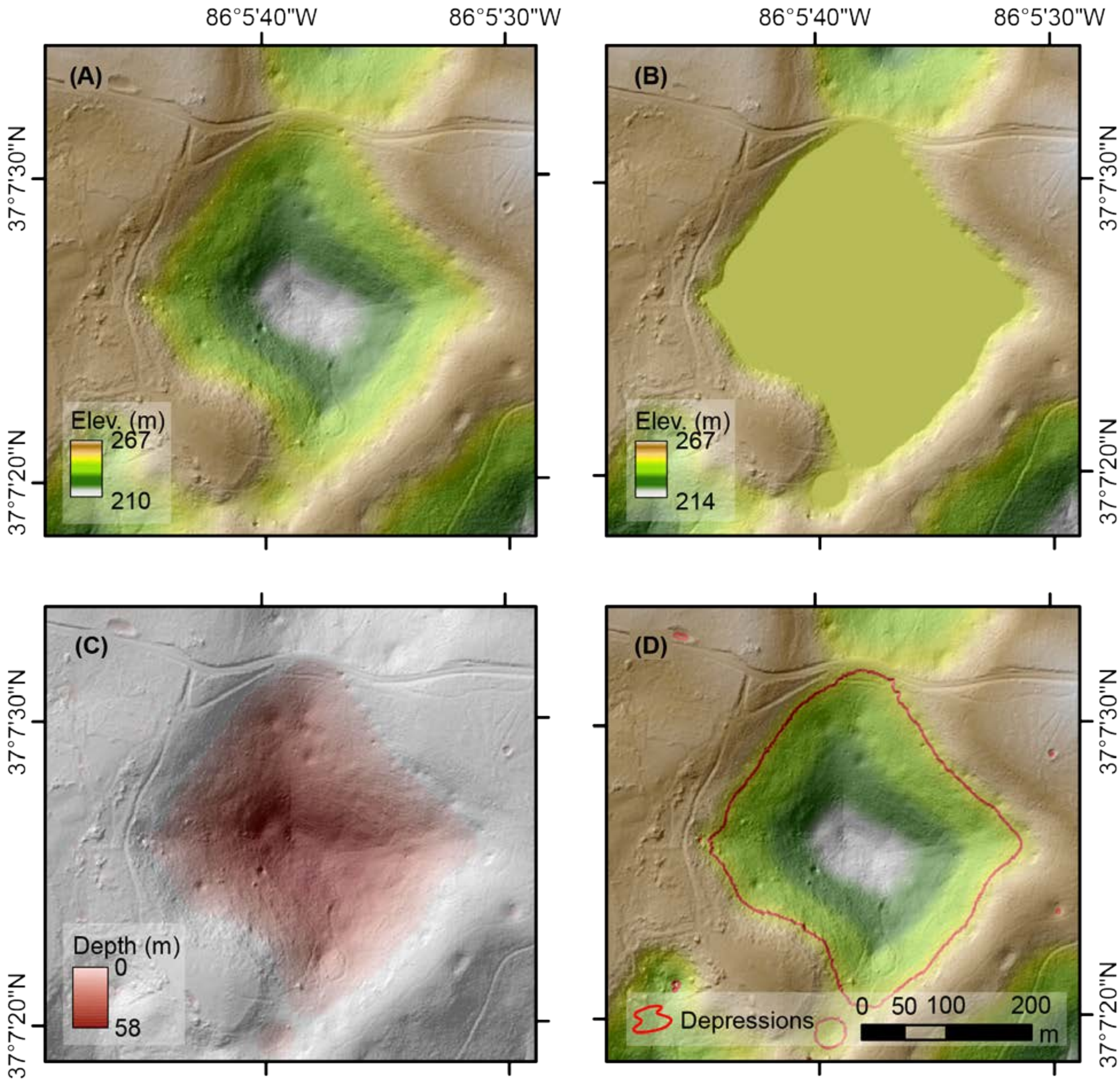

Figure 2. A simplified explanation of the automated method developed and employed for this study. **(A)** *An initial digital elevation model (DEM) is processed from light detection and ranging (lidar) data or acquired from a data service.* **(B)** *The DEM is hydrologically conditioned using a depression filling routine already provided by ArcGIS.* **(C)** *The initial DEM is subtracted from the hydrologically conditioned DEM resulting in a depth raster.* **(D)** *All values within the depth raster greater than 0.73 m were converted to polygons resulting in a depression inventory.*

(e.g., Sanderson et al., 1995; Kerr-Upal et al., 1999; Stotler et al., 2011), protection of ecology (e.g., Herault and Theon, 2008; Etienne et al., 2013), and archaeological predictive modeling (e.g., Mayer, 2002; Bement, 2010).

In 2014, the Cave Research Foundation provided funds to investigate the efficacy of an automated method to delineate closed depressions at Mammoth Cave National Park (MACA), Kentucky and Apalachicola National Forest (ANF), Florida using high-resolution digital elevation models derived from light detection and ranging (lidar) data (Figure 1). As a result, an automated tool was developed for use in ArcGIS 10.X (Figure 2). In order to determine the ability of the automated method to generate inventories of karst depressions at these two locations, the automatically generated inventories were compared to manually generated inventories (Paylor et al., 2004; Florida DEP, 2005) based on topographic closed-contours delineated from 7.5-minute USGS topographic quadrangles (1:24,000 scale).

When compared to manually generated inventories, the automated method is able to spatially identify 95% and 87% of karst depressions at MACA and ANF, respectively. The automated method additionally increases catalog size by 183% (n = 797) at MACA and 505% (n = 3,377) at ANF. At MACA, 633 unique relationships were identified between the catalogs while 685 were identified at ANF. Of these unique relationships, one-to-one accounted for 531 (84%) at MACA and 502 (73%) at ANF. While the majority of the relationships are one-to-one, one-to-many relationships indicate aggregation or disaggregation at these locations. Thus, 102 (16%) one-to-many relationships were identified at MACA and 183 (27%) at ANF. Spatial co-location of records between manual and automated catalogs indicates that the automated method is impacted by the quality and resolution of lidar data.

The automated method is able to repeat the findings of earlier, manual inventories, provided some caveats, without subjective human-induced errors, while additionally increasing catalog size in far less time. When multiple topographic karst depressions coalesce, the decision to classify one depression or multiple depressions as an individual karst feature is strictly dependent on the definition of a karst depression. The automated method delineates the boundary of the depression based on the inability of water to be routed across the surface (resulting instead in the ponding of 'virtual' water in the GIS environment), whereas the manual method relies on a definition adhered to by an agency or other group tasked with digitizing closed-contours. Despite the differing definitions of what constitutes karst depressions used between manual and this automated approach, this analysis indicates that the automated method is appropriate for regional studies, particularly for comparing characteristics between karst regions. This includes karst terrain beneath both heavy forest canopy and shrub/scrub vegetation communities, where lidar topographic data may be the primary source of information available for the assessment of landforms.

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Assessing Human Activities, Sediment Deposition, and Pedogenesis at Crumps Cave Vestibule and Sink, Warren County, Kentucky

2015 Cave Research Foundation Grant Recipient Report

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I conducted excavations at Crumps Sink between July and September 2015 to collect archaeological and geoarchaeological data as part of my dissertation project to refine the chronology of prehistoric occupation, determine the range of activities, and assess prehistoric erosion and soil formation in a karst landform. More specifically, my research seeks to trace manifestations of Middle to Late Holocene (ca. 8000–3000 years B.P.) environmental change and human forest management by fire in the archaeological and sedimentological record of cave and sinkhole sites in south-central Kentucky.

During the Middle to Late Holocene, expansion of prairie-like grasslands known as barrens took place. Increasing charcoal frequencies in pond sediments dating from the early Late Holocene suggest forest fires had become more common (Baskin et al. 1994; Delcourt et al. 1998; Wilkins et al. 1991). These changes were occurring in concert with early plant domestication in the region and humans may have played a role in altering ecosystems (Crothers 2008; Smith 2006; Watson 1985). This multidisciplinary study derives methods and lines of inquiry from archaeology, karst and soil geomorphology, and forest ecology, and builds upon previous research by the Cave Research Foundation Archaeological Project in the Mammoth Cave area (Carstens 1980; Watson 1969, 1974). It is providing a foundation for further research questions and investigations into prehistoric human-environmental dynamics in the region.

Crumps Sink is a large sinkhole with an associated cave situated in the Sinkhole Plain of Kentucky. Rainfall in the Sinkhole Plain drains quickly into subterranean rivers (Hess et al. 1989, Wells 1973). Prehistoric people would have entered sinkholes and caves to access this underground water. Previous archaeological investigations of the cave and fields surrounding the sinkhole suggest that the site was frequented for at least 9000 years (Carstens 1980; Fowke 1922). Undoubtedly, these sites became important beyond the water sources they provided. Charcoal from mud glyphs found deep in the cave interior were radiocarbon dated to the early Woodland period. The rarity of such glyphs throughout the Interior Low Plateaus further attests to the cultural significance of the site (Davis 1996; Simek et al. 2001).

Though the cave was known to have archaeological deposits, the potential of the sinkhole was much less certain. In 2009, George Crothers augered the deposits within the sinkhole revealing charred hickory nut shell and chert flakes to a depth of at least 3.2 meters. The deposit was determined to be significant, warranting further

Figure 1. Excavations in progress. At the time of the photo, the unit was 2.3 meters deep.

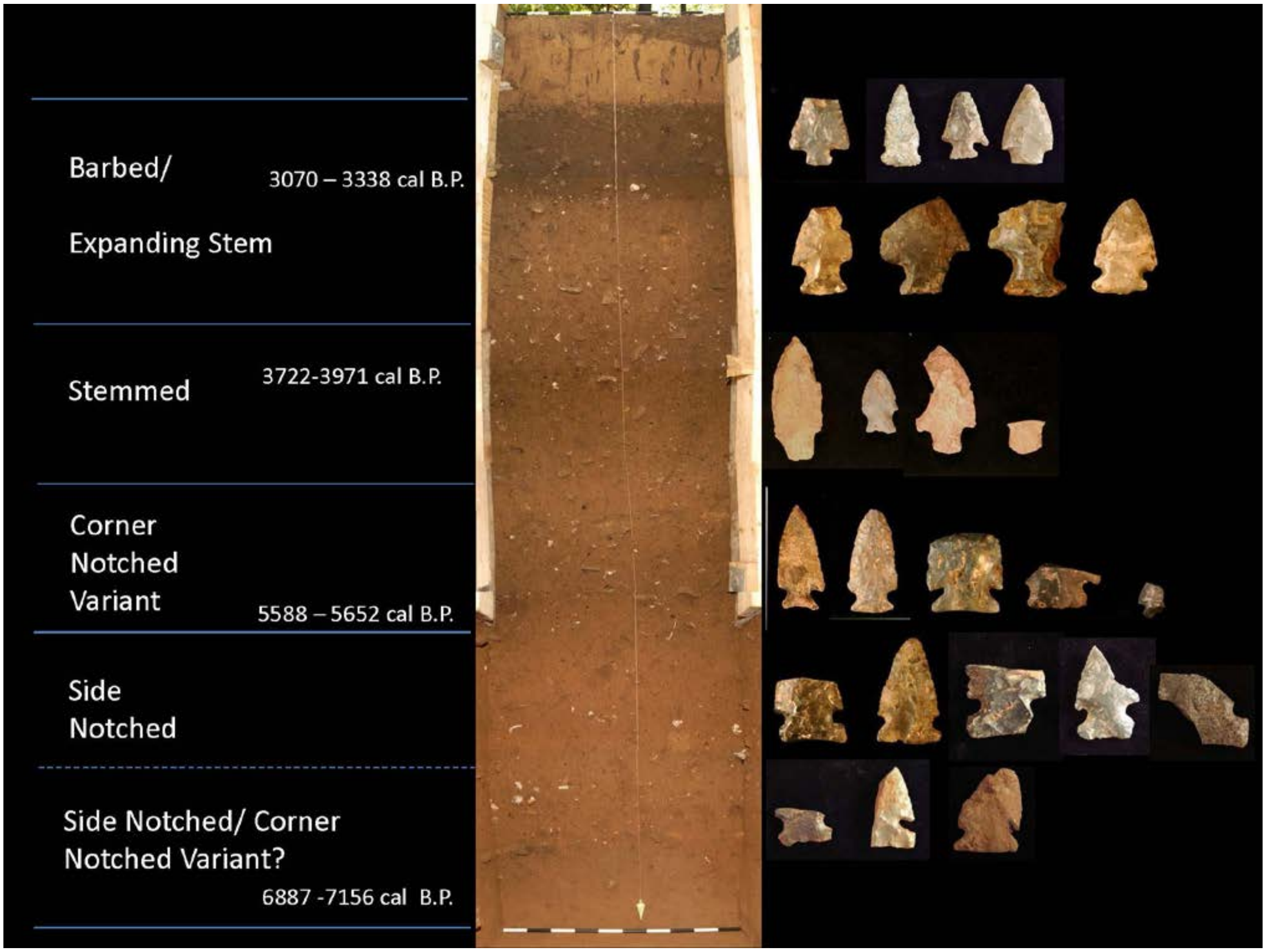

Figure 2. Radiocarbon dates and projectile points in relation to the north sediment profile. Total depth of the archaeological deposits, 3.8 m.

archaeological investigation. While the goal for the summer and fall of 2015 was to dig test units in both the sinkhole and cave, the sinkhole excavations spanned the entirety of the late summer and early fall field season, lasting more than 2 months (Figure 1). When excavations were complete, archaeological deposits were determined to be 3.8 m deep. At the conclusion of hand excavations, we cored culturally sterile deposits to a depth of approximately 5.2 m, collecting soil samples, before reaching what is likely roof fall from collapse of the cave during sinkhole formation.

The excavations yielded thousands of artifacts including flaked stone, ground stone, and bone tools. We also uncovered personal items including shell beads and a limestone pendant fragment. Four radiocarbon dates of charred nutshell, three of which were funded by this grant, suggest that the most intensive human use of the site was during the Middle and Late Archaic periods, approximately 7000 to 3200 calibrated years before present. As a catchment basin, the sinkhole steadily collected sediment that covered archaeological remains soon after the site was abandoned by humans. This allowed for a stratigraphically intact profile, preserving archaeological remains from each time-period. Future analysis of dozens of projectile points along with additional radiocarbon dates will provide information on changing stone tool technologies in the Sinkhole Plain (Figure 2).

Animal bone and charred plant remains, fragile remnants of the foods hunter-gatherers processed at the site, will provide information about changing ecosystems in the area and human diet over time. To ensure proper collection of charred plant nuts and seeds, I collected approximately 20 liters of sediment per 10 cm level. I am currently processing these samples by water flotation. The soil is poured into water and gently agitated to allow dispersal of light seeds and wood charcoal that float and are collected in a very fine mesh net. Denser materials such as charred nutshell, rock, artifacts, and animal bone, which sink, are recovered in a fine mesh screen.

Sediment analyses are an integral part of this study. I collected loose sediment samples in 5 and 10 cm intervals for tests of magnetic susceptibility, organic matter, carbonate content, particle size, and phosphorous. I also removed 47 *in situ* blocks of sediment from the profile, capturing nearly the entirety of the archaeological deposits. Some of these blocks will be lithified with epoxy resin and then cut to create thin sections that can then be analyzed under a microscope. These analyses will be significant for identifying periods of soil formation vs. erosion and delineating between human and environmental impacts on the landform.

The data collected from the excavations at Crumps Sink are significant to cave and karst studies for a number of reasons, including (1) developing a model of hunter-gatherer and early horticultural utilization of holokarst terrains; (2) contributing to contemporary forest management literature by considering long-term history of karstic barrens and cedar glades ecosystems in response to environmental and human-induced changes; and (3) elucidating the Holocene history of geogenic, biogenic, and anthropogenic sediment deposition and soil formation in karst features, as a result of environmental change and prehistoric human land use on cave systems. Analyses of the Crumps Cave samples will continue through 2017 with an expected completion date in spring of 2018.

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Impact of Exogenous Nutrients on Mn-oxidizing Microbial Consortia among Caves of the Southern Appalachian Mountains

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Introduction

Cave systems are generally carbon limited environments where endogenous microorganisms have adapted to oligotrophy. These cave systems and the microflora can be sensitive to eutrophication or anthropogenic disturbance (Carmichael & Brauer 2015). Biotic Mn(II) oxidation in caves can be limited by carbon availability (Carmichael & Brauer 2015; Carmichael et al. 2015). Therefore, the impact of eutrophication on these sensitive systems can be visually observed as dark brown to black manganese (Mn) oxide biofilms comprised of Mn(II)-oxidizing microbial communities (Carmichael & Brauer 2015; Carmichael et al. 2015).

The exact mechanisms for biotic Mn(II) oxidation are still elusive, and biomineralization pathways seem to be species specific (Bargar et al. 2000; Geszvain et al. 2012; Santelli et al. 2011; Tang et al. 2013; Tebo et al. 2004). Scanning electron microscopy has been used to visualize Mn(II)-oxidizing microbes and where the Mn(III/IV) oxides are deposited within the cultures (Hansel et al. 2012; Learman et al. 2011b; Santelli et al. 2011; Tang et al. 2013). Mn(III/IV) oxides surrounding cells has been attributed to MCO enzymatic oxidation and oxides in the extracellular matrix are formed via extracellular molecules (Carmichael et al. 2013b; Santelli et al. 2011; Tang et al. 2013).

Previous research has focused on constraining microbial Mn(II)-oxidizing capabilities *in situ*, while there are no current studies that have addressed *in vitro* parameters that may be affecting biotic Mn(II) oxidation. By combining microbiological and geochemical techniques, we were able to identify 1) environmental parameters that impact Mn(II) oxidation in cave systems, 2) enzymatic pathways utilized by microbes to oxidize Mn(II).

Methods

Caves and Sites Chosen for This Study

Three caves were chosen for this study: Carter Saltpeter Cave (CSPC), Daniel Boone Caverns (DBC), and Rye Cove–Cox Ridge (RCCR). CSPC was/is considered to be an anthropogenically impacted cave, while DBC and RCCR were classified as near "pristine" caves (sensu-Carmichael et al. 2015) These caves are all part of the upper Knox Dolomite bedrock formation. Between five and six sites were chosen with each cave for carbon treatment experiments. Sites that were chosen for treatments tested slightly positive for Mn(II) oxidation via leucoberbelin blue (LBB) tests. For brevity, sample sites will be herein referred to first by the cave in which the sample was taken and then by the site name. For example, site MNF in CSPC will be referred to as CSPC-MNF.

Baseline Microbial Mn(II)-oxidizing Communities

Sediment samples were taken in triplicate from each site before incubations and DNA was extracted from the sediment samples. Extracted DNA was amplified using PCR and barcoded primers. Fungal DNA samples were amplified using the protocol outlined by Zorn (2014), and bacteria were amplified following the protocol used by Caporaso et al. (2012). Following PCR amplification, samples were standardized, pooled, and gel purified. Paired-end sequencing was performed on the purified samples using a MiSeq sequencer (Illumina, Inc., San Diego, CA, USA).

PANDAseq commands (Masella et al. 2012) in QIIME (Caporaso et al. 2010) were used to build contigs from forward and reverse reads. Sequences were de-replicated with USEARCH (Edgar 2010), while UPARSE was used in conjunction with USEARCH to cluster operational taxonomic units (OTUs) at a 97% identity (Edgar 2010; Edgar 2013). UCHIME (Edgar et al. 2011) was used to filter chimera's using the RDP Gold database (Wang et al. 2007). Bacterial taxonomic classifications were performed on the clustered OTUs with QIIME and the Greengenes database (DeSantis et al. 2006). Fungal taxonomic classifications were assigned to OTU clusters using the BLAST method and database (Altschul et al. 1990). Singletons were then discarded using a QIIME supported command (Caporaso et al. 2010).

OTU tables were modified to BIOM formatted tables (McDonald et al. 2012) and imported into R (Team 2015) using the phyloseq package (McMurdie & Holmes 2013). Vegan was used to calculate Bray-Curtis distance matrices in R (Oksanen et al. 2016). A permutational multivariate analysis of variance (PERMANOVA) was completed using the Adonis function within the Vegan package in R (Oksanen et al. 2016).

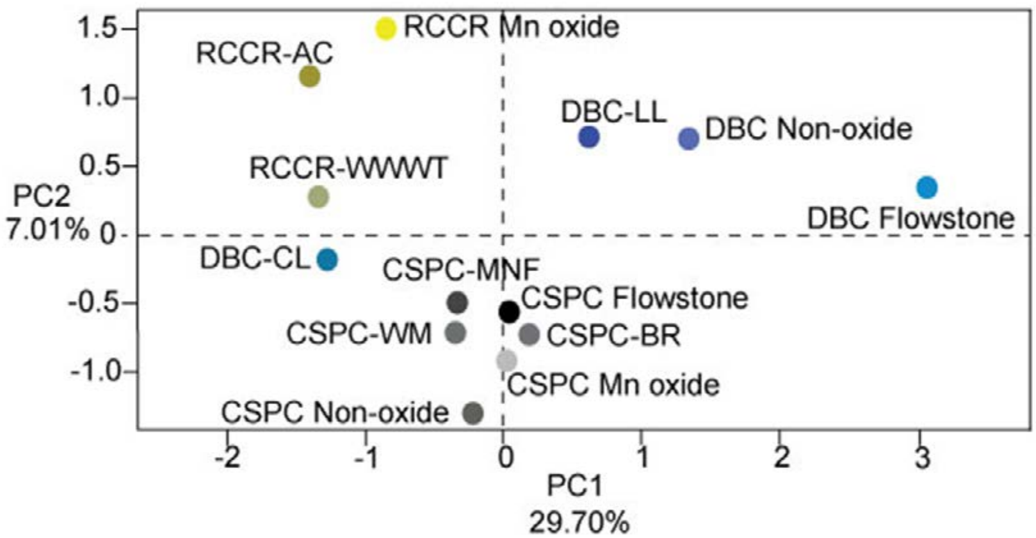

Figure 1. Principle component analysis of whole rock geochemistry at sites within CSPC, DBC, and RCCR.

Carbon Source Incubations

Nutrient agar casts were deployed at all of the sites chosen for carbon incubations. FMO2 nutrient agar casts that were intended to stimulate bacterial Mn(II) oxidation were supplemented with organic acids (arabinose, casamino acids, and succinic acids) and followed the outline by Carmichael et al. (2013b) to stimulate fungal Mn(II) oxidation, agar casts were supplemented with malt extract, glucose, and yeast extract (AY) (Santelli et al. 2010). All agar casts were augmented with 100 μM $MnCl_2$. Additional sets of nutrient media were appended with 100 μM $MnCl_2$ and 100 μM $CuCl_2$ to test whether biotic Mn(II) oxidation *in situ* would be inhibited with Cu(II). LBB tests were then performed to test whether Mn(II) oxidation had been stimulated.

Geochemical Analysis

Whole rock geochemistry (WRG) was performed on sediment samples to determine which metals may be inhibiting or stimulating Mn(II) oxidation at sites in DBC, CSPC, and RCCR. WRG samples were taken from sites where Mn(II) oxidation was stimulated and control samples were also collected from calcite flowstones and Mn(III/IV) oxide deposits that were not manipulated by this study. Samples for WRG were collected in sterile vials and shipped to ActLabs, Inc. (a commercial laboratory in Ancaster, Ontario) for analysis using the 4E-Research Total Ident package. Principal component analysis was performed in R to determine relationships between sediment samples and caves.

Culturing

Samples that were collected were streaked aseptically on nutrient agar casts including AY and citrate agar and were supplemented with 100 μM $MnCl_2$. Cultures were continually re-plated using the stab and swipe transfer method until they were axenic and were continually monitored for Mn(II) oxidation using LBB as a chemical indicator. Isolated cultures that tested positive for oxidation were colony PCR amplified, purified, prepped for quick lane sequencing, and sent to Beckman Coulter Genomics (Danvers, MA, USA). Amplified sequences were identified using a BLAST search (Altschul et al. 1990). To test whether or not a Sr may be inhibiting Mn(II) oxidation, Mn(II)-oxidizing isolates were cultured on nutrient media that contained 50 or 100 μM $SrCl_2$ and were tested for Mn(II) oxidation via LBB. Electron microscopy was performed following the outline by Carmichael et al. (2013b).

Results/Discussion

Baseline Prokaryotic Community Analysis

Analysis of pairwise comparisons from the Bray-Curtis dissimilarity matrix suggests that the beta-diversity of bacterial and archaeal communities at DBC-CL and DBC-LL were not different than the anthropogenically impacted sites in CSPC (PERMANOVA, $P > 0.05$), and RCCR sites, AB and WWWT, were different than CSPC sites (PERMANOVA, $P < 0.05$) (Table 1). It was first hypothesized that the DBC sites may have similar WRG to the CSPC sites, as other studies have found a correlation between bacterial community composition and WRG (Barton & Jurado 2007; Wu et al. 2015). However, WRG at site DBC-CL was most similar to the WRG of site RCCR-WWWT, and DBC-LL did not cluster with CSPC or RCCR sites (Figure 1). If WRG was driving the prokaryotic community structure within

	Pairwise Comparisons		R^2	Pr(>F)	Pairwise Comparisons		R^2	Pr(>F)
Bacterial and archaeal communities	AB.B	CL.B	0.364	0.003*	LL.B	MNF.B	0.097	0.05
	AB.B	LL.	0.226	0.097	LL.B	NOOK.B	0.116	0.022*
	AB.B	MNF.B	0.142	0.005*	LL.B	WM.B	0.092	0.068
	AB.B	NOOK.B	0.146	0.006*	LL.B	WWWT.B	0.087	0.072
	AB.B	WM.B	0.126	0.01*	MNF.B	NOOK.B	0.022	0.932
	AB.B	WWWT.B	0.149	0.004*	MNF.B	WM.B	0.033	0.773
	CL.B	LL.B	0.079	0.044*	MNF.B	WWWT.B	0.139	0.006*
	CL.B	MNF.B	0.026	0.894	NOOK.B	WM.B	0.038	0.645
	CL.B	NOOK.B	0.030	0.826	NOOK.B	WWWT.B	0.165	0.002*
	CL.B	WM.B	0.041	0.615	WM.B	WWWT.B	0.133	0.008*
	CL.B	WWWT.B	0.137	0.006*				
	Pairwise Comparisons		R^2	Pr(>F)	Pairwise Comparisons		R^2	Pr(>F)
Fungal communities	AB.B	BR.B	0.184	0.002*	LL.B	MNF.B	0.170	0.003*
	AB.B	LL.B	0.065	0.428	LL.B	NOOK.B	0.095	0.104
	AB.B	MNF.B	0.111	0.024*	LL.B	PUD.B	0.099	0.073
	AB.B	NOOK.B	0.080	0.166	LL.B	WM.B	0.060	0.492
	AB.B	PUD.B	0.060	0.54	MNF.B	NOOK.B	0.159	0.001*
	AB.B	WM.B	0.050	0.692	MNF.B	PUD.B	0.162	0.006*
	BR.B	LL.B	0.189	0.001*	MNF.B	WM.B	0.147	0.006*
	BR.B	MNF.B	0.223	0.001*	NOOK.B	PUD.B	0.066	0.416
	BR.B	NOOK.B	0.162	0.002*	NOOK.B	WM.B	0.101	0.079
	BR.B	PUD.B	0.164	0.002*	PUD.B	WM.B	0.058	0.559
	BR.B	WM.B	0.185	0.001*				
*denotes significant P-values								

Table 1. PERMANOVA pairwise comparisons of microbial communities.

CSPC, DBC, and RCCR, then microbial communities at DBC-CL and RCCR-WWWT would have been similar and DBC-LL would have a unique microbial community, which was not observed (Table 1).

Baseline Fungal Community Analysis

Previous analyses of fungal beta-diversity measurements from sites in CSPC and DBC indicated that sites within CSPC had significantly different beta-diversity than sites within DBC (Carmichael et al. 2015). Beta-diversity of fungal communities before stimulation showed some differences according to PERMANOVAs calculated with the Bray-Curtis index ($P < 0.05$), though there appeared to be no difference between beta-diversity at sites between caves (Table 1). The similarity in fungal beta-diversity across all sites suggests that WRG does not drive fungal community structure (Figure 1). It is possible that fungal community structure is dependent on another abiotic factor like pH or moisture (Zhang et al. 2016).

Carbon Stimulations

Incubated carbon sources chosen for this study stimulated biotic Mn(II) oxidation at multiple sites within CSPC, DBC, and RCCR, with the exception of the organic acid enrichments supplemented with Cu(II) and yeast extract. Bacterial growth was not visibly observed on or around any plates *in situ*. Fungal Mn(II) was stimulated with glucose and malt extract and was also stimulated with glucose and malt extract that was supplemented with Cu(II).

Mn(II)-oxidizing Isolates

Axenic cultures were isolated from caves CSPC, DBC, and RCCR. Most of the Mn(II)-oxidizing isolates obtained had been previously isolated from either CSPC or DBC

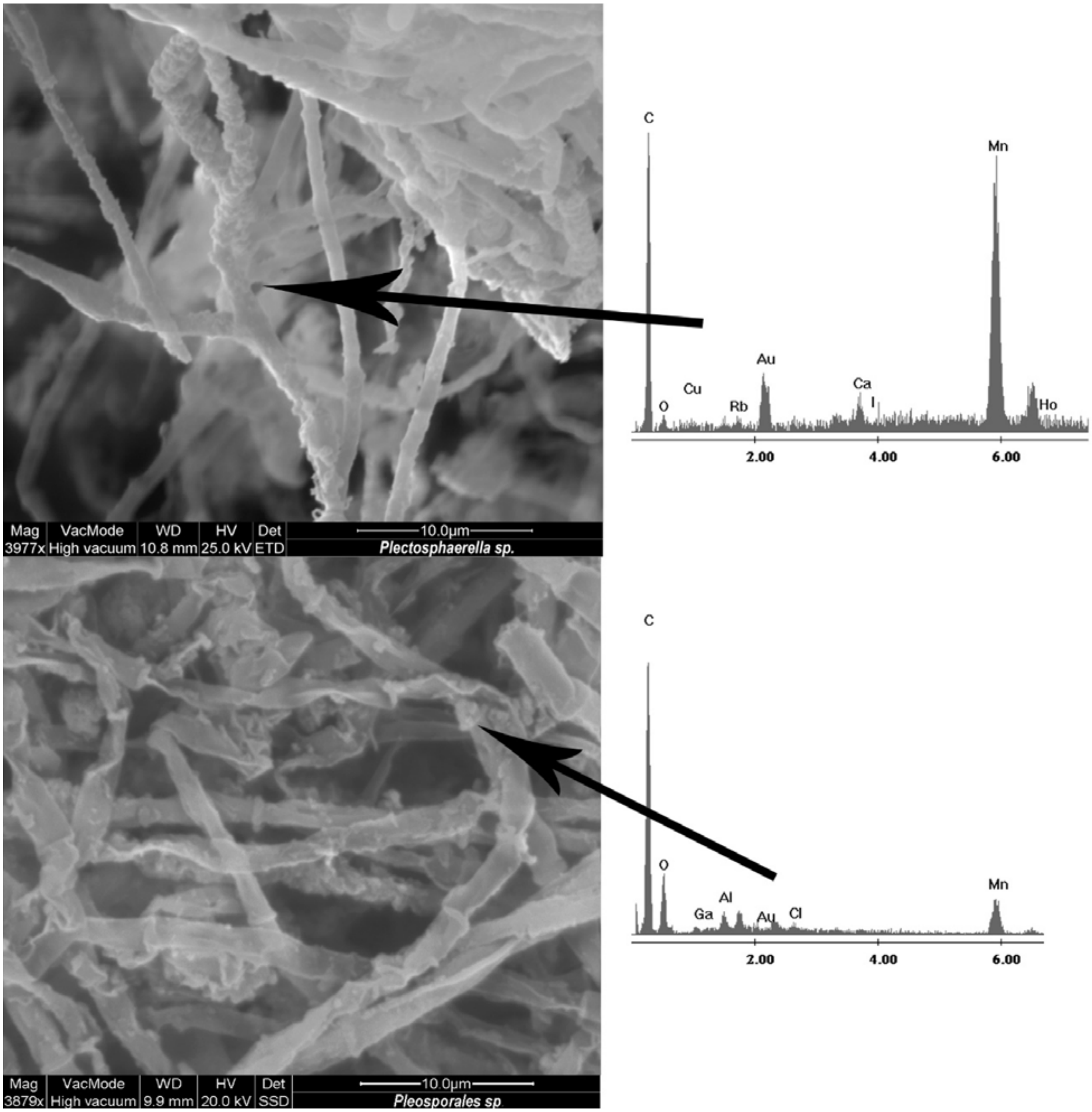

Figure 2. SEM images of Mn(II)-oxidizing* Plectosphaerella sp. (top) *and* Pleosporales sp. (bottom) *isolates from CSPC-MNF. EDS elemental analysis shows Mn(III/IV) oxides associated with the fungal hyphae.

(Carmichael et al. 2013b; Carmichael et al. 2015). One new Mn(II)-oxidizing fungi was isolated with citrate agar from CSPC-MNF and is 99% identical to *Trichosporon spp*., which belongs to the Tremellales order and Basidiomycota phyla. This *Trichosporon spp.* is the first Mn(II)-oxidizing Basidiomycete isolated from subterranean habitats (see review by Carmichael & Brauer 2015). SEM images of the Ascomycotal fungi were taken from Mn(II)-oxidizing isolates and EDS analyses confirmed the presence of Mn(III/IV) oxides associated with the fungal hyphae (Figure 2).

Biotic Mn(II) Oxidation vs. Abiotic Factors

The role that copper plays in the enzymatic oxidation of Mn(II) *in situ* has yet to be determined. MCO catalyzation of Mn(II) oxidation is stimulated with ≤ 180 μM Cu(II) (El Gheriany et al. 2011) and superoxide catalyzation is inhibited with 100 μM Cu(II) (Hansel et al. 2012). For this study, carbon sources supplemented with 100 μM Cu(II) aimed at stimulating bacterial Mn(II) oxidation inhibited Mn(II) oxidation *in situ*, whereas the same carbon sources without Cu(II) promoted oxidation suggesting that bacterial

Mn(II) oxidation is occurring via superoxide production and not MCOs. Fungal Mn(II) oxidation was stimulated with 100 μM Cu(II) supplemented malt extract or glucose suggesting that the fungal species oxidizing Mn(II) are most likely using MCOs and not superoxide. This hypothesis is supported by the presence of Mn(III/IV) oxides associated with the cell wall of fungal hyphae observed on the Mn(II)-oxidizing isolates from this study (Figure 2).

One site in CSPC, site BR, was expected to promote fungal Mn(II) oxidation due to the observable presence of fungal hyphae in response to simple sugar treatments. BR was the only site where fungal growth was observed and Mn(II) oxidation was negative. BR was originally chosen as a study site due to the presence of Mn(III/IV) oxides on a bottle rocket (BR). Geochemical analyses performed at BR showed increased concentrations of Sr which are common ingredients for bottle rockets, leading to the hypothesis that Sr may be inhibiting biotic Mn(II) oxidation. However, Mn(II)-oxidizing fungal isolates did not lose their ability to oxidize Mn(II) in the presence of Sr in *in vitro* experiments, which may indicate that Sr does not inhibit biotic Mn(II) oxidation or that Sr inhibits specific Mn(II)-oxidizing biotic reactions but not others (i.e. MnP vs superoxide).

Conclusion

Previous *in situ* research has focused on factors that may affect the Mn(II)-oxidizing ability of a single, isolated species, whereas this research has identified environmental parameters that may be affecting the Mn(II)-oxidizing capability of entire microbial communities. By combining results from previous *in vitro* studies, this research was able to elucidate the mechanistic pathway in which microbes are actively oxidizing Mn(II) *in situ*. This research has important implications for groundwater health and the health of cave ecosystems, specifically those that are in urban areas or are used as show caves, as Mn(II) oxidation may be used as an indicator of contamination.

Acknowledgments

The authors thank Dr. Sarah Carmichael for her assistance with geochemical analyses, Dr. Mike Madritch and Michael A. Carson for assistance with sequencing, and Michael Rojas-Steinbrecher, Andrew Hughes, Javier Cattle, and Jacob Montgomery for field assistance. Partial support was provided by the Philip M. Smith Graduate Research Grant for Cave and Karst Research and the Appalachian Women Scientists Research Grant.

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Quantifying Parameters of Climate Variability on Soil and Speleothem Carbon Isotopes

Coupling Modern Cave Monitoring with a Multicomponent Reactive Transport Model

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Introduction

Karst systems provide an exceptional window of observation into the processes that occur in the critical zone (CZ), the near-surface zone where interactions among rock, soil, water, air, and living organisms occur. Caves allow subsurface monitoring of the water that has been altered by interactions with vegetation, soil, regolith, and bedrock over a range of length and timescales. Speleothems formed by these waters serve as long-term archives of these CZ interactions. Through modern observations over seasonal and interannual time-scales, a framework for understanding speleothem proxy variability can be constructed. However, extrapolating this short-term understanding to interpret the long-term changes recorded by speleothems can be challenging. I present here the initial develops of a reactive transport model to simulate the transformation of carbon in a karst region to determine the environmental controls on speleothem carbon records. A successful application would then allow for improved carbon isotope interpretations in paleoclimate research. Speleothem $\delta^{13}C$ is underutilized in the paleoclimate community due to the multiple environmental factors that might influence it; however, it holds a potential for recording changes in hydroclimate, vegetation, soil respiration, and/or chemical weathering in the CZ if properly constrained (e.g., Dorale et al., 1998; Genty et al., 2003; Oster et al., 2009; Polyak et al., 2012).

One method of gaining an understanding of factors controlling drip water and speleothem $\delta^{13}C$ is by monitoring radioactive carbon (^{14}C). ^{14}C is continually produced in the upper atmosphere by cosmic ray interaction with ^{14}N. As the carbon is incorporated into the soil, it begins to decay. As the half-life of ^{14}C is relatively short (5730 years), after ~50,000 years following exchange with the atmosphere, a carbon deposit is considered to be "radiocarbon dead." Determining the percentage of dead carbon in soil water or gas and cave drip water reveals insight into water interaction with sub-surface carbon pools. In a cave system, there are three carbon pools that can alter both the $\delta^{13}C$ and ^{14}C of dissolved inorganic carbon (DIC): atmosphere, soil respired CO_2 (microbial or root-induced), and limestone (host rock). Atmospheric carbon will carry a modern ^{14}C value, whereas soil respired CO_2 will vary as a function of the turnover rate of soil organic matter above the cave allowing multiple pools/ages to exist, and limestone will typically be radiocarbon dead (Genty et al., 2001; Noronha et al., 2015). By comparing the ^{14}C of deep soil gas to the atmospheric ^{14}C value, one can verify if soil respired CO2 at a specific depth is dominated by a young or old carbon pool. In karst environments, the $\delta^{13}C_{DIC}$ in drip water, and thus the carbon in speleothems, can be influenced by dissolution of host limestone, and input from deep roots or old organic matter, providing a mixture of young, old, and radioactively dead carbon (Breecker et al., 2012; Genty et al., 2001; Noronha et al., 2015; Oster et al., 2010). If the deep soil gas is young, one can quantify the amount of host limestone contribution to the DIC pool through measurements of ^{14}C in cave drip water DIC (Frisia et al., 2011). The amount of host limestone dissolution can cause fluctuations in the $\delta^{13}C$ signature, as limestone tends to have a $\delta^{13}C$ value close to 0‰.

This on-going project integrates high temporal resolution observations and measurements of a modern cave system with an isotope-enable reactive transport model to provide an improved understanding of the controlling factors of carbon isotopes in speleothems. CrunchTope, the isotope-enabled module of the reactive transport model (RTM) CrunchFlow, is under development to contain the ability to run the three-isotope carbon system (^{12}C, ^{13}C, and ^{14}C) with simultaneous ^{14}C decay in both fluid and solid phases. The model development is the focus of collaborative work being completed with Dr. Jenny Druhan and students at the University of Illinois, Urbana-Champaign. Data collected from an on-going, multi-year modern monitoring project at Blue Spring Cave, TN is utilized as a calibration method in model development. The initial model is parameterized with soil and host rock chemical and mineralogical properties and validated with annually averaged cation concentrations of waters from two drip sites within the cave to determine the appropriate thermodynamic, kinetic, and flow rates. Isotope validation will be completed with monthly $\delta^{13}C_{DIC}$ and seasonal ^{14}C signatures measured in drip water along different flow paths within the system. Once the model has been completely parameterized and validated at Blue Spring Cave, modifications to boundary conditions can be made to determine key controls (e.g., variations in seasonal precipitation, length of growth season—soil respiration, change in vegetation, etc.) on the evolution of $\delta^{13}C_{DIC}$ and ^{14}C in drip waters, and therefore speleothems, on multiple timescales. The ultimate goal of this on-going work is to provide a novel tool that can be used in various climate and temporal settings to investigate how carbon cycles in karst systems, and that will improve interpretations of speleothem $\delta^{13}C$ records.

Background

Blue Spring Cave—White County, TN

Blue Spring Cave (BSC) is a privately-owned cave located on the eastern edge of the Cumberland Plateau. It is the 11th longest cave in the US and the longest cave in TN. Over 60 km of cave passage has been extensively surveyed and georeferenced to the cave entrance, providing latitude/longitude coordinates and soil/rock overburden at multiple points. The cave is formed in the Mississippian Monteagle Limestone, and portions of the cave are overlain by Pennsylvanian sandstones and conglomerates (Matthews and Walter, 2000). The overlying sandstone serves as a confining layer to water seepage, causing the majority of the cave to remain dry, except along the edges of the hill slopes on the surface. Ongoing monitoring in the cave has been focused on the Cathedral Room, which is located on the edge of the sandstone cap layer and thus has actively dripping water and an abundance of actively growing speleothem formations.

The climate above BSC is classified as humid subtropical with hot summers and mild winters. Precipitation occurs throughout the year with a slightly drier period from Sept–Nov. The average annual precipitation at the nearest National Climatic Data Center monitoring site in Cookeville (~25 miles NW of BSC) from 1968 to 2012 was ~1410 mm/yr. Vegetation above the majority of the cave system, including the Cathedral Room, is mature deciduous hardwood forest. A pollen study, approximately 15 km northwest of BSC, provides a record from the present to 25 ka BP and suggests that during the Last Glacial Maximum (LGM), conifer forests dominated the area, with interspersed C4 grasses (Cyperaceae) between 25–19 ka BP (Liu et al., 2013a). After 19 ka BP, a quick die off of the grasses occurred with a slower (~3 ka) transition from conifer to deciduous hardwoods. Soils consist of clay loam on top of clay, weathered from the limestone and sandstone. Soil samples show that the majority of the soil carbon at BSC occurs as organic carbon, with minor inorganic input.

CrunchTope

CrunchTope is an isotope-enabled module of CrunchFlow, a thermodynamically and kinetically driven multi-component reactive flow and transport model that allows for discretization of the water flow path from the surface to the cave (Steefel et al., 2015). Recent applications to quantify the partitioning of both stable and radiogenic isotopes have led to improved comprehension of (bio)geochemical cycling through marine sediments (e.g., Dale et al., 2009; Maher et al., 2006a), secondary mineral growth (e.g., Druhan et al., 2013; Steefel et al., 2014), fluid transport and mechanisms of mixing (e.g., Druhan and Maher, 2014; Van Breukelen and Rolle, 2012), terrestrial weathering rates and mechanisms (e.g., Maher et al., 2006b), and contaminant fate and degradation pathways (e.g., Druhan et al., 2014; Wanner et al., 2014).

Two recent modifications of the software will enable quantitative description of the partitioning of carbon isotopes through the soil-epikarst-cave system and speleothem archive. The first is an isotope-specific modification of the Monod rate law (Rittmann and McCarty, 2001), initially applied to nitrogen isotope systems by Maggi and Riley (2009, 2010). The modification permits simultaneous runs of two isotopologues that are sensitive to microbial controlled redox reactions by the same biomass (e.g., sulfur isotopes—Druhan et al., 2012, 2014).

The second isotope-specific modification deals with the standard Transition State Theory (TST) rate law that treats dissolution and precipitation as reversible reactions at equilibrium. This modification in CrunchTope allows for solid precipitation incorporating multiple isotopologues of the same element by means of a solid solution model. These modifications then create an RTM capable of quantitatively simulating both stable carbon isotopes and radiocarbon in a unified framework.

CrunchTope Parameterization

A number of parameters need to be understood when setting up discrete layers within CrunchTope. These include mean free path length of water through the system, geochemistry of solids in each layer (e.g., mineralogy of soil layers and host rock), and residence time in the soil-epikarst layers. The minimal mean free path can be initially estimated by the depth of overburden above the cave, which is well constrained by the cave survey. Soils above the cave have been analyzed using quantitative XRD to determine the types and amounts of non-clay minerals. Epikarst flow regimes are also a complication when attempting to model such a system as flows can be a result of fracture or diffuse flow paths, or more likely a combination of the two. Models will be run with each end member (fracture vs diffuse) and an acceptable mixture of the two can be used to best fit our data.

Approach to Utilizing CrunchTope

Continuous monitoring of BSC was started in June 2013. Directly above the Cathedral Room location, there are soil temperature and moisture probes at two depths to constrain controlling factors on soil respiration rates and three depths of soil lysimeters and gas wells. Monitored cave parameters include air temperature, humidity, and CO_2 concentrations along the Cathedral Room route, and drip rate loggers at three locations. Soil lysimeter (n≈5) and cave drip waters (n≈8) were sampled monthly for $\delta^{18}O$, $\delta^{2}H$, $\delta^{13}C_{DIC}$, pH, and cation and anion concentrations. Drip locations that have different flow regimes, intermittent (fracture) and continuous (diffuse) flows, have been targeted to sample various flow path lengths through the soil and epikarst. Based on drip logger data and drip water $\delta^{18}O$ and $\delta^{2}H$ (Figure 1), continuous drips are hypothesized to be fed by a well-mixed diffused flow through a perched water table, while intermittent drips are more variable, similar to soil water samples. Additionally, intermittent drip water $\delta^{13}C_{DIC}$ samples are variable and closer to soil water $\delta^{13}C_{DIC}$ (average = −18.5‰), while diffuse locations are less variable (Figure 2). Seasonal ^{14}C samples have been collected since summer 2015 at the deepest lysimeter and four different drip sites, in addition to deepest soil gas and cave air samples. By initializing the CrunchTope model with the surface information, other parameters (e.g., flow rate, soil organic matter input, etc.) can be adjusted to create similar outputs as measured from cave drip waters of various rates, providing a best-fit model for new samples.

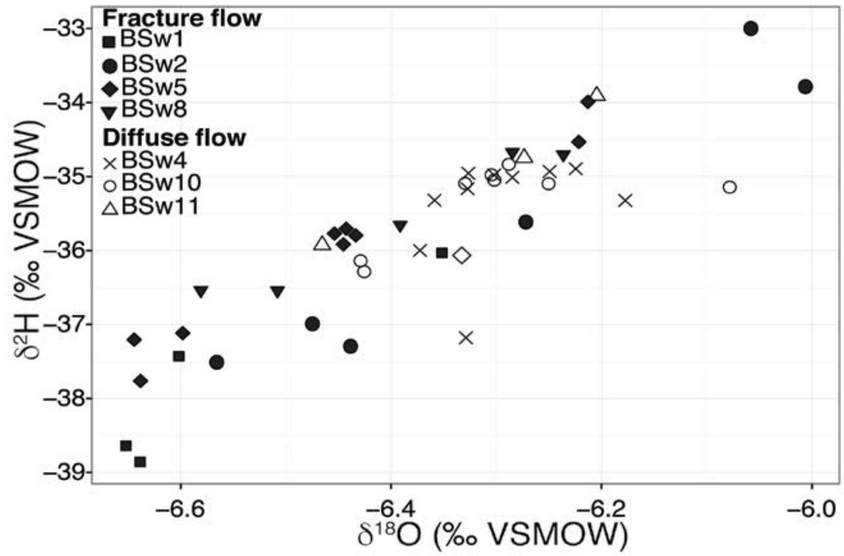

Figure 1. $\delta^{18}O$ and $\delta^{2}H$ for Blue Spring drip water labeled by drips believed to be fed by fracture (closed symbols) vs. diffuse flow (open symbols). Fracture flow drips show greater variability than diffuse flow drips.

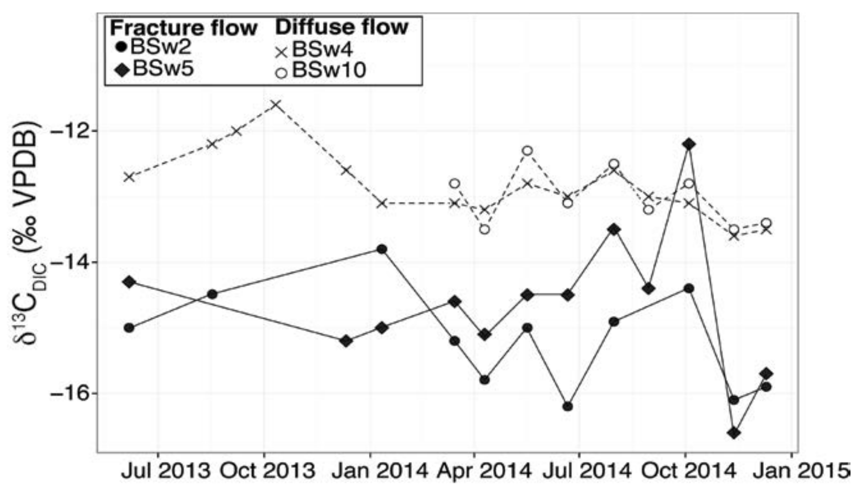

Figure 2. Monthly drip water $\delta^{13}C$ time series of fracture (closed symbols) and diffuse (open symbols). Fracture flow drips show greater variability than diffuse flow drips, and similar to average soil water $\delta^{13}C$ (-18.5‰).

Results

The goal of preliminary model development is to simulate water chemistry change due to the coupled fluid transport and water-mineral interactions in the limestone at BSC. The model is setup as a 1D domain of 12 m of limestone, the approximate overburden at the drip water sample locations. The limestone chemical composition is based on one sample from within the cave that was measured to be $Ca_{0.984831}Mg_{0.014477}Sr_{0.00691}Ba_{0.000001}CO_3$. The initial input fluid composition was calculated by averaging the annual precipitation from the three closest locations around BSC (Bristol, TN; Bowling Green, KY; Jason, TN; NADP database), with a pCO_2 reflecting equilibration at a pH of 5.3 and is allowed to infiltrate the model at a steady flow rate. The dissolved $[Ca^{2+}]$ as a function of depth from the

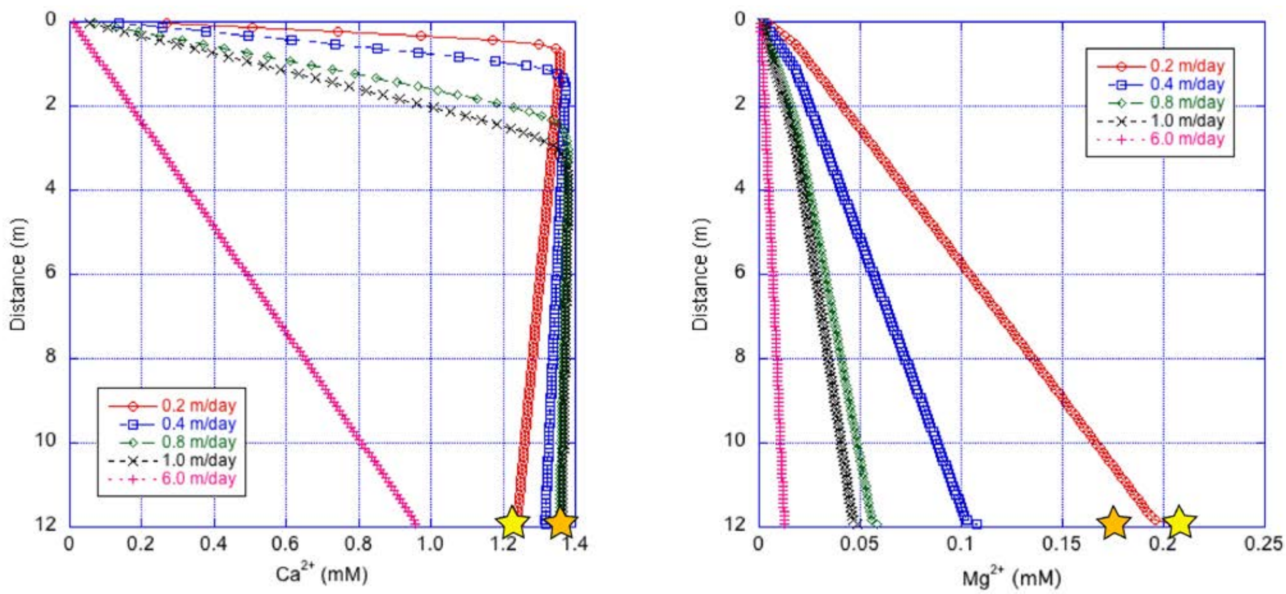

Figure 3. 1D model representing BSC with dilute atmospheric fluid infiltrating 12m of limestone resulting in concentration profiles of Ca^{2+} (A) and Mg^{2+} (B) varying with flow rates. Orange stars represent annual average concentrations at a fracture flow drip and yellow stars represent annual average concentration at a diffuse flow drip.

surface (0 m) to 12 m, demonstrates the balance of rapid dissolution of limestone followed by precipitation of pure calcite. The turning point is a function of fluid transport and signifies the point at which precipitation of calcite removes more Ca^{2+} than can be dissolved from the limestone. The annual average [Ca^{2+}] of a diffuse drip site (yellow star) and intermittent (fracture) drip site (orange) is marked on Figure 3A, and show good agreement with the modeled concentrations. Modeled drip water [Mg^{2+}], Figure 3B is inversely correlated with [Ca^{2+}] as concentrations increase with slower flow rates (i.e., increased residence time).

Conclusions

The Cave Research Foundation grant was instrumental in the initial efforts to gather the data necessary to parameterize the preliminary model. Model development from this research is an on-going effort to fully integrate carbon isotopes. However, from this initial step, the annual averages of the [Mg^{2+}] in measured drip waters are not in agreement with the model, suggesting that the addition sampling of the limestone within the cave is needed to properly characterize the chemistry of the limestone. Further characterization of the host rock, as well as precipitated calcite (soda straws) from inside the cave, is part of the on-going efforts of this project.

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Using Geochemical and Isotopic Data to Partition Sources of Groundwater in Epigenic Karst Aquifers

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Abstract

Epigenic karsts are characterized by surface and subsurface development features (such as sinkholes, springs, caves, and losing, sinking, underground streams) and strong hydrological connections with the surface (Ford & Williams 2007; White 1988). For decades, epigenic karst aquifers have been known to be more vulnerable to surface contaminants than non-karst aquifers. Therefore, they have raised specific concerns for water managers in terms of water quality and water resource protection (Brahana et al. 2014; Mull et al. 1988). In addition, the recent widespread use of confined animal feeding operations (CAFOs) facilities on epigenic karst terrains have raised new concerns about the vulnerability of karst aquifers (Brahana et al. 2014).

This study focuses on Grayson-Gunnar Cave (GGC, Figure 1), an 11-km-long cave system in the Cumberland Plateau of Southeastern Kentucky. The regional lithology consists of Mississippian carbonates capped by Pennsylvanian clastic rocks (Figure 2). The cave is developed in the St. Louis formation (red arrow). Surveyed passages in GGC include two branches of an underground stream with strong connections to surface input–epigenic karst aquifer. The south branch of this watershed includes low-density grazing and residential septic tanks. The north branch includes a CAFO.

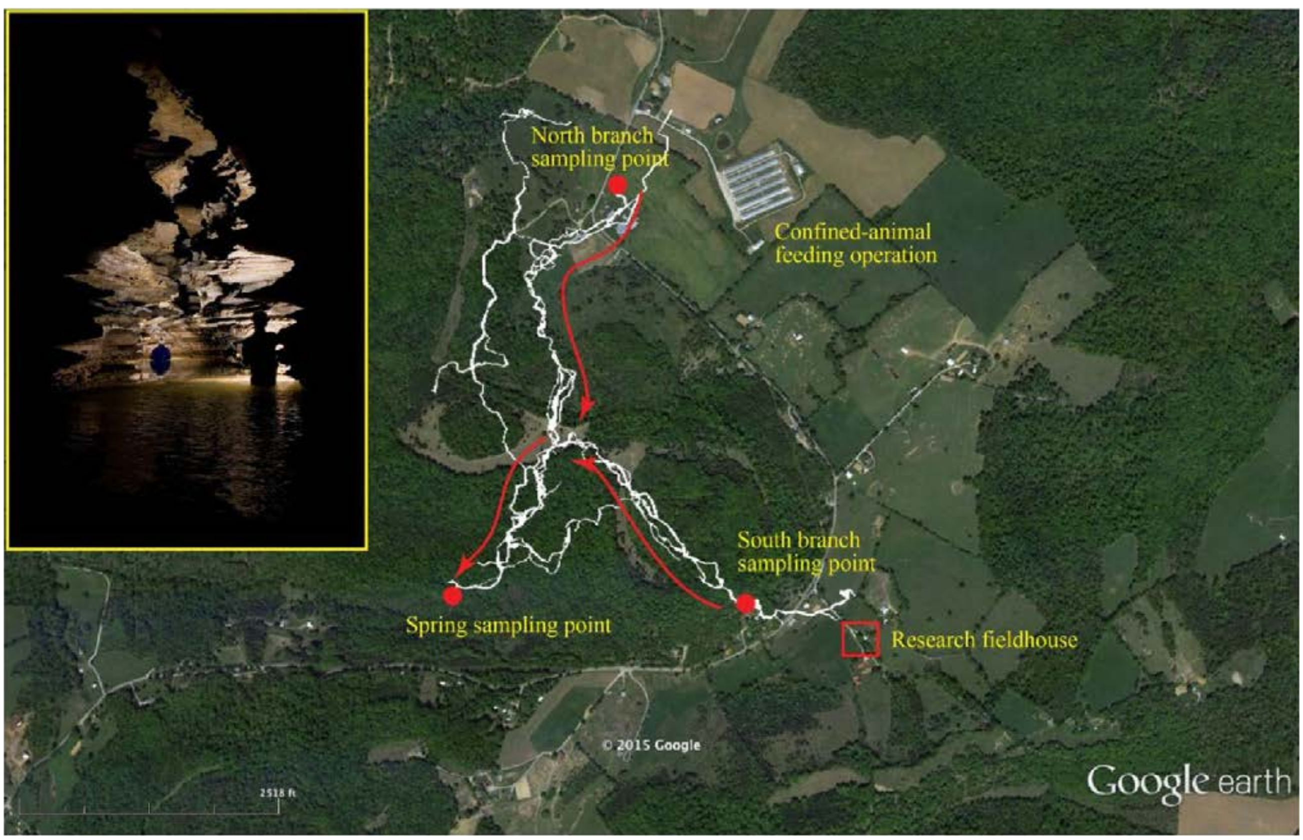
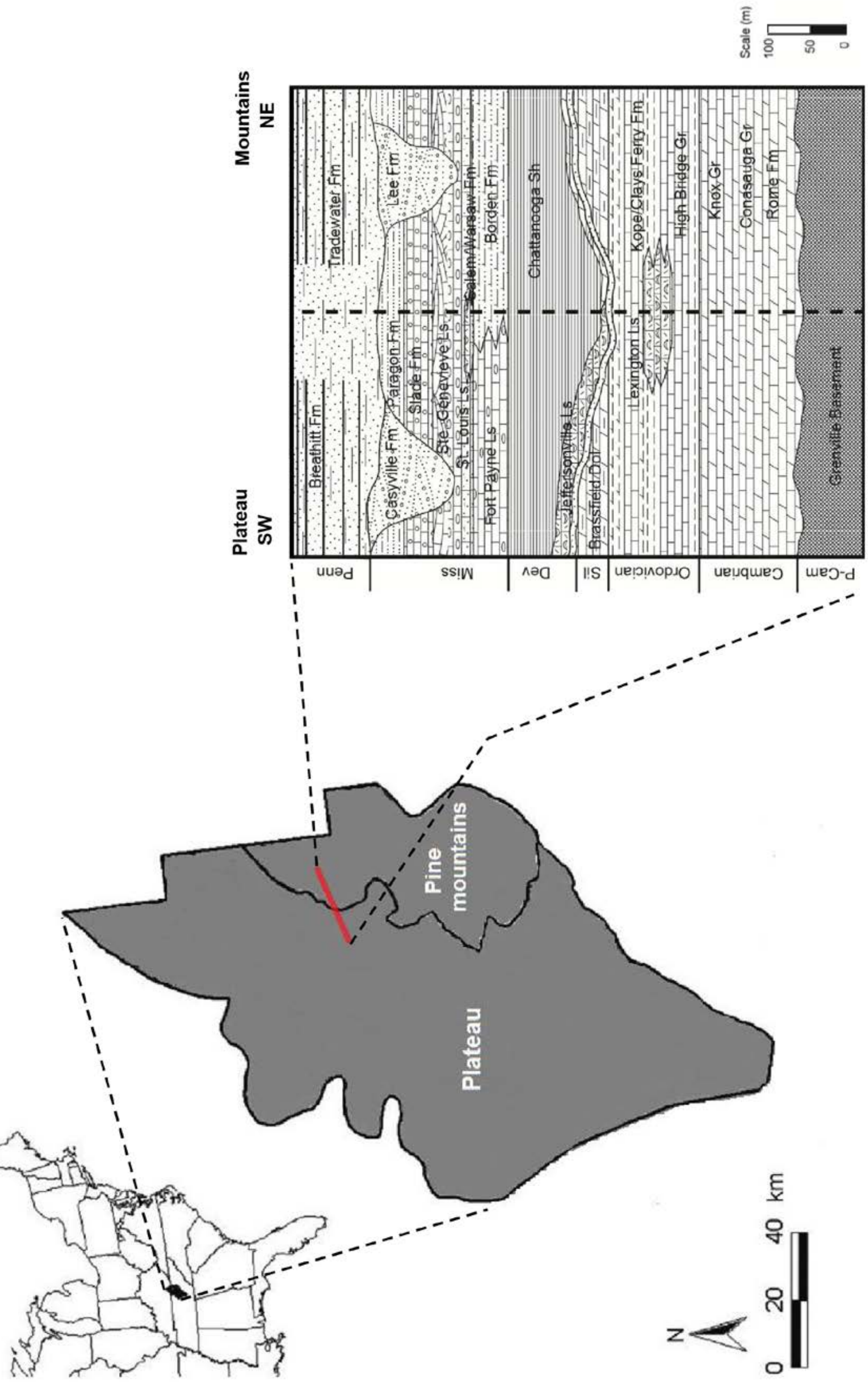


Figure. 1. Surveyed passages of GGC in white. Yellow dots are dye injection sites. Red arrows are expected groundwater flow paths. Blue dots are activated charcoal packets deployment sites.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Ordovician
Cambrian
P-Cam
Breathitt Fm
Tradewater Fm
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Paragon Fm
Lee Fm
Slade Fm
Ste. Genevieve Ls
St. Louis Ls
Salem/Warsaw Fm
Fort Payne Ls
Borden Fm
Chattanooga Sh
Jeffersonville Ls
Brassfield Dol
Lexington Ls
Kope/Clays Ferry Fm
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Knox Gr
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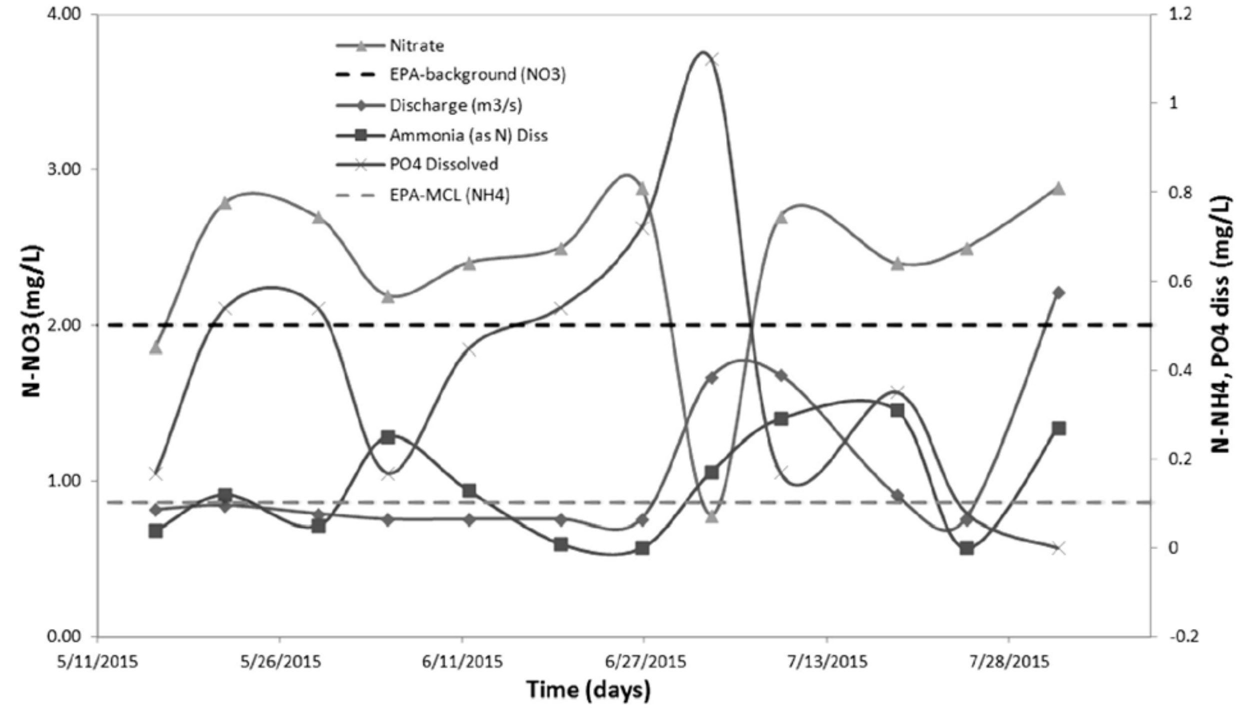

Figure. 3. Concentrations of nitrate, ammonia and phosphate measured from weekly samples at GGC spring and plotted with discharge. The horizontal dashed lines represent EPA standards for nitrate (black) and phosphate (gray).

This research comprises two related objectives in the study of the GGC system: 1) to assess its connectivity with potential point sources of anthropogenic contamination (septic systems and CAFOs), and 2) to determine the fate and travel time of nutrients within the cave. The results from this study will provide a greater understanding of the critical zone, deeper groundwater, and the impact of changing land use on epigenic karst aquifers in the Cumberland Plateau.

Preliminary Results

Nitrogen and phosphate are elevated as expected (Figure 3). Nitrate concentrations are more dilute during storm events, but phosphate levels increase due to the mobilization of sediment substrates. Dissolved organic carbon concentrations spike during storm events (Figure 4) and, combined with Specific Ultra-Violet Absorbance values, suggests the rapid transfer of organic matter from the land surface with limited degradation. Seasonal variations in carbon isotopes composition (Figure 5) reveal the combination of various sources of organic carbon, highly depleted sources in the fall (fertilizers and dead leaves) and less depleted sources by the end of the summer (growing crops-corn, and animal wastes).

Preceding page: ***Figure. 2. SW to NE stratigraphic cross section along the Cumberland Escarpment (Simpson & Florea 2009).***

Conference Publications

Tagne, G., Florea, L.J., 2016. Anthropogenic nutrient transfer within an epigenic karst aquifer in south-central Kentucky. Geological Society of America Abstracts with Programs, vol. 48, no. 7.

Tagne, G., Florea, L.J., 2016. Anthropogenic contamination of cave groundwater in Southeastern Kentucky. Ball State University Student Symposium. Ball State University.

Tagne, G., Florea, L.J., 2016. Using nutrient data and dye tracing to infer groundwater flow paths and contaminant transfer time in Grayson-Gunnar Cave, Monticello, KY. AgroEnviron 2016: 10th International Symposium on Agriculture and the Environment. Purdue University.

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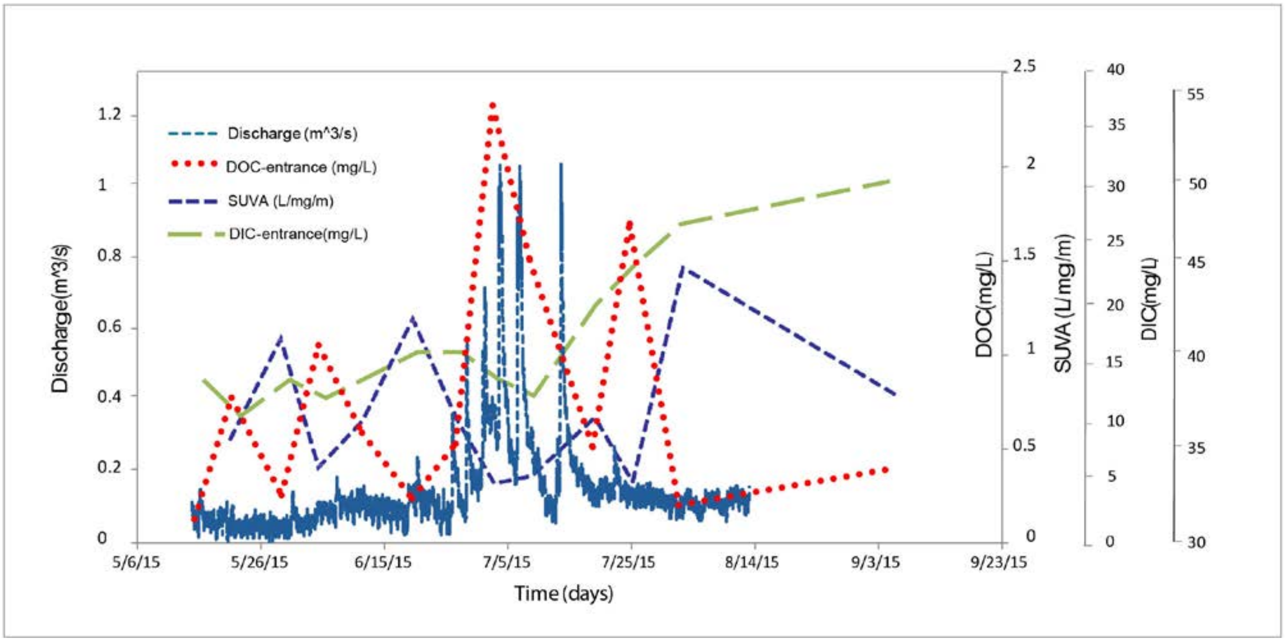

Figure 4. Dissolved Organic Carbon concentrations, Dissolved Inorganic Carbon concentrations, and Specific Ultra-Violet Absorbance values as measured from weekly samples at the GGC spring from May to August 2015.

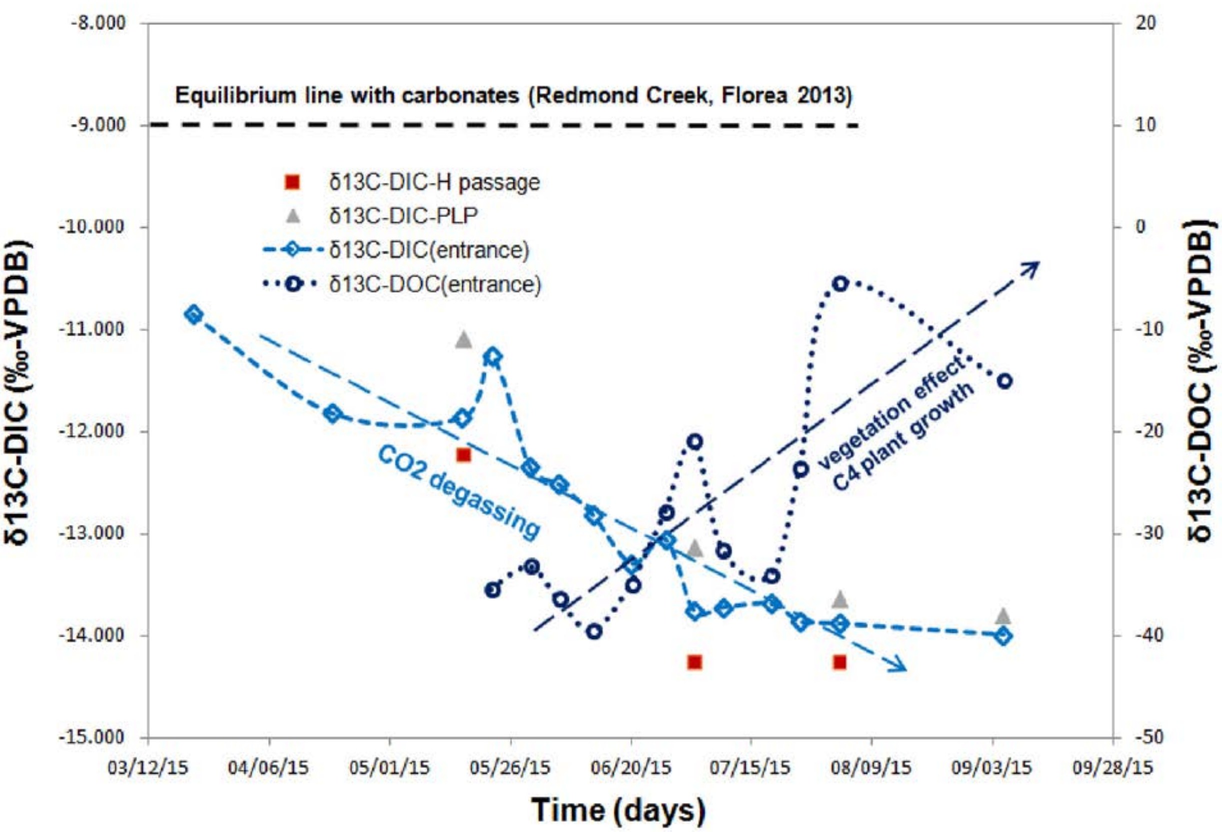

Figure 5. Dissolved Organic Carbon isotope (δ^{13}C-DOC) and Dissolved Inorganic Carbon isotope (δ^{13}C-DIC) as measured from weekly samples at the GGC spring from May to August 2015.

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