



# **Cave Research Foundation**

**Annual Reports**  
**1998-2000**

The Cave Research Foundation (CRF) is a private non-profit organization, incorporated in 1957 under the laws of the Commonwealth of Kentucky. Its purpose is to:

- facilitating research, management and interpretation of caves, and karst resources
- forming partnerships to study, protect and preserve cave resources and karst areas
- promoting the long-term conservation of caves, and karst ecosystems

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*Cover photo: Stream passage in Fitton Cave, Arkansas*  
*Photo by Scott Dankof*

# Annual Reports

## 1998-2000

**Cave Research Foundation  
177 Hamilton Valley Road  
Cave City, Kentucky 42127**

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# **Cave Research Foundation Activities 1998**

## **Cave Research Foundation Directors**

**1998**

Patricia Kambesis  
President

Rick Toomey  
Fellowships and Grants Program

Paul Cannaley  
Treasurer

Dick Maxey  
(beginning October 1998)  
Hamilton Valley Project

Peter Bosted  
Secretary

Chuck Pease  
International Projects

Phil DiBlasi  
National Personnel Officer

Bob Osburn

Roger McClure  
(through September 1998)

Chris Groves  
Fellowships and Grants Program

## **Operations Council**

Arkansas Operations Area: Pete Lindsley

Eastern Operations Area : Dave West

Southwestern Operations Area : Barbe Barker

Lava Beds Operations Area : Janet Sowers

Missouri Operations Area: Scott House

Sequoia Kings Canyon/Mineral King  
Operations Area: John C. Tinsley

# 1998 Highlights *Compiled by Patricia Kambesis*

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## CRF's Ancient Cavers Reunion

To commemorate the 40th anniversary of the Foundation, and the 25th anniversary of the Flint-Mammoth connection, CRF held an Ancient Cavers Reunion, on the weekend of November 27, 1998. One hundred and twenty of CRF's "ancient cavers" attended the weekend to reminisce about the beginnings of CRF and to recall the now famous Flint Ridge-Mammoth connection. Tours of the Hamilton Valley property were conducted by members of the Building Committee. Sarah Bishop, past president (#8), was the keynote speaker at a banquet at Park Mammoth. She gave a wonderful talk on the past, present, and future of CRF. Live musical entertainment followed by some of the CRF's musically inclined ancient cavers.

The 64th Annual Meeting of the Cave Research Foundation took place in Carlsbad, New Mexico in October. Dave and Carol Belski hosted a pre-meeting social. Meeting space was generously provided by Jim Goodbar on behalf of the BLM at their Carlsbad Office. In addition to the Board and Operations Council closed meetings, there was also an open Members' Meeting which featured reports from our various operations managers and talks by Dale Pate and Jason Richards of the Cave Resource Office, Carlsbad Caverns National Park.

## Personnel changes on the Board and Operations Council

In September of 1998, Peter Bosted was elected to fill the director and secretary positions vacated by Dr. John Tinsley in November of 1997. Bosted is a longtime member of CRF and the Chief Cartographer for the Lilburn Cave Project.

Rick Toomey and Chris Groves will take over the administration of CRF's Fellowship and Grants program.

At the end of 1997, Mike Yocum stepped down as the Operations Manager for our Eastern Operation

Area. During his time as EOM, Mike restructured and reorganized some of the administrative workings of Eastern Operations. In addition, he renegotiated the current "Memorandum of Understanding" with Mammoth Cave National Park. Mike brought a sense of professionalism and organization to Eastern Operations and his efforts are greatly appreciated.

In March of this year, the Board appointed Dave West as Eastern Operations Manager. Dave is a longtime CRF member, expedition leader, cartographer, and trip leader at Mammoth Cave. The board believes that his expertise and experience as a project and expedition caver both within and outside of CRF along with his laid back style, balanced with a solid sense of professionalism, make him an excellent choice for EOM.

In November of 1998, Roger McClure resigned from the CRF Board. Roger was on the board for 21 years and was the treasurer for 18 of those years. During his tenure as director and treasurer, his service to the Board was exceptional. He was instrumental in getting CRF on sound financial ground. He accomplished this by helping establish an Endowment Fund, and by running a campaign for contributions to that fund. Over the years, those contributions were invested and as a result the Endowment fund grew to \$250,000. \$100,000 of that has been used over the years for CRF's Grants and Fellowships program and to provide some of the money needed to buy the Hamilton Valley property. That Fund still has approximately \$150,000 to support Foundation Programs. Along, with Red Watson, Roger created Cave Books, CRF's publishing affiliate. Many books have been published over the years and the operation continues to grow. Its profits are used to support Foundation Programs and publish other cave related books. Roger will continue to be involved with CRF's Hamilton Valley project and will also oversee the Land Management Committee.

### **Hamilton Valley Ground-Breaking**

Ground was broken for the Hamilton Valley Project on Thursday, May 21, 1998. A team of CRF volunteers labored in inclement weather for the next two days to excavate a trench for the footer of a utility building. The Hamilton Valley Building Committee, chaired by Dick Maxey, offered to donate time, labor and materials to build the utility shed on the Hamilton Valley Property. The ground breaking was a significant step forward toward seeing the CRF Headquarters and Research Center become a reality. (Work crew: Roger McClure, Richard Zopf, Joyce Hoffmaster, Daniel Gregor, Dick Maxey, Cheryl Early, Rick Toomey, Dave Hanson, Gordon Smith, Jim Borden, Lacie Braley, Patty Daw).

### **Lava Beds Research Center**

Janet Sowers, Operations Manager for the Lava Beds National Monument area in California, reports that they have entered into a Memorandum of Agreement with the National Park Service, and the Lava Beds History Association, to raise funds to help construct a research facility for the National Park Service at Lava Beds. CRF will raise the funds and enlist the expertise to complete the design, construction, and furnishings for the Research Center. They will then donate the completed facility and all related improvements to the National Park Service. The facility will be used to provide work and meeting space and housing for researchers at Lava Beds National Monument. The project is currently in the planning stages.

### **Friends of Karst and the International Geological Correlation Program Conference**

CRF participated in a joint meeting of the Friends of the Karst and The International Geological Correlation Program Project 379: "Karst Processes and the Global Carbon Cycle". The meeting took place on September 23-25, 1998, at Mammoth Cave, Kentucky. The conference included two days of presentations on all aspects of karst science with an emphasis on the role of karst in the global carbon cycle. There were 130 people in attendance and 19 countries represented. The conference attracted many of the world's leading karst

scientists. Seventeen CRF members and fellows attended, seven who were invited speakers. There were a number of field trips held during the conference. Roger McClure and Derek Ford led a "Geology and Speleogenesis of Flint Ridge" trip through Crystal Cave and near the Austin entrance. Roger Brucker, Steve Worthington and John Mylroie led a similar geology trip to Cascade Hall. From the Austin Entrance, Art Palmer, Peg Palmer, Richard Zopf and Tom Brucker led the "Geology of the Mammoth-Flint Ridge Connection" trip.

CRF made significant contributions to the meeting's success in a number of ways including providing travel support for Drs. Camille Ek and Zaihua Liu. Professor Ek, from the University of Liege, Belgium, is well known for his many contributions to the understanding of CO<sub>2</sub> dynamics in karst. Dr. Liu is the assistant director of the Karst Dynamic Laboratory at the Institute of the Academy of Geological Sciences in Guilin, China. The travel support provided the meeting participants the opportunity to interact with these scientists and established bonds that will be helpful for CRF work in south China and potential work in Europe.

### **CRF Session at the 1998 NSS Convention**

CRF made an "official" appearance at the NSS Convention in Sewanee, Tennessee. An open session, held on Friday afternoon of convention week, featured ongoing research, restoration, exploration, survey and cartographic projects from our various operation and project areas. Chris Groves started off the session with a paper (coauthored with Joe Meiman, NPS), overviewing projects in the Mammoth Cave area which are being conducted in cooperation with the National Park Service. Bill Howcroft presented the current results of his research entitled "Statistical and Fractal Characteristics in the Redwood Canyon Karst aquifer, Tulare County, California." Peter Bosted did an excellent talk on the history and current status of the Lilburn Cartography Project (California). Ian Baren reported on the 1998 China Cave Project Exchange. From CRF West, Barbe Barker, area manager, talked about restoration/conservation philosophies and projects that are ongoing at Carlsbad Caverns National Park.

Bill Frantz gave a presentation on lava tube inventory at Lava Beds National Monument. The highlight of his talk was a virtual cave display that he and Peri Frantz are developing for educational and resource management in Lava Beds. The session was well received not only by those unfamiliar with CRF activities, but also by CRF members who now have a broader perspective on what goes on in all of our operation areas and projects.

### **1998 Joint Mammoth Cave/CRF Science Conference**

The Mammoth Cave/CRF Science Conference is a multi-disciplinary conference that has become an excellent forum in which park and area researchers provide update on their projects and exchange ideas. This year's conference was held at the Park's training center on July 31, 1998, in conjunction with CRF's Summer expedition (July 31-August 2, 1998). Superintendent Ronald Switzer, and Jerry O'Neal, Chief of Resource Management, welcomed participants to the conference. The agenda featured 13 presentations along with discussions that spanned ecology, archeology, paleontology, cultural resources, and cave conservation and management.

### **China Caves Project and Exchange**

During the summer of 1997, CRF sponsored four Chinese karst researchers during the month of June. They attended the NSS Convention in Missouri and were hosted by CRF and NSS cavers during their stay. In the spring of 1998, Ian Baren led an exchange expedition to Guizhou Province in south central China. Project participants included Ian, Paula Ledbetter, Peter and Ann Bosted, Roger Mortimer and Paul Massey. The expedition spent five weeks in the country, dividing its time between the Guado and Da Fong areas. Sev-

eral kilometers of cave were documented and surveyed, and many leads remain.

### **CRF Participation in Hawaii Projects**

This year, opportunities opened up for CRF participation in various ongoing projects on the Big Island of Hawaii. These opportunities would be in partnership with the Hawaii Speleological Survey. Current projects include resurvey of Kaumana Cave and potential work in Hawaii Volcanoes National Park.

### **CRF Website**

CRF went on-line with a new website this year. The site includes information about CRF, the various operation areas, and research projects. There are also separate pages on Cave Books, CRF membership information, a calendar of events, and a password-protected Members page. The URL for the Foundation website is: <http://www.cave-research.org>.

### **CRF Fellowships and Grants for 1998**

CRF did not award any research grants or fellowships for this year.

### **CRF Member Awards in 1998**

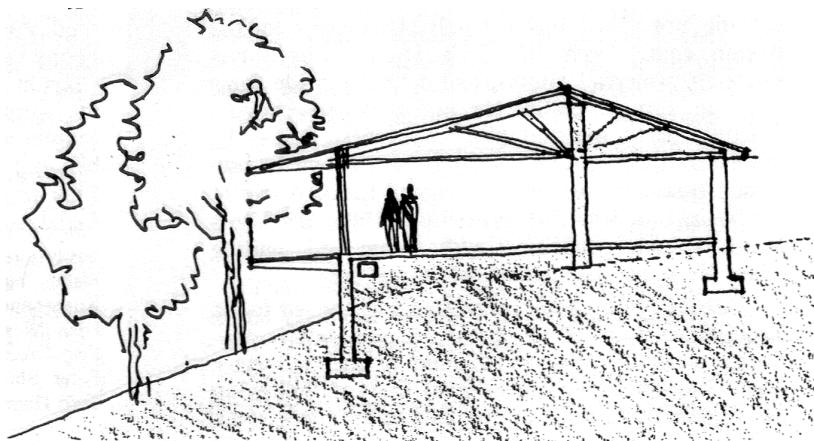
The following CRF members were named Fellows of the Foundation: Joe Meiman (KY), Ann Bosted (CA), and Paul Nelson (CA).

Certificates of Merit were awarded to Lynne Jesaitis, Merrilee Profitt, Bill Sawyer, and Tracy Van Eps.

# Hamilton Valley Project Update - 1998

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*Joyce Hoffmaster  
Hamilton Valley Building Committee*



The third incarnation of the Building Committee has been in existence and busy for over a year. The committee membership consists of Dick Maxey (Committee Chairman), Cheryl Early, Sheila Sands, Richard Zopf, Dave Hanson, and Joyce Hoffmaster. A presentation of the Committee's progress was made to the Board of Directors at the last annual meeting in November of 1997.

The Building Committee began with a set of plans designed several years ago by architect Ron Hemni and drawn by Volker-Winn, an architectural firm in Louisville. Efforts have concentrated on the main building (field house) because the restrooms and kitchen will be located in that structure. A great deal of thought went into this set of plans and hours have been spent picking at nearly every detail; the conclusion was reached that this is basically the facility that we need.

The total size of the main building is 3300 square feet which is about the size of many new homes. We have made a few changes, principally in the main room. The location of the proposed fireplace was moved from a short interior wall to a short exterior wall. This wall was also out 8 feet making the room size 20 by 57 feet. This room will seat 75 people for meals or to attend a lecture. Moving the wall did away with many of the windows on that end the building and the long exterior wall which was to have been mostly window; it will now have a solid knee-wall 32" high. This retains the

marvelous view of our nearly mile-long Hamilton Valley but eliminates the glass at floor level which just gets dirty and bumped.

The ceiling of the main room slopes from 8 feet on the exterior wall to nearly 18 feet at the interior wall which gives the space necessary for ventilation and comfort for a large group of people. The interior long wall of the main room has a row of clerestory windows close to the ceiling which will face the southwest and thus provide indirect natural lighting much of the day. The main building will also have a 20-foot x 20-foot work room which we ultimately see as map storage and display but which likely may be bunking space in the short term. The main building contains a commercial kitchen commensurate with the dining space in the main room, and a pantry. There are both men's and women's restrooms including showers, a smaller room designed as an office, and several storage closets of varying sizes and configurations. All floors will be concrete, and will be sealed and tinted to avoid the dismal gray. Walls will be finished in a combination of paneling and drywall although the restrooms will likely be tiled.

The only traditional Kentucky structure the size of this field station is a tobacco barn which is not really how we want to look. The design of all the buildings is contemporary yet incorporates traditional elements. The architect spent some time driving around looking at older

Kentucky buildings including the Crystal Cave ticket office before he designed our buildings. The low eaves and large porches of the field station are reminiscent of the ticket office. The clerestory windows are a very old way of lighting the upper part of large public rooms. The roof will be standing seam, another old material that has enjoyed a revival of popularity and has the virtue of lasting at least 50 years and often 100.

Though stone exterior was our preference, it was beyond our price range, so we settled for split face block. These are cement blocks that retain much of the appearance and low maintenance of stone but at a fraction of the cost. Besides the porches on the ticket office, both the Austin house and Spelee Hut had large covered outdoor areas which were heavily used in warmer weather. The legacy of these areas lives on in the large porches on the field house which protect the building from weather while they provide useful space for us.

This is a commercial-grade building and like it or not, they are more expensive than residences. Even if we decided to build a lesser structure, it must still meet commercial code which covers everything from wiring and plumbing to the spacing of porch railings.

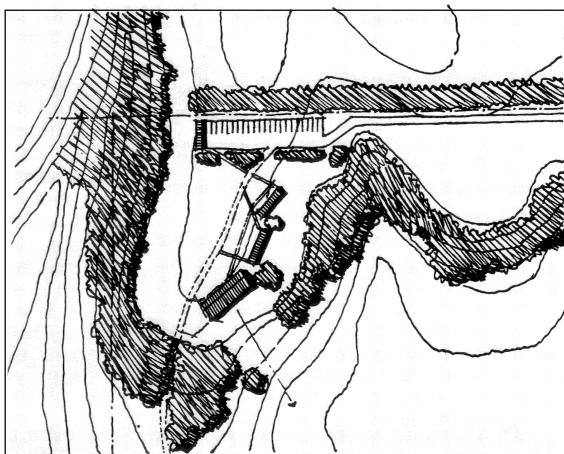
Once we solicit and receive bids from contractors, we will know how much the building is going to cost us. Until that time, we can make an educated guess. A new pharmacy building in Dayton cost \$215/square foot, and we think we can do our field station for about \$120/square foot if we get started soon. Of course there are differences between these two types

of buildings but the point is we are not doing badly on cost for a commercial building this size. Limiting the plumbing to the field house means that is the only building we have to heat in the winter which should substantially reduce utilities. The only real extravagance in the field house is the fireplace and the cost of this has been far more than offset by a generous donation.

One of the things we have stressed in the planning of this building is low maintenance and to a lesser extent, easy cleaning. I think that all of us would rather cave than paint or scrub floors. It has been primarily the building committee who has restored the tenant house and moved the Spelee Hut, and continues to maintain them. They certainly have their uses and will likely provide much of our bunking space until the bunkhouses are built, but they are high maintenance buildings. We can economize on some aspects of the main building but cutting too many corners will result in a building that will haunt us with constant annoying and expensive repairs. In fact, we are so certain that this field station as designed will be easy to maintain that we are volunteering to do the maintenance.

The plans also call for a utility building near the well. The electrical service will come into this building and likely some of the water system will be located there. We also foresee it as storage for mowing equipment, ropes, carbide, etc. Because the utilities will be involved with this building, it needs to be built before or concurrently with the field house. We, the building committee, proposed to donate all the money and labor to build this utility building according to Volker-Winn's plans and the Board has accepted our offer.

We have worked hard on this project and feel we have a versatile, beautiful, good quality, and low maintenance building. We have borrowed from the past designs that work well and learned lessons from those that did not. We see this field house as the first phase of the Hamilton Valley project and have tried hard to anticipate the needs of the Foundation membership of the next generation.



**Plan view of Hamilton Valley Facility**

# Operation Area Reports - 1998

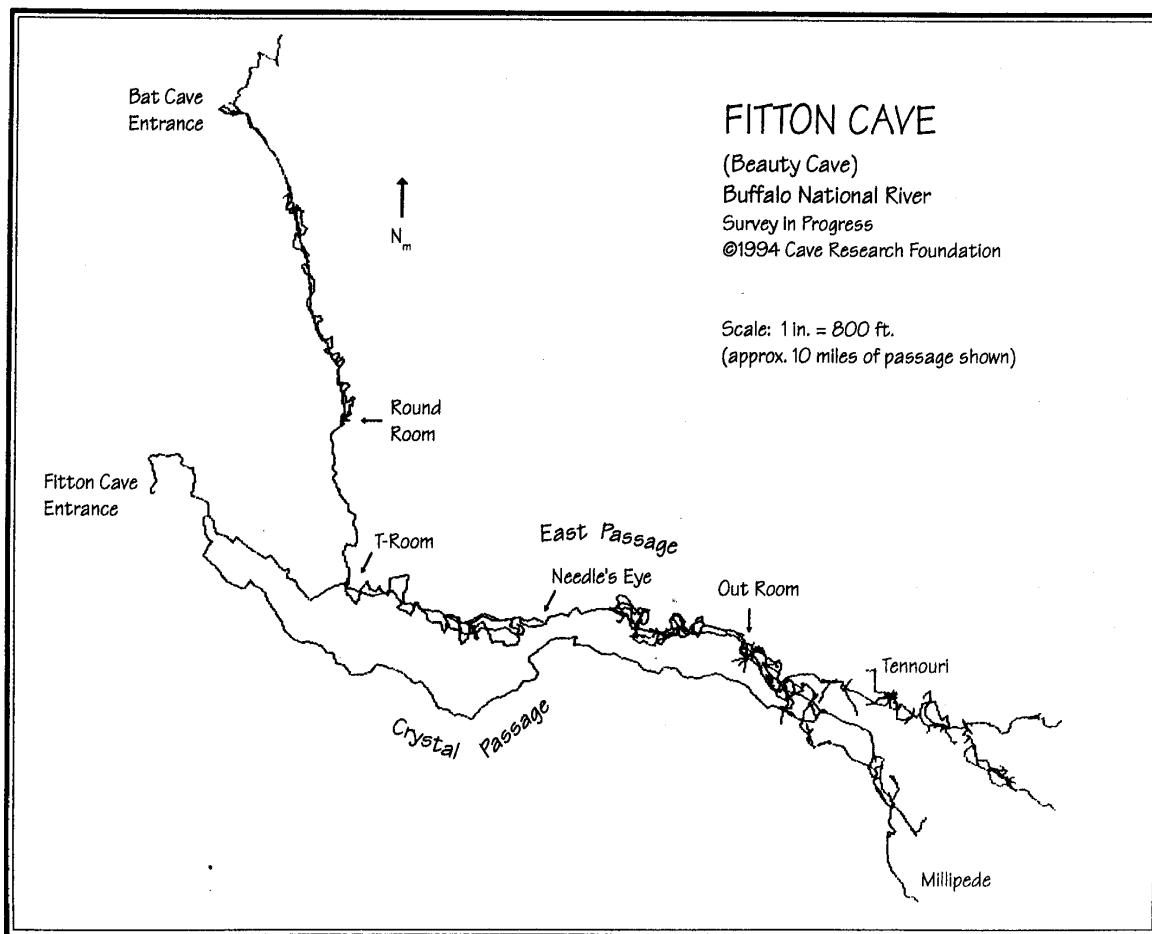
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## Arkansas Operations Area Fitton Cave Survey Project Report

*Pete Lindsley*

The Fitton Cave Survey Project in Arkansas, fielded three expeditions during 1998. A total of five survey parties worked in the cave during 1998 with expeditions on June 13th, August 7-8th, and October 10th. An expedition planned for September 12th was canceled at the last minute due to lack of attendance and was instead replaced with a day's work on the survey data in North Texas. Next spring we are planning a cave mapping workshop to help address our current goals of increasing output from the map factory.

Work continued on the vertical cross section at the 41-Foot Waterfall area in Bat Cave by two teams on the June 13th expedition. Laser range finder survey methods were used to enhance our data for a passage profile and cross section through this complex and interesting area. A small articulated skeleton was noted for the first time in this area. During the August expedition, a team completed the survey of the Oasis Room near the back of the cave in the New Maze area.



During the August trip as well as the October trip, work continued in the Altar Rock area of the Tennouri Passage in identifying some previous survey tie errors which will solve a closure error problem for this section of the cave. During the October expedition several brass tacks were installed in the Altar Rock area to act as permanent stations. A resurvey connected several of the area stations to the brass cap located in the Tennouri Room. A second team evaluated the feasibility of cleaning up some muddy footprints on the flowstone in the Millipede Passage area past Grand Central. A preliminary restoration attempt was made and will continue on future trips during both CRF survey expeditions and other trips by our members and other interested parties.

Cartography is high on our list for 1998. The bulk of the major passage in Fitton Cave has been surveyed now, but there is a lot of cleanup work that is turning up a surprise passage here and there. A partial computer database (COMPASS format) that was provided to the Park Service early in 1997 was found to have some small embedded closure errors and we are working towards improving our accuracy. The first cartographic goal is to update the whole cave database into several smaller sections which will allow us to correct some closure errors by areas. The next goal is to verify closures on multiple tie points by using the WALLS program being developed by David McKenzie in Austin. A third goal is to start six new quads plus some special sheets for the precision passage cross sections. We will continue emphasizing passage detail and cross sections throughout the cave in 1999.

CRF members can help by drawing up small sections of a draft map, inking quads, field checking existing maps, and checking system closures on the computer. We plan to hold a mapping workshop on a weekend next spring to train people in map making and en-



Tennouri Room, Fitton Cave, photo by Scott Dankof

hance the interest level in completing the map. We will hold the mapping workshop at either Chestnut Cabin (which will require bringing an electrical generator) or at the NPS Steele Creek Facility (where we already have power available).

The Fitton Cave Project is continuing to solicit scientists that may have an interest in doing work in the cave. We have invited both a geologist and a biologist to come to an expedition, but to date neither has been able to attend. For a scientist with access to carbon dating equipment, we have some interesting carbon chips in the lowest 10-15 feet of the Lower East Passage. This material is possibly related to a major flood following a forest fire or perhaps represents flood water washing through campfire material in the Bat Cave entrance. But no known flood of this proportion has occurred in recent historical times. In addition, there are several other potential projects including mineralogy, geology, hydrology and biology that will be of interest to qualified scientists and researchers. The present survey data base offers data on various water sources in the cave and there are several other small springs in the area in addition to the known Fitton Spring resurgence. A biological survey of the cave is needed and could be correlated with a previous survey done in nearby caves by CRF in past years. Interested primary investigators should contact Pete Lindsley, Project Manager, or Danny Vann, CRF Arkansas Area Manager, for additional information.

## Eastern Operations Area Update

*Dave West and Patricia Kambesis*

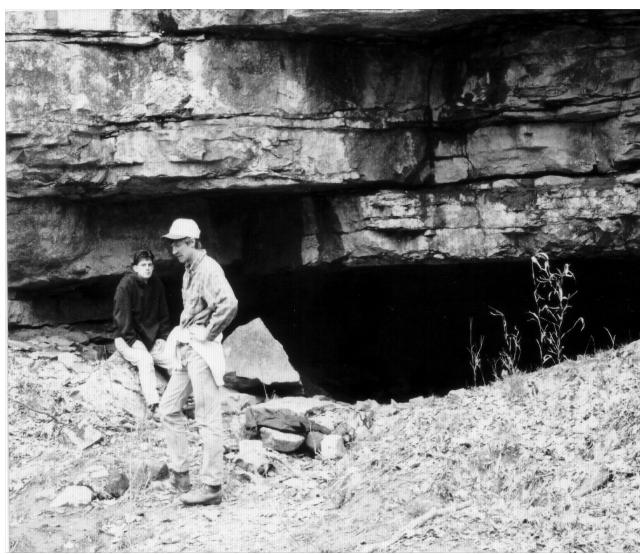
### Relations with Mammoth Cave National Park

The Park's Division of Science and Resource Management has a new chief, Mr. Jerry O'Neal. Jerry has a strong background in environmental protection, and we look forward to working with him.

### Small Caves Inventory

This project, originally scheduled to be completed last year, was extended into this year at the parks request. Eastern Operations continues to provide Scott House (principal investigator) with logistical support and personnel as required.

In support of the Lesser Caves Inventory, parties surveyed and inventoried Haunted Cave, the A survey of Bat Cave, and Pagoda Cave was located. In addition, a previously unreported small cave, called Thomas' Cave, was located (by Thomas Borden). Subsequently, Pagoda Cave and Gothic Cave (both near Bedquilt) were surveyed and inventoried. Other small caves that saw activity this year included Wilson Cave, Long Cave, and Dixon Cave.



Small Caves Inventory work in Mammoth Cave National Park. Photo: Mike Lace

### Mammoth Cave Cartography Program

Survey in the "big cave" remains the main focus of the Cartography Program. Cartographers continue to provide objectives to the expedition leaders to support work on the various quad sheets. Survey teams worked on cartography-generated objectives that included fixing closure errors, refining sketches and cleaning up remaining leads on the various quad sheets. The sections of the Mammoth Cave System that saw activity this year included: Bedquilt, Unknown, Colosal, Salts Cave, Mammoth Cave, and Proctor Cave.

Eastern Operations fielded out-of-Park trips to Roppel Cave (in conjunction with the Central Kentucky Karst Coalition), Sides Cave, Cub Run Cave, and Diamond Caverns.

### Paleontology

Eastern Operations continues to provide logistical and personnel support to Rick Toomey on the project, "Characterization of Past Bat Usage of the Historical Entrance Area, Mammoth Cave".

Teams entered via the Historic Entrance and continued work on the survey of bat remains in Broadway. Work focused on the area along the left and right side of Broadway between the Rotunda and the transformer across from the entrance of the Corkscrew. More material was found than anticipated including several mummified bats including one *Corynorhinus*.

Inventory in Little Bat Avenue yielded relatively little material, and the passage appears to have been cleaned out in the past. Backsliders Alley has interesting remnants of what must have been an extensive bat bone deposit. Material was flagged along Main Cave from the Water Clock to the Acute Angle, where remains included raccoon scat and bat bones. Archeological material was also profuse, but difficult to assess owing to a veneer of lint and dust. In Olive's Bower, a possible source for a hypothetical past input of cold air

was located. Present temperatures are too warm to support the large bat colony which historically existed in this area.

Paleontologists Rick Toomey, Mona Colburn, and Blaine Schubert continued and eventually finished the paleontological inventory in Wrights Rotunda. Paleofeces, mummified bats, bat guano, bat bones, and a stain sample were collected for radiocarbon dating.

A paleontology inventory crew flagged material from the Violet City entrance to the bottom of Albert's Staircase. In this damp area, all material noted was bone. "In addition to some bats, rat and mouse remains were relatively common. Mice were noticeably more common than in other areas we have inventoried [Toomey]."

### **Data Management and Support**

EO is consolidating its data into two different survey data processing programs to assist in the integration of the data into the park's GIS system. A web site is being established to simplify tracking of leads on the multitude of map sheets that are in progress.

Data support is also being provided to Alan Glennon for his thesis project: "Application of Morphometric Relationships to Active Drainage Networks within the Mammoth Cave Karst Aquifer" and to Bill Howcroft in support of his dissertation work "Fractal Characterization of Conduit Systems in a Karst Aquifer."

### **Geology of the Mammoth Cave System**

Art and Peg Palmer examined cave sediment and passage relationships throughout the Historic Route of Mammoth Cave. Methodist Church and Backsliders Alley were examined to learn if Gothic Avenue was the upstream end of upper Broadway, as hypothesized. It appears to be true. Although there is considerable evidence for multiple phases of sediment accumulation in the upper levels of the cave, the last phase of sedimentation prior to Pleistocene glaciation was apparently a massive event that filled all passages in the upper levels, including Collins Avenue in Floyd Collins' Crystal Cave. All of these passages have sediments of the same date - about 2 to 3 million years maximum, but with no systematic relationship to passage elevation. This supports the 25-year-old-hypothesis of the Palmers that

the Ohio River valley underwent a major period of sediment cover just prior to glaciation. After glaciation, rapid erosion of the Ohio and its tributaries (e.g. Green River) allowed many small passage levels to form, and most of the sediment at the surface was eroded away. The cave passages retain most of it and provide the crucial evidence. This evidence is supported by sediment dating by Darryl Granger of Purdue University.

The bottom line is that although the sediment is no older than three million years, that date occurs in passages at about the 600-foot elevation. The passages at that level had to be considerably older than that. Collins Avenue is 80 feet higher, and formed below Green River level (as shown by its irregular ceiling profile), which means that it must have been much older than 3 million years - probably the 10 million years that the Palmers originally speculated.

Time was spent examining Sylvan Avenue and Pensico Avenue to figure out their strange passage patterns (irregular passage shapes, unusual junctions, confusing scallops, high ceiling pockets). These features all seem to have formed as a result of flooding, which is to be expected at the very downstream ends of passages such as those.

**Work Remaining:** Although the sequence of major passages is fairly clear, as is the relation to the land surface, there are still lots of questions about other passages and the geologic conditions that control their patterns.

### **Publications**

The CRF Personnel Manual for Eastern Operations is in the process of being updated. Completion is expected by 1999.

### **Signatures Project**

Signature documentation continues along Main Cave from Wrights Rotunda to some way beyond Chief City. Among the luminaries noted were George Gatewood, Charles Proctor, and Stephen L. Bishop (not to be confused with "the" Stephen Bishop).

## Lava Beds Project Report

*Janet Sowers*

### Cave Survey, Inventory, and GPS Location

We have continued efforts in the area of basic cave documentation —cave location, survey and cartography, and inventory. Bill Devereaux continues to lead the cave location effort, working with monument staff to obtain high-precision cave locations with the monument's GPS system. He has also been installing brass markers at the cave entrances that serve as our GPS reference points as well as identify the cave by name and by number.

In 1998, we completed the survey of Downtown Cave and Bypass Cave, and surveyed Channel Z, Jack William, and several others. Several caves surveyed remain to be drawn up.

### Monitoring

We continued with long-term monitoring of ice levels in the ice caves and winter bat population counts. This year, Bill Frantz began re-shooting photomonitoring points that had been set up in 1992. He is teaching Lava Beds cave specialist Kelly Fuhrman how to relocate and shoot these points, so that the park can take over the program.

### Documentation of Merrill Ice Cavity

On President's Day weekend, we spent a good amount of time documenting the peculiar ice cavity in Merrill Ice Cave. This hole in the ice was first reported by Bill Devereaux in January, and it has been growing ever since. A report that we submitted to Lava Beds will be distributed at the meeting.

### Gating Project

Mike Sims and John Blume designed and constructed a bat friendly gate for the downstream entrance of Post Office Cave. They made two trips to do it: the first to measure and design, and the second to install

the gate. The monument staff are very pleased with the results and will probably ask us to do another gate next year.

### Virtual Reality Tour

Peri and Bill Frantz conducted an experimental photography session at Valentine Cave, to begin developing the techniques needed for constructing a virtual reality (VR) tour of the cave. This could potentially provide the park with a simulated trip for people who are unable or unwilling to go caving. It would also provide simulated trips to caves that are closed to the public, such as Crystal Cave. A VR simulation differs from a video of the cave in that the viewer controls the movement through the cave, selecting which way to go at junctions, and choosing to turn in any direction to approach and examine objects such as formations. They shot pictures from five locations in the cave, taking 18 pictures at each, from which they constructed a walk around the first pillar. The trial run was successful and the Superintendent is enthusiastic about developing it further for use in the Visitor Center.

### The Lava Beds Research Center

We are moving, slowly but surely, toward the dream of a field research facility at Lava Beds. Our goal is to provide a base of operations for researchers of any stripe whose work will contribute to the understanding of Lava Beds natural or cultural resources. CRF has long wished for such a place to do cave-related work, and we know of other researchers who would jump at the chance to work at Lava Beds if they had a facility to work from.

Our plan is to design the facility, raise the funds, and supervise the construction ourselves, then hand the Park Service the keys to the Lava Beds Research Center. By doing it this way, we can ensure that the building is designed and built to best serve the needs of researchers like ourselves, and we can make it happen for about half the cost and in half the time compared to

the Park Service. It is unlikely that such a project would be built otherwise. Lava Beds has tried in the past to get NPS funds for a facility but it must compete with other more high-profile parks for increasingly scarce funds. CRF sees this research center as a long term contribution to the future of one of the premier cave parks in the country.

The building, as drawn, is 1600 square feet with a simple, elegant design that is inexpensive and fits in with the rustic setting. It has a deck, and sits on a knoll with a spectacular view of the Tule Lake valley. It contains work space, storage space, kitchen, and living quarters.

We signed a Memorandum of Agreement (MOA) among the three parties involved: the National Park Service, the Cave Research Foundation, and the Lava Beds Natural History Association (NHA), in April 1998. It states, briefly, that CRF will be responsible for design, fund raising, and construction. The NPS will assist with the design, handle environmental clearances, permits, and inspections, grade the site, install utilities connections, and provide general support during all phases of the project. The NHA will be responsible for collection and disbursement of the funds. All parties are very enthusiastic, and we look forward to working together on this worthy project. We have had monthly meetings since May to plan the fund raising effort.

## Missouri Operations Area Report

*Scott House*

### Ozark National Scenic Riverways (National Park Service)

CRF has several projects in progress on OZAR land: Mick Sutton and Scott House continue to participate in the OZAR Cave Management Team. The team met three times in 1998.

CRF continues to map caves and assemble all data for the Riverways. The data is in FileMaker Pro. A database for monitoring caves in OZAR was developed by CRF-Missouri. Sutton and House held a workshop for NPS personnel on monitoring. This included a field experience. This year, the rangers took monitoring trips to 80 priority caves using the forms created by CRF.

A bio-inventory project involving stream censuses in wet caves along the lower Current River is being completed. Cave mapping is being done in conjunction with the bio-inventory. The census work has been completed though some of the cave survey still remains to be completed.

### Mark Twain National Forest (U.S. Forest Service)

The Mark Twain National Forest (MTNF) continues to be CRF's major project. Specifically, work has continued on bio-inventory and survey work on the Eleven Point District, where lead mining has, and is, a controversial subject.

Mick Sutton has completed Phase 2 of this work. The Phase 1 report was published by the Missouri Speleological Survey (MSS) as Volume 33 of *Missouri Speleology*. Phase 3 is well under way and the MTNF anticipates that there will be a Phase 4 negotiated later this year. Smaller caves elsewhere on the Forest are also being mapped and inventoried.

Database work for the MTNF was funded this year. This is a cooperative effort with the MSS and MTNF. CRF has purchased and distributed copies of the FileMaker Pro program and template. Updates of data are being forwarded to the Forest Service.

CRF was awarded the USFS Certificate of Achievement for our work in Missouri. The USFS estimates that our cooperative and volunteer work in Missouri has saved the government \$300,000.

### **Missouri Conservation Department (MCD)**

Project for MCD continues. Doug Baker and crew continue the survey of Powder Mill Creek Cave which is now in excess of seven miles in length.

Several smaller caves on Department land have been or are in the process of being surveyed and inventoried. These include Shop Hollow Cave, Spring Hollow Cave, Forester Cave, and others, mostly in Shannon County near the Current River.

Matt Beeson and crew continue the survey of caves in Three Creeks Conservation Area in Boone County.

Mick Sutton, Sue Hagan, and Scott House participated in the Department's Cave Policy Advisory Committee.

Scott House wrote a natural areas nomination for the Department on the Sunklands.

A new major gray bat colony was found by CRF.

### **Pioneer Forest**

CRF continued doing miscellaneous work on Pioneer Forest land, specifically: data maintenance on the caves of this private forest, cave mapping, and providing advise on cave management, including bat management.

### **Missouri Speleological Survey (MSS)**

The MSS works to collect all cave information in the state. CRF cooperates fully as follows:

Maps and reports are turned in to the MSS and are archived by the Missouri Department of Natural Resources.

*Missouri Speleology* is published with CRF's assistance

CRF coordinated a Cave Resource Committee meeting involving most of the interested agencies as well as the MSS and Missouri Cave and Karst Conservancy.

CRF is leading the way by facilitating the development of a new type of state cave database.

### **United States Geological Survey (USGS)**

CRF has been cooperating with the USGS on a project involving geologic mapping of lands around the Ozark Riverways

Bob Osburn and Scott House are developing models of cave and karst development in the Lower Ozarks. CRF is sharing their database information with this project.

Mapping is being done on some privately-owned caves as part of this project, in particular, Sutherland and Bunker Caves.

## Sequoia and Kings Canyon/Mineral King Operations Area

*Compiled by John C. Tinsley,*

### **Cartography**

*Peter Bosted*

This has been a slow year for cartography at Lilburn Cave, in Redwood Canyon, Kings Canyon National Park, California. The CRF has so far fielded only two expeditions involving cartography: May 27-28 and July 3-4, 1998. The unusually wet winter precluded access to the cave before Memorial Day, and even on that weekend we tromped through snow and had a 6.5 mile long hike rather than the usual 5 miles. There were a total of six survey trips into Lilburn Cave, with a total of 915 feet of new passage being surveyed using 82 stations. The total length of Lilburn Cave (excluding redundant surveys and tie-ins) is now about 16.6 miles (26.6 km), with a total of 7350 stations set. This includes about 0.2 miles of underwater survey which is not yet available for computer entry.

Three of the July survey trips were to the new area in the very southern end of the cave, discovered late last year. Even in July, it was a very wet trip to get through the Yellow Floored Domes and past the Mousetrack turnoff to climb up to this muddy breakdown and phreatic tube area. Two pits (each about 40 feet deep) were dropped and a waterfall could be heard ahead through boulders. A return trip in dryer conditions could lead to interesting discoveries! Another July trip found new passage at the end of the Pandora Complex, which came within a few feet of connecting to a new section of the Underworld surveyed during the May trip. Some new passage was found in the Clay Palace beyond a tight squeeze. It connected to a larger passage which later study of the map revealed to be unsurveyed, so more potential remains here as well. Finally, some mop-up survey was done in the Attic, and one team spent a day checking the complicated Schreiber Complex, but no surveying was done.

The surveyors for 1998 so far are Peter Bosted (3 trips), Charlie Hotz (2 trips), Lynne Jesaitis (2 trips), Roger Mortimer (1 trip), Merrilee Proffitt, (1 trip), and Mark Scott (3 trips). Weather permitting, we hope there will be a few more trips this year. Certainly many leads still remain to be investigated.

The map-drawing effort continued to progress well in 1998, with several new quadrangles being drawn, and the existing ones updated with the new surveys. Presently there remain about eight quads to be drawn in the Attic area (part of the D series), six of which will be done by Joel Despain (SEKI Cave Specialist), and two by myself. I am about halfway through drawing the live F series quads. The A, B, C, and E series are completely done. The rest of the quads (G through M series) are all 80% to 100% complete. Overall, the quadrangle project is about 85% done. We hope to have a complete quad book by the end of 1999. Joel drew a nice map of Mays Cave (a small cave northeast of the Attic section of Lilburn) which we plan to publish in the California Caver.

### **Summary of Hydrologic Studies in Redwood Canyon**

*William D. Howcroft and John W. Hess, Graduate Program of Hydrologic Sciences and the Desert Research Institute, University of Nevada, Reno*

Activities of the Hydrology Group in 1998 centered around three main tasks within Redwood Canyon: 1) maintenance and repair of data logger sites within Lilburn Cave, on Redwood Creek, and at Big Spring, 2) sampling and analysis of surface waters, spring waters, and cave drip waters, and 3) fractal analysis of survey data from Lilburn Cave, Cedar Cave, and Mays Cave.

Following the 100-year flood event of January, 1997, the three data loggers within Redwood Canyon were found to be nonfunctional. Thus, in 1998, the data logger within Lilburn Cave was retrieved, cleaned, and reinstalled, the data logger at Big Spring was replaced, and a new thermistor was installed at the site on Redwood Creek. At present, all three data loggers are now functioning though wiring problems still persist. Additional maintenance is scheduled for the end of October, 1998.

Sampling of waters within Redwood Canyon continues on a bimonthly basis for the purpose of identifying natural tracers suitable for the characterization of

flow through the vadose zone. Previous sampling events have eliminated TFA and the environmental isotopes of oxygen- 18, deuterium, and carbon- 13 as suitable tracers. Additional sampling is scheduled for late October, 1998. Initial results from the fractal analysis of survey data from the three Redwood Canyon caves suggest a lack of self-similarity in the cave systems. However, additional fractal measuring algorithms are currently being developed and will be applied to the survey data. Results of the fractal analyses were presented in a special CRF Session at the 1998 NSS Convention in Sewanee, Tennessee and will be further discussed at the Geological Society of America (GSA) Fall Meeting in Toronto, Canada in October.

### **Sedimentology of Redwood Canyon**

*John Tinsley*

The winter of 1997-1998 was the second wettest year in most of California, with a record snow pack at Grant Grove in Kings Canyon National Park. Consequently, the potential for observing the effects of high runoff in the Redwood Canyon drainage in 1998 seemed to be ideal. However, when snows finally melted (by mid-June), and melt water discharges had ebbed, flood levels and sediment movement was obviously much less than one would anticipate from the thickness of the snow pack. This situation contrasted markedly with extreme flooding conditions that prevailed during 1996-1997, when 130+ feet of head developed on Big Spring, and major movements of sediment and patterns of sediment dispersal were mapped. Why the observed difference in flood levels?

Of course, the year to year contrast in patterns of sediment movement and intensity of flooding is explained simply by corresponding differences in the rate at which the respective snow packs melted. The spring of 1998 was so chilly that the snow pack melted slowly and the flow of melt water input to Lilburn Cave was thereby limited. Water stages and therefore peak levels of discharge last winter were wholly unremarkable, as indicated by static sediment samplers and by observed strandlines.

In contrast, during 1996-97 the mountains received large amounts of wet snow in November and December. This snow pack melted in a couple of days in early January when an intense "El Nino" precipitation pattern commonly dubbed the Pineapple Express occurred.

A Pineapple Express exists when, for several days at a time, atmospheric circulation funnels moisture-laden warm air from the vicinity of Hawaii directly into the mountainous areas of southern and south-central California. The Sierra Nevada receive intense voluminous precipitation of unusually long duration. As the rain is extremely warm, it efficiently drives snowline back up from 4000 to 7000 feet or more, releasing lots of fossil precipitation to help to increase the intensity of floods. So in 1996-97, the lower third of Lilburn Cave filled up with runoff and the intense currents moved lots of sediment through the cave and both above ground, too. This event blew out the sediment plug from Big Spring, enabling the successful diving of 1997 by Bill Farr. The observations of the past two years emphasize the importance of fossil precipitation in an El Nino year in determining the impact of seasonal flooding on sediment transport processes.

### **Cave Diving**

*Bill Farr and James Brown*

After the Herculean efforts of 1997, in which Bill Farr penetrated about 1000 feet and over 260 feet deep into Big Spring and 1050 feet into the Upstream Rise and returned with survey, the Dive Project has been quiet this year. Principal efforts have been directed toward acquiring special pumps for filling tanks on site, to minimize the need to hire stock to move 30+ tanks needed to stage one of these dives.

### **Cave Restoration**

*Bill Frantz*

The Cave Restoration project has conducted one foray to date and continues to work on restoring the area below the Jefferson Memorial. Additional sorties are planned for expeditions later this year.

### **Logistics**

*John Tinsley, Mike Spiess, Joel Despain, and Roger Mortimer*

A pack string was retained in early July to haul 600 lbs of cement, some tools, and bear-proof food boxes from Redwood Mountain Saddle five miles to the Lilburn Field Station, and then to remove SCUBA tanks and assorted rubbish from the vicinity of the field station back to the trailhead. It went quite well, except for the Despain-procured food caches that proved to be too

large and unwieldy for the packer to haul. These affairs were tool boxes like those the beer-swilling good ol' boys commonly stuff into the backs of their pick-up trucks. Efforts to shanghai at least eight testosterone-crazed individuals into hauling the boxes in the manner of sedan chairs using two long poles met with polite but stony silence. We are now exploring the possibility of arranging for the Navy to haul the boxes into Redwood Canyon on a training mission from their base at LeMoore Naval Air Station near Hanford, CA, using their incomparable HUEY rescue helicopter and winch and cable gear. Stay tuned for a future report of a great Redwood Canyon Airlift, should it materialize.

The July 4 expedition was dedicated to interacting with the Western Region's only duly certified cave rescue group, which hails from San Bernardino, CA. We had about 30 people on site (with a special exemption to our party size limits furnished by the Superintendent in support of this venture). The objective was to introduce them to the challenges of a rescue in a cold, wet, 3-D maze cave that just keeps coming at you. Depending upon them to rank themselves as to their caving ability, we staged the trips so their hardest-core folks got to go caving with our hardest core cartographers to the nether-reaches of the cave system, and their less-experienced folks got tours of the trade routes. All were satisfied with their respective experiences, and we are delighted to have this major resource available to us and the National Park Service in the event of a major rescue in Redwood Canyon. Likely there will be future cooperative ventures between our two groups.

Efforts continue to stabilize the Lilburn entrance and its ladder by building up the eroding floor to enhance stability. In fact, this project will consume most of the cement packed into the field station earlier this summer. Little work was done earlier this year owing to high levels of water flowing into the entrance that made it impossible to pour concrete without it washing away. Hopefully, the late autumn will afford less inclement conditions for this sort of construction.

#### **Air Flow Monitoring at Lilburn Cave**

*Howard Hurtt, with field assistance from Stanka Sebela, S. Smith, and John Tinsley*

Portable anemometers were used to obtain preliminary air flow measurements at the Lilburn (historic) and Meyer entrances of Lilburn Cave in Sequoia/Kings

Canyon National Parks, California. A two-hour series was logged at each entrance on 7/3, 7/4, 7/18, and 7/19/98. Flow at the entrances was predominantly static. Inflow and outflow events lasted 0.5 to 2 minutes and occurred without evident synchrony, though there were fairly strong modes at 10 and 20 minutes. A connection between the air flows and the flushing behavior of Lilburn's resurgence (Big Spring) could not be established. The air flow patterns observed may be an overlay of resonance on thermal and/or barometric effects.

#### **Mineral King Operations Area**

*Roger Mortimer, Joel Despain and John Tinsley*

There were four CRF expeditions to the Mineral King area, two involving cartography, one hydrologic study, and one photo trip.

Roger Mortimer coordinated cave surveys of the White Chief Basin, mainly focused in White Chief Cave, formerly the basin's largest known cave resource. White Chief Cave and the White Chief Mine, a privately held, patented lead and silver mine, were acquired early this summer by the National Park Service after years of negotiations.

Joel Despain led an expedition to survey Jordan Cave and other small caves lying north of Timber Gap. After a good start surveying there, the next day the group climbed to 11,000 feet to Empire Cave and Empire Mine, where much surveying remains. Next year should be productive!

John Tinsley conducted a water trace that confirmed White Chief basin drains to Tufa Springs, the largest resurgence in the MIKI area. The new cave system is at least 2.8 miles long, and the size of the catchment that feeds Tufa Spring is about doubled in area. The work extends hydrologic studies initiated 20 years ago by Bruce Rogers and builds on recent studies of the White Chief basin completed by Lori Schultz. The results require that published geologic maps be revised to reflect the new karst system.

Jeff Cheraz led Peter and Ann Bosted on a photographic trip to Beulah Cave. Jeff discovered 100-foot Beulah Cave on the east side of the Mineral King Valley. This cave is part of the system dye-traced from Panorama Basin by Tony Troutman.

## Southwest Region Operations Area

*Barbe Barker*

### **Relations with Carlsbad Caverns (CCNP) National Park**

All Cave Resource Office Personnel and Management are very pleased with CRF efforts and contributions.

#### **Projects Supported**

*Survey & Cartography:* CCNP is putting all of the updated survey on their computer. CRF has ongoing projects, headed by approved sketchers, in different parts of the cave.

*Scientific & Geology Inventory:* Approved Scientific & Geology Inventory personnel are on each survey team and training continues in this area.

*Restoration:* Ongoing projects continue and new ones are accomplished as the Park requests. The CRF restoration teams are the most respected among all the different groups who work in Carlsbad.

#### **Data Management**

All original survey data stays with the NPS. Copies are distributed to each individual sketcher, project manager and area manager.

#### **Other Items**

*Rent:* CRF was the only group who was paying rent on the huts. This arrangement had been set up years ago before so many other groups were also working in the cave. I talked to Dale Pate, Cave Resource Specialist, this year and explained to him that we didn't mind paying rent as long as everyone else was too. He agreed with me, and we are not paying rent anymore. However, we will continue to have storage areas in both huts.

*Old CRF Data:* I spoke with Pat Helton, former cartographer and holder of the CRF data. He told me that he was going to take it to the Park. I will either pick

it up in Lubbock before he does this or he will deliver it to the Park.

#### **Memorandum of Understanding**

Ours has expired and a new one has not been drawn up. Both Dale Pate and I agree that this needs to be done especially since we are no longer paying rent on the huts.

*Insurance:* We are now signing a "Volunteer Agreement" with the Park Service which covers all volunteers under their worker's compensation insurance and also enables them to count our volunteer hours.

*Expedition Fees:* We have stopped providing food for each expedition and therefore, reduced our costs dramatically. Currently, charges for an expedition are a minimum of \$5.00 to cover cost.

*Financial Status:* We are still self-supporting and have around \$1000 in the bank. We will slowly build up our bank account with the five dollars expedition fees but have stopped our losses by not paying rent and not providing food for each expedition.



Calcite Rafts, Carlsbad Caverns National Park, New Mexico. Photo by Chris Beck

# Archeology

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## CRF Archeological Project

*Patty Jo Watson  
Washington University*

Fieldwork. At Hamilton Valley on October 11, Angela Gordon (see her report here) and Pat Watson examined a stand of *Eryngium yuccifolium* (rattlesnake master, button snakeroot) pointed out to us by Mammoth Cave National Park ecologist, Rick Olson. We were elated to find 56 plants on this first visit, and scheduled a return trip for the succeeding weekend to map the entire stand. Mapping was directed by George Crothers, who was aided by Angela and three other Washington University anthropology graduate students: Ben Carter, Jenna Hamlin, and Jim Schechter.

Gordon's Master's project (Gordon 1999) is a study of fiber sources for some of the prehistoric artifacts left in Salts Cave and Mammoth Cave, especially the vegetal fiber footwear, variously called slippers or sandals. The long, fibrous leaves of rattlesnake master, a prairie plant, were a favorite source of raw material for these shoes, but little is known about the ancient techniques for selecting and harvesting the leaves. We are delighted to have a large and well-protected *Eangium* stand to observe and work with over the next few years. Joan Miller, who succeeded in replicating the ancient shoes using jute (hemp) (Miller 1988), is looking forward to experimenting with some of the Hamilton Valley *Eandu* leaf stock.

On November 21, 1998, Angela Gordon and Pat Watson were in Mammoth Cave National Park with palynologist Eric Grimm of the Illinois State Museum. In collaboration with Bob Ward and Jerry O'Neal of the Division of Science and Resource Management, we were trying to obtain a pollen sequence that would

give us some idea about pre-modern vegetation patterns in the Park and its vicinity. Candidates for pollen coring were Hawkins Pond and Sloans Crossing (Beaver) Pond. Grimm judged Hawkins Pond not at all promising because of its appearance and because we were told that had it been enlarged artificially and apparently used as a hog yard in the recent historic, pre-Park period. Hence, he decided to give Sloans Pond a try, at least with a bucket auger. Grimm and Watson went out to the center of the pond in the NPS johnboat, where they found the following sequence:

30 cm of water and *Brasenia* (an aquatic plant, very abundant here)

36-37 cm of soft sediment

Tough clay pond bottom (probably Pleistocene in origin)

We managed to obtain about 40 cms. of core (very watery and soft) plus a bucket auger sample of the pond bottom sediment from 1.19 m below the water surface. These samples are to be worked up at the Illinois State Museum but results are not yet available.

On November 22, Grimm, Gordon, and Watson drove over to 100 Acre Pond (northeast of Horse Cave, and near Monroe, Kentucky). Grimm thought it might have coring potential, but as it is on private land we must get special permission from the landowner to make the attempt.

## The Salts Cave Slipper Revisited

Angela Gordon  
Washington University

In the mid- to late-1960s, CRF conducted archaeological investigations in Salts Cave in conjunction with the Illinois State Museum, under the direction of Patty Jo Watson and Robert Hall. I recently conducted fiber identification tests on a group of ten twined slippers collected during the Salts Cave survey and excavation. These slippers have been described in print by King (1974), Miller (1988), and Watson (1969), but the botanical source of the fiber has remained unknown. Working at the Missouri Botanical Garden, under the direction of Dr. Richard Keating, I compared the anatomical features of the archaeological samples and known reference materials. The results, described in detail below, confirmed a long-held suspicion that the Salts Cave slippers were made using the leaves of *Eryngium yuccifolium* (rattlesnake master).

The samples I worked with were collected during the 1963 field season of the Illinois State Museum/Cave Research Foundation archaeological project. The samples were taken from fiber artifacts sent to Volney Jones at the University of Michigan, Ann Arbor. There are 23 vials of material, only eleven of which are samples taken from slippers.

### Methods

Dry plant material, such as these archaeological samples, must be restored, or softened, before sectioning for microscopic examination (Keating n.d.:28). Kodak Photoflo 200, a chemical used in film processing, was used in a 1:3 aqueous solution. The samples were soaked in Photoflo at least overnight and then rinsed by drawing off the Photoflo with a pipette, and adding and drawing off clean water.

Once the fibers were softened, they were treated in several different ways for viewing under the microscope. Some were simply teased with a probe to spread them out on the slide, and then mounted in calcium chloride ( $\text{CaCl}_2$ ).

Other specimens were stained with either cresyl violet acetate (CVA) or iodine potassium iodide ( $\text{I}_2\text{KI}$ ). The archaeological specimens did not take the stain well, although staining was very useful for the comparative materials. An attempt was made to clear some of the archaeological specimens by heating in a microwave and a conventional oven while in a 5% aqueous solution of sodium hydroxide (NaOH). This was not very successful in the archaeological samples, but, as with the staining, very useful clearings of the reference materials were made using the same technique.

Archaeological samples were compared with the prepared reference materials using an Olympus compound light microscope, with magnification ranging from 40x to 400x. The arrangements of fibers and soft tissues were compared, and cell lengths and widths were measured at 400x magnification. The archaeological material is generally degraded, with much of the soft tissue lost, but some epidermal tissue is still present, including stomata. This helped to narrow the focus to leaf fibers or fibers from outer stems, because bast (inner bark) fibers do not contain stomata.

### Results

Despite the narrowed focus, it took several months of lab work to confirm the identification of fibers retrieved from Salts Cave. The general features including the layout of the fiber bundles, occasional branching of the bundles, and stomata with two subsidiary cells, resemble *E. yuccifolium* more than any of the other reference materials.

Final results show that nine of the 14 analyzed samples can be classified as *E. yuccifolium*, an identification based on a combination of features. The strongest evidence comes from the stoma/subsidiary cell pattern, and the leaf hairs that are present in two of the samples (Figure 1). Together with the general patterns of fibers and intervening soft tissue, nine samples, rep-

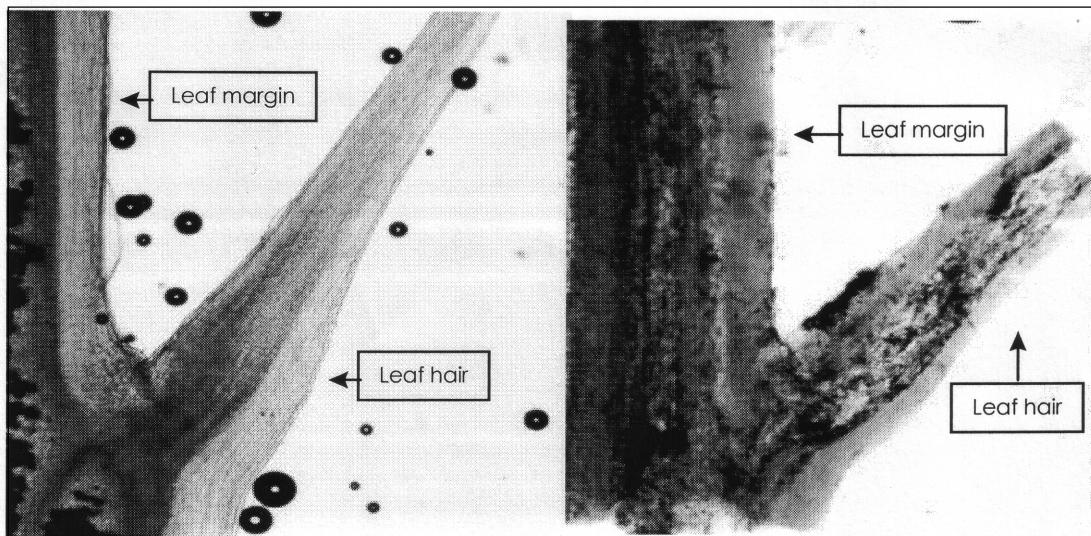


Figure 1 Comparison of leaf margin hairs of *E. yuccifolium* (left) and Salts Cave archaeological material (right). Taken at 10x magnification

resenting four slippers, can be identified as *E. yuccifolium*. Of the five other samples, three strongly resemble *E. yuccifolium*, based on general characteristics and similarity to the identified archaeological specimens, but do not have either of the strongly diagnostic features.

## Discussion

Other recent fiber studies (e.g., Kuttruff et al. 1998) have shown that rattlesnake master was a commonly used fiber source for slippers and other types of footwear in Eastern North America. The results of my Salts Cave research add yet another example of this pattern. The presence of rattlesnake master in close proximity to Salts Cave (See Watson's article p.26) added an exciting component to this study. Further study of rattlesnake master itself will give a better understanding of the techniques required to turn the raw materials into slippers, and allow us to study fiber yields and possible management strategies of wild stands.

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## Foraging Societies of Eastern Central Brazil: An Evolutionary Ecological Study of Subsistence Strategies During the Terminal Pleistocene and Early/Middle Holocene

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The archaeological work reported on here is part of a long term project being carried out in the karst region of Eastern Central Brazil, mainly at Lagoa Santa/Serra do Cipó and Peruaçu valley regions. The research focus on three archaeological sites with evidence of human occupation dating back to 11,000 B.P.: (1) Santana do Riacho, a rockshelter formed by the falling of quartzite blocks from the base of a cliff, is an exception in an area dominated by limestone karst caves and rockshelters associated with the *Bambuí* group of Silurian age; (2) Lapa do Boquete, and (3) Lapa dos Bichos both located in the Peruaçu Valley, in the northern region of Minas Gerais. The Peruaçu River's origin is located on gneiss bedrock, 80 km northwest on the left bank of the São Francisco River. Its middle course cuts through Precambrian calcareous formations, and in the past, it was almost entirely subterranean. A roof collapse exposed the river bed, forming a canyon with cliffs 50 to 100 meters high, characterized by karst forms (e.g., lapies, dolines, and residual forms), and subterranean sections 1 to 3 km in length.

The work takes an ecological approach that is justified for both empirical and theoretical reasons. There is a growing body of archaeological evidence that the Pleistocene/Holocene transition was an important period in human evolution, specifically the appearance of a diversity of economic and cultural systems. The lowland tropics witnessed climatic and vegetational changes at the end the Late Pleistocene and Early Holocene epochs that might not have been as profound as those experienced at higher latitudes; nevertheless, they led to major shifts in resource densities and distributions in space and time which necessitated significant cultural responses relating to the food supply.

Anthropologists have generally assumed that tropical environments are spatially and temporally homogeneous. However, tropical environments are very complex and highly diverse ecosystems, with important

local variations in resource availability, seasonality and inter-annual fluctuations.

It has been assumed that climatic changes during the Terminal Pleistocene affected the whole of lowland South America equally, and that environmental changes during this period were not significant in the tropics. However, in the last decade new paleoclimatic studies from different areas in Brazil, and specifically Central Brazil, have produced a more complex picture. Moreover, the dramatic environmental changes associated with deglaciation at the end of the Pleistocene have also been recorded in tropical regions.

Although the degree of environmental change in the tropics, and particularly in Brazil, might not have been as pronounced as it was in high latitude or high altitude regions, general paleoclimatic fluctuations in the tropics were synchronous with oscillations elsewhere in the world.

Based on recent paleoecological reconstructions of lowland South America, Piperno and Pearsall (1998) have suggested that the Late Pleistocene neotropical habitats with the highest-ranking resources should, for the most part, have been those in which the now-extinct big game was to be found in highest numbers. Their reasoning assumes (1) that energetic efficiency was a primary variable conditioning settlement and subsistence strategies; (2) that humans operating under conditions of energetic constraints should have first exploited habitats in which return rates were relatively high and then moved into more "unfavorable" habitats after those first occupied began to experience drops in return rates; and (3) that humans first entered the neotropics when the big game fauna was still present in the region.

The systematic analysis of three sites in Central Brazil, which is the core of this work, together with

available information from other late Pleistocene and early Holocene sites from the neotropics of South America, does not show evidence of big game hunting, *contra* Piperno and Pearsall's expectations. The Late Pleistocene and Early Holocene archaeological record of Central Brazil suggests a broad spectrum diet based mainly on gathered roots and fruits backed by hunting game, with no clear evidence of people hunting megafauna. A very similar pattern is found in Amazonia. I examine the hypothesis that when the first Late Pleistocene/Early Holocene hunter-gatherers settled in eastern Central Brazil, some of the high-ranked items (e.g., large fauna) were extremely scarce to begin with or even absent, and based on an optimal diet breadth model developed, it is predicted that those foraging societies would have employed a generalized gathering and opportunistic hunting strategy, with the inclusion of several low-ranked resource types. Furthermore, an expansion of the diet breadth and intensification of food processing as risk-buffering mechanisms were very limited because several of the low-ranking items were already part of the diet, consequently, higher level risk-management strategies were employed by prehistoric hunter-gatherer societies in Central Brazil, notably mobility and development of regional social networks as risk-buffering mechanisms.

The theoretical perspective I take to investigate and explain the archaeological record of foraging strategies in Central Brazil during the Late Pleistocene and Early Holocene epoch derives from evolutionary ecology, and particular emphasis is given to the diet breadth model, which is used to generate expected values for comparison with empirical data. Two key concepts, risk and information, are the bases for the development of a set of hierarchical risk-management mechanisms employed by human societies. Based on paleoecological conditions in Central Brazil during the Terminal Pleistocene and Early Holocene epochs, I generate some general expectations for prehistoric foragers' responses to environmental fluctuations in eastern Central Brazil according to the diet breadth model and the risk-buffering mechanisms.

The research is based on a detailed characterization of the climate and vegetation of the region. Emphasis is given to the *caatinga* and *cerrado* vegetation types that predominate in Central Brazil. The work focused on *cerrado* and *caatinga* productivity (i.e., plant

and animal biomass). The ecological settings of Central Brazil are used as parameters for paleoenvironmental reconstruction proposed as a background for the description of the archaeological material from Peruacu valley and Santana do Riacho.

Information on late Pleistocene and Holocene environments derived from pollen cores, geomorphology, and faunal remains is used to construct a paleo-ecological scenario for the postglacial period of Central Brazil. Although Central Brazil is the focus of the paleoecological reconstruction, I incorporate data from other parts of Brazil in order to understand general trends and local variations in the past. The broadly reconstructed paleoenvironments provide an essential foundation for deriving testable hypothesis based on the diet breadth model.

The archaeological record (radiocarbon assays, lithic, botanical and faunal remains) for Central Brazil, and the evidence for a Late Pleistocene human occupation in the area, are reviewed in the work. A general characterization of the archaeological record (i.e., lithic assemblage and organic remains) associated with subsistence economy of foraging societies in Central Brazil together with a review of Central Brazilian rock art is carried out. A detailed description of the archaeological evidence from stratified deposits of the three postglacial archaeological sites from eastern Central Brazil, Santana do Riacho, Lapa do Boquete and Lapa dos Bichos.

The interpretation of faunal evidence requires a careful consideration of the agents of bone accumulation and modification; thus, I make a detailed taphonomic analysis of the faunal material from the three archaeological sites. Variables such as bone fragmentation, burning damage, cut marks, and skeletal element representation are all examined to better understand the history of bone accumulation at these sites. Taken together, the evidence indicates that hunter-gatherer populations accumulated and discarded the vast majority of the faunal remains at all three sites. Fragmentation is related to both forager carcass processing and postdepositional processes. Burning damage has not biased the degree of identification and is a strong indicator of human origin of the animal remains.

The core of the work is the development of

testable expectations from the diet breadth model based on the ecology and paleoecology of Central Brazil. Specifically, the diet breadth model is constructed for application in the Lagoa Santa and Peruaçu region. Paleoenvironmental parameters are projected based on published algorithms that predict plant productivity and mammal biomass as a function of climatic parameters (e.g., precipitation, temperature, evapotranspiration). I construct a series of linear regression equations for making projections about foraging parameters such as prey-encounter rates and pursuit time, and animal processing time based on the natural history of Neotropical fauna and on ethnographic data from lowland South America. The different foraging parameters are used to model diet breadth. The models provide frameworks to understand and explain the postglacial economies of foraging societies living in eastern Central Brazil.

The models are compared with faunal data from Lapa do Boquete, Lapa dos Bichos, and Santana do Riacho. Information on taxonomic richness, evenness, and diversity is generated based on the faunal assemblages, and used to examine the models. Although the prey-choice model works well as an explanatory framework, the archaeological evidence analyzed in this study does not conform entirely to the model's expectations.

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# History

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## History of the Peoples and Caves of Flint Ridge, Kentucky

*Stanley D. Sides*

New facets on the life of Max Kamper continue to be discovered. Collaboration with Bernhard Kliebhan and Charles DeCroix has resulted in new understanding of his life in Europe and the United States. Bernhard Kliebhan found and photographed Kamper's grave in a military cemetery near Cambria, France, near where Kamper fell in the Battle of the Somme. Charles DeCroix has learned much on names on the Kamper Map, and the history of W. Stump Forwood.

German Engineer, Max Eyth, visited Mammoth Cave in 1866, and made a survey of the visitor's trails. The map was published in his book "Wanderbuch eines Ingenieurs," in 1871. Max Eyth's book was republished as "Im Strom unserer Zeit," in 1904 without the map, but with color drawings of prominent chambers of the cave.

At Bernhard Kliebhan's request, the grandson of Max Kamper, Klaus Kamper, searched his grandfather's library and found a copy of "Im Strom unserer Zeit." It is, therefore, likely that Max Kamper knew of Mammoth Cave before he arrived in the United States, even though the possibility remains that the book was purchased on his return to Germany. It is tempting to speculate that the lack of a map in Kamper's copy of Eyth's book might have stimulated Max's interest in surveying the cave. Eyth's map was published in W. Stump Forwood's, "An Historical and Descriptive Narrative of the Mammoth Cave of Kentucky," with no credit to Eyth. Kamper might have found this map when he arrived at Mammoth Cave in February, 1908. Certainly, the cave description and survey performed by Max Eyth seem to figure prominently in Max Kamper's decision to visit and survey Mammoth Cave.

### Library Research

On November 20th, 1998, I visited the New-York Historical Society, 2 West 77th Street at Central Park West, New York City, to continue research on the life of Max Kamper in the United States before his arrival at Mammoth Cave National Park. Research in the library collections has revealed the following about Kamper's life in New York from June, 1907, to January, 1908.

Lidgerwood Hoisting Engines was at least 30 years old when Kamper began working for the firm in June, 1907, shortly after arriving in the United States. The firm made conveyors and hoisting engines, including suspension cableways and boilers. By 1934, the firm was in decline, and based in Morristown, New Jersey. Kamper worked at their plant in South Brooklyn at the foot of Dikeman Street, on Upper New York Bay. He earned \$16 monthly.

Kamper arrived in New York on May 16, 1907, first living in Hotel Belvedere. Nine days later, he moved into a furnished room at 306 East 14th Street. He probably traveled the Brooklyn Bridge (built 1883) from New York to work, but might have taken a ferry to work in Brooklyn each day. At this period in New York's history, there were more persons of German descent than American origin, and the German population was more numerous than in any city except for Berlin. Kamper lived in a \$3 per week room in a fashionable area, rather than in the widespread teeming tenements of the city. On December 7, 1907, he moved to a better area at 45 West 25th Street, in the theater district, near the current location of Madison Square Garden.

On September 26, 1907, Kamper recorded in his diary that "Drummel and Voelcker"

notes "Inwood" in his diary, and the address: Carl Voelcker, 216th Street, Bolson Road, Inwood, New York City. Thereafter, he returned often to Inwood, including Thanksgiving and Christmas Eve. Franz and Emil Voelcker may have been sons of Carl Voelcker.

The atlas of the City of New York in 1908 indicates Inwood Station for the train system was at the far northern tip of Manhattan near the junction of the Hudson River and Harlem River. The station was at Inwood Street and Bolton Road. In 1907 and 1908, this area only had several lots and streets platted, and was chiefly farms. Research continues on the Voelcker family, and whether they owned a farm at Inwood.

Research on the life of H. C. Ganter will continue in 1999. Correspondence with the Huntington Library, San Marino, California, has not achieved the goal of obtaining copies of Ganter's correspondence with trustees of the Mammoth Cave Estate. Records in the Mammoth Cave collection will be examined before further letter copies are purchased.

## Interviews

Interviews with Bill Austin on the history of caving in Floyd Collins Crystal Cave and Flint Ridge have continued. An accurate chronology of cave exploration is slowly emerging. The history of exploration

of Crystal Cave is intertwined with the exploration history of Salts Cave. Study of the history of both caves continues.

## Cave Research

One cave trip was made on April 11, 1998, during the Cave Research Foundation Easter Expedition in support of MACA H-1. The route from Bird Avenue to Burley's Way via Emily's and Thorpe's Avenues was studied as a possible route for class travel. Sites of potential damage to the historic resources of the cave were identified and recorded. Four underground survey trips were made on scheduled Cave Research Foundation Expeditions.

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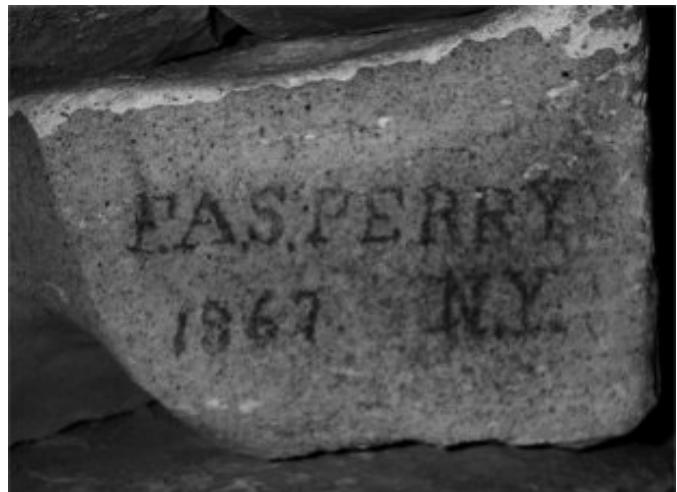
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## Mammoth Cave Register Project

*Philip James DiBlasi*



### Introduction

It has long been recognized that historic signatures exist throughout Mammoth Cave and other caves within the National Park. These signatures, many of which are dated, represent a unique form of artifact rarely found except in and on places of natural wonder, monuments, and on old world archaeological sites visited by masses of tourists, especially in the 19th and early 20th centuries. Now, it is recognized that this form of self aggrandizement is, in reality, a form of defacement of these wonders.

In the past there has been considerable discussion as to what should happen to those signatures found throughout the cave. To record and study them was, at one time, believed to glorify those individuals who defaced the cave. In the late 1980s it was suggested that a systematic removal of the names and signatures within the cave be undertaken. However, discussions of this plan resulted in raising questions causing a review of the graffiti removal proposal. For example, which names should be kept? Should the names of historically significant individuals (such as Max Kaemper, Stephen Bishop, Gorin, Croghan, Willard Rouse Jillson, among others.) be kept, while all others removed? The graffiti removal proposal focused on those areas where the old graffiti was believed to cause modern tourists to deface the cave and other site specific management areas. Historic signatures, now recognized as a unique resource, offer insight into cave utilization and alterations. Additionally, they provide a basis for interpretive vignettes concerning historic tourism in the cave.

An historic signature in Mammoth Cave

Photo by Alan Welhausen

### Objectives of the Mammoth Cave Register Project.

It is the intent of the Mammoth Cave Register Project to search the tourist routes used in the 19th and 20th centuries and document each and every signature in a systematic way, tying those signatures into the existing Cave Research Foundation's survey grid and entering those data into a digital format that is machine readable on a number of platforms (DOS, Windows, Macintosh and UNIX) using standardized software (FileMaker). FileMaker can export data to most other database formats, including Microsoft's Access.

Concurrent research being conducted by this author is generating a picture of tourism and commercialization of the Historic Sections of Mammoth Cave in the 19th and early 20th century. Historic documents have demonstrated that there were essentially two principle tourist routes used during this period. These include the 'short' route and the 'long' route. Typically, the short route entailed entering the cave, traversing the Narrows, viewing the Rotunda, traveling Main Cave to the Church, passing the Giant's Coffin, traveling past Proctors Arcade and viewing the Star Chamber. The long route followed the short route to the Giant's Coffin. Just past the Giant's Coffin, the tour turned down-

ward toward the Rivers, down the Steps of Time, through the Deserted Chambers, to Gorins (and sometimes Minerva's) Dome, through the Winding Way, Fat Man's Misery, Great Relief, Bacon Chamber, River Hall, River Styx, across the Natural Bridge, Lake Lethe, Echo River, the Great Walk, Silliman's Avenue, through the Pass of El Ghor, to the Snowball Room, Cleveland's Cabinet (and various named niches) to the Rocky Mountains, into Croghan Hall and either to the Maelstrom or to Serena's Arbor. Through time there were minor variations of the long route that involved Penscolola Avenue, Mammoth Dome (from the bottom) and, in the late 19th century, the use of the Corkscrew (An Officer 1851; Anonymous 1852; Anonymous 1861; Anonymous 1866; Anonymous 1871; Anonymous 1879; Amell 1847; Barnwell 1849; Burroughs 1887; Farnham 1820; Finck 1898; Howe 1854; Hubbard 1880; Jones 1844; Knox 1875; Piatt 1887; Proctor 1898; Stevenson 1932; Stone 1879; Taylor 1860; Ward 1816; and Wortley 1851).

To date, most of the modern 'Historic Tour' route has been examined and recorded. However, passages to be yet to be examined include those that were part of the 'long' tour during the mid-and late-19th century. This includes completing the Pass of El Ghor, then data collection in the following passages: Mary's Vineyard, Washington Hall, Snowball Room (completed), Sophy's Avenue to Kennedy Domes, Cleaveland's Avenue (and various niches and stopping points), Dollar Pass, Clark's Avenue, Donna's Garden, Roger's Avenue to Olivia's Dome, Rocky Mountains, Croghan Hall, Dismal Hollow and Franklin Avenue to Serena's Arbor.

In addition, there are several notable areas of the cave that were toured in the mid 19th century on the short route that have not been examined, to date. These include: Solitary Cave, Fairy Grotto and Coral Grove. This portion of cave was shown in the mid-19th century, but appears to have stopped being shown in the late 1850s and early 1860s. Once these passage are examined, this should cover the majority of the cave as toured in the 19th century.

## **Project History**

In the late 1980s, this author conducted a names inventory in Serena's Arbor. This area of the cave was well documented as being the most distant location avail-

able to tourism in the mid to late 19th century. Analysis of the names and dates found in Serena's Arbor demonstrated that even those individuals who were not 'historically significant' left behind a record of visitation and though an individual signature might not be significant, collectively they represent a significant resource. Analysis demonstrated that signatures began appearing within months of the discovery of this area and continued at a regular rate until the descent of the Maelstrom. Analysis of the dated signatures showed that the cave was heavily visited during the months of August and September, the hottest months in Kentucky. In addition to the signatures proper, some text occasionally includes where the visitors were from. The signatures in this very distant and therefore very expensive tour showed that those visitors were non-local and indeed, most were individuals who had traveled great distances from large metropolitan areas who could afford this trip into the cave. Many of the individuals came from foreign countries to visit this 'Wonder of the World'.

Signature inventory languished after this very brief initial study, until Spring 1991, when Larry Pursell began to collect signatures in earnest. Pursell dubbed his project the 'Mammoth Cave Register'. Pursell was a seasonal guide who had gained a great amount of detailed information concerning the early tourism in Mammoth Cave. Using this knowledge, he began collecting signatures along many of the old tourist routes in the cave, beginning with Pensacola Avenue. Pensacola Avenue was chosen because it was extensively used in the past, yet is presently unused as a tourist attraction. This passage was used to develop and refine recording methods. This author assisted Pursell in organizing the data into a standardized digital format. Pursell moved to Marion Avenue, once Pensacola Avenue was completed. In 1992, Robert Parrish began working on the project while Marion Avenue work was being conducted. The 'Mammoth Cave Register' project then moved into: the Labyrinth, Snowball Room, Black Snake to Great Relief, Fox Avenue, El Ghor, and Lower Silliman's Avenue.

Pursell left the region in 1994, and the project continued to operate under Robert Parrish's direction. Parrish continued to gather signature information in Great Relief Hall, Sparks Avenue, Mammoth Domes, Little Bat Avenue, Audubon Avenue toward the Ro-

tunda, Broadway and the Wooden Bowl Room. This completed the modern Historic Tour Route. In September 1995, they began collection along Main Cave to the Blue Springs/Symmes Pit Branch area. The immediate intent was to finish the passage from El Ghor to Lower Silliman's, Lower Silliman's to Echo River, and the Main Cave passage to Violet City. This would have completed another segment of main trunk passage that was used, in the late 19th century, as tourist route.

In summary, the Mammoth Cave Register project has recorded all of the signature clusters from the following passages:

Audubon Ave (Little Bat Avenue to Rotunda)  
Black Snake Avenue  
Broadway  
Great Relief Hall the Labyrinth  
Little Bat Avenue  
Lower Silliman's Avenue  
Mammoth Dome  
Marion Avenue

Pensacola Avenue  
River Hall  
Rotunda  
Snowball Dining Room  
Sparks Avenue

Those passages that have been partially complete include Main Cave from Acute Angle to Blue Springs/Symmes Pit Branch, and El Ghor

The time taken to complete a single passage varies with a number of factors. Primary among those factors are: the length of the passage and the number of signature clusters present. Factors, such as ceiling height, expanses of smooth wall, and duration the passage was shown commercially. Passage complexity is another factor in determining how much time it takes to inventory an individual passage.

The in-cave work has been conducted by members of CRF. The grid location is recorded and all of the data has been gathered in the most efficient means possible.

# Geosciences

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## New Karst Connection in Mineral King Valley

*John C. Tinsley*

Scientists of the Cave Research Foundation (CRF) with the cooperation of the National Park Service recently conducted a groundwater trace in a tributary to Mineral King Valley using two tracing agents during late August and early September. Both tracers were detected at dilute concentrations at Tufa Spring, but dye did not appear at Eagle Creek. White Chief Creek enters closed depressions in lower White Chief valley, then apparently follows the trend of the marble bedrock northward beneath Tioga stage glacial deposits for a distance of 1.8 miles under the ridge that separates White Chief basin from Eagle Creek basin. The tracers emerge in about 3.5 days at Tufa Spring. The trace unifies and doubles the extent of the karst system located along the western flank of Mineral King valley. The results suggest geomorphic and hydrologic continuity of the marble bedrock. A fault mapped by others as offsetting the marble is thus questionable. Published maps of the geology of the western margin of Mineral King valley require minor revision to depict the new cave system correctly. A caver connection remains to be demonstrated.

This karst system was identified during the past two decades. In 1978, B.W. Rogers and J.C. Tinsley of the San Francisco Bay Chapter, NSS, used fluorescein dye to trace water from Eagle Creek Sink to Tufa Spring. This experiment established that the Eagle Valley drains via an unexplored karst system from south to north, and follows the marble bedrock along the western flank of Mineral King valley. In 1996, L. Schultz of CRF, wished to fulfill independent study requirements for W.B. White's ground water hydrology summer course at Western Kentucky University, and to complete a senior thesis at Sonoma State University. Tinsley and J. Despain, Cave Management Specialist at Sequoia and Kings Canyon National Parks, suggested that studying

the White Chief karst would be ideal. CRF had recently initiated a mapping and inventory project for Mineral King caves.

Schultz, Tinsley, and Despain successfully repeated the 1978 Eagle Valley-Tufa Spring trace, and Schultz established baseline hydrochemistry, linkage, and travel times for ground water within the karst of White Chief Valley proper. Tinsley had mapped a linear array of small sinkholes that extended from lower White Chief Valley across an intervening ridge nearly one mile northward to Eagle Creek and Eagle Sink. This train of sinkholes suggested that a much more extensive alpine karst system lay hidden under late Pleistocene morainal deposits. By this time, snow was imminent at the elevation of nearly 10,000 feet. A late-season, rather desperate dye trace from White Chief Basin to Tufa Spring failed, presumably owing to insufficient dye, adsorptive losses in the soil in White Chief Basin, relatively high volumes of storage in the karst aquifer, and dilution of the signal owing to the large flow from Eagle Creek.

In 1998, armed with 20/20 hindsight, Tinsley, B.F. Lyles, A. Wilson, Schultz, and S. Toprak used eight pounds of fluorescein, charcoal, ten pounds of sodium chloride, and a Campbell 21-X data logger, an electrical conductivity probe, and a thermistor to repeat the 1996 experiment when the entire discharge of White Chief Creek was flowing into the input sink. Although diluted, the salt pulse raised the conductivity measurably in Tufa Spring; Nick Crawford's laboratory in Bowling Green, KY, confirmed fluorescein at 800 parts per trillion. The salt pulse's transit time was 3.5 days. Bugs from Eagle Creek placed below Eagle Sink were negative at the late summer levels of discharge.

## Middle To Late Wisconsinan Vegetation Change At Little Nankoweap, Grand Canyon National Park, Arizona

Larry Coats  
Northern Arizona University

Previous investigations of dry caves and sheltering ledges on the Colorado Plateau have revealed extensive deposits of archaeological and paleontological resources. The dry climate and protection from moisture at these sites have resulted in excellent preservation of plant and animal remains providing considerable paleoecological information. These caves and crevices, commonly contain botanical materials (Fig. 1) preserved in packrat (*Neotoma* spp.; Rodentia) middens (nest and den waste accumulations) frequently dating to the late Pleistocene. Deposits older than 25,000 yr BP are relatively rare. A review of published midden records found that only 2% (3 out of 151) of middens from the Colorado Plateau exceeded 25,000 yr BP in age.

Twenty-two packrat middens, dating from 46,000 to 10,000 radiocarbon yr B.P., were collected from seven cave sites in Little Nankoweap, Grand Canyon, Arizona. These middens were analyzed for floral macrofossils, and provide important data on the nature of vegetation change over 40,000 years. Six middens yielded a mid-Wisconsinan age, dating from  $29,980 \pm 300$  to  $46,370 \pm 3270$   $^{14}\text{C}$  yr B.P. These are the oldest dates for middens found in the Grand Canyon (Fig. 2), and allow examination of plant communities that were present prior to and during the last glacial maximum. Two sequences of dates were obtained from two cave localities, with ages ranging from  $13,970 \pm 90$  to  $46,370 \pm 3270$   $^{14}\text{C}$  yr B.P. for Rebound Cave (6 dates) and  $18,120 \pm 100$  to  $44,480 \pm 1700$   $^{14}\text{C}$  yr B.P. (5 dates) for Crescendo Cave. Information derived from the midden assemblages surpasses any research previously done pertaining specifically to mid-Wisconsinan paleoenvironments in Grand Canyon. The information generated by this study both supports and refutes findings by other authors who have examined similarly aged botanical materials from the Colorado Plateau.

The vegetation record from Little Nankoweap indicates relatively mesic conditions throughout the duration of the record, with *Chamaebatiaria*, rose,

*Holodiscus*, *Prunus*, and *Symporicarpos* all present from 46,000 to 10,000 yr BP. All of these taxa retreated upward in elevation or to more mesic settings some time after the end of the Pleistocene. The Wisconsinan full glacial is clearly signaled at Little Nankoweap by the arrival of four tree and shrub taxa. Seeds of *Acer glabrum* were recovered from three midden samples (19,050-16,610  $^{14}\text{C}$  yr BP), and this species is currently distributed at elevations of 2379 m and higher within the Grand Canyon, suggesting a maximum vertical displacement of 1200 m during the full glacial. Very small samples of *Juniperus communis*, *Ostrya knowltonii*, and *Ptelea trifoliata* var. *pallida* were found in middens dating to  $24,570 \pm 160$ ,  $20,310 \pm 130$ , and  $19,050 \pm 100$ . *Juniperus communis* is a prostrate shrub commonly found in conifer and aspen forests at elevations of 2250 m and higher, indicating vertical displacement of almost 1100 m for this species. *Acer glabrum*, and to a lesser

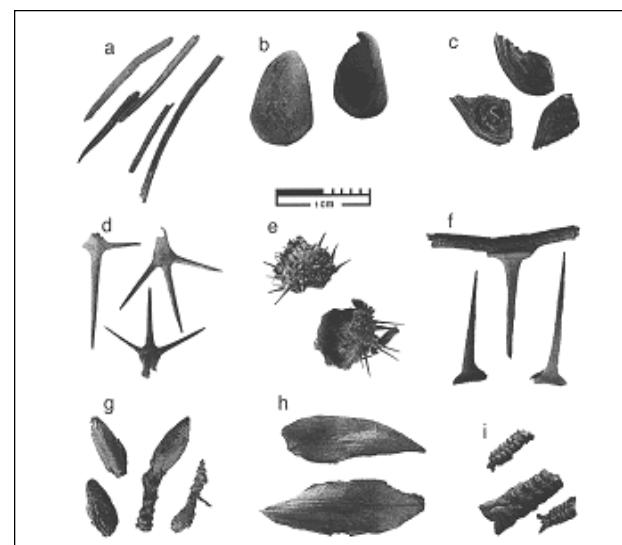


Figure. 1. Selected plant macrofossils from Little Nankoweap samples. (a) *Pinus flexilis* fossil needles and (b) seeds. (c) Fossil samaras of *Acer glabrum*. (d) Fossil trident spines of *Ribes* cf. *pinetorum*, and (e) fruit. (f) Fossil thorns of *Rosa* cf. *stellata*. (g) Fossil leaf buds of *Chamaebatiaria millefolium*. (h) Fossil samara and (i) terminal buds of *Fraxinus anomala*. Photos are shown at 3X magnification (note scale).

extent *Juniperus communis*, are limited in their lower elevational ranges by maximum temperatures, as well as moisture availability. *Ostrya knowltonii* is found as low as 870 m in the Grand Canyon today, but always near water sources. Likewise, *Ptelea trifoliata* var. *pallida* ranges as low as 600 m in moist side canyons and riparian environments. Greatly increased moisture availability would be required to explain the presence of *Ptelea* and *Ostrya* on the ledge systems in Little Nankoweap. To produce a hanging garden environment at this extremely exposed site, great increases in precipitation would be required, as well as increased effective moisture due to depressed temperatures. No aquifer or substantial thickness of soil exists above these ledges, so long-term storage of water is not possible; thus, cool but dry conditions cannot accurately describe this paleoenvironmental setting.

As in most other glacial-aged middens from the desert southwest, Little Nankoweap exhibited a disharmonious mix of taxa during the Wisconsinan, with many desert species present throughout the record and persisting at the site to the present. Macrofossils of *Coleogyne*, *yucca*, *Atriplex*, *Chrysothamnus*, *Fraxinus*, and *Juniperus osteosperma* are found in samples from all time periods, and with the exception of *J. osteosperma* which has retreated upward. The final shaping of the modern community must have occurred after 10,260 yr BP, the youngest midden sample, with loss of fernbrush, rose, snowberry, and rabbitbrush from the site caused by subsequent drying and/or warming.

These results indicate remarkable stability in the plant communities present before and during the last glacial maximum in Little Nankoweap, Grand Canyon. At least 11 species (47%) are present for the duration of the entire record. The available floral evidence indicates that climatic conditions in Little Nankoweap during the mid-Wisconsinan were cooler than present, and substantially wetter.

The Middle Wisconsinan environments of the Colorado Plateau are poorly known in comparison to full glacial and late glacial environments. New data from this study suggest that plant distributions and climatic regimes indicate a surprisingly high amount of precipi-

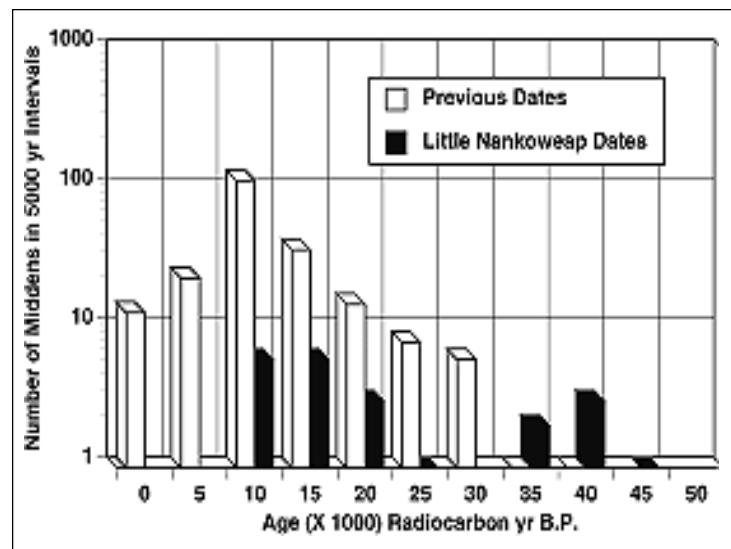


Figure 2. Comparison of Little Nankoweap midden radiocarbon dates with published midden dates from all other sites in the Grand Canyon. Note log scale.

tation in the southern and lower elevations of the Colorado Plateau. Clearly noted in the packrat midden record from Grand Canyon National Park is confirmation of the individualistic response of plant species to changes in climate that has been noted by numerous researchers. Plant species responded to climate change by adjustments to their range of elevational distribution based upon individual criteria. In this way, past assemblages were formed that are considered anomalous by modern comparisons, and modern assemblages can seem anomalous by past comparisons. Trees and shrubs ranged in depressions of elevational range from no apparent depression (*Atriplex* sp., *Cercocarpus intricatus*, *Coleogyne ramosissima*, *Fraxinus anomala*, *Opuntia* sp., *Yucca angustissima*) to as much as 1200 m (*Ribes cf. pinetorum*, *Picea pungens*, *Pinus flexilis*, *Acer glabrum*). Also notable is the fact that desert scrub and succulents remained at the sites and were not absent during stadial episodes.

### Acknowledgements

The Little Nankoweap middens were collected under permit from the National Park Service, and analyzed with support from the National Geographic Society Grant No. 5422-95, the Cave Research Foundation, and the Geological Society of America.

# GIS Program

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## Cave and Karst Information Systems (CKIS) Workshop

*Mike Yocum, Program Director*

The Cave Research Foundation's Geographic Information Systems Resource Development Program (GISRDP), in cooperation with the Kentucky Office of Geographic Information Systems (OGIS) convened a CKIS Workshop at OGIS offices in Frankfort, Kentucky on November 12-13, 1998.

The workshop was devoted to discussing common GIS goals and problems, as well as individual needs of the participants, who were: Dan Carey (Kentucky Geological Survey), James Currens (Kentucky Geological Survey), Alan Glennon (Center for Cave and Karst Studies), Peter Idstein (Ewers Water Consultants), Ronald Kerbo (National Park Service), Teresa Leibfreid (National Park Service), Joe Meiman (National Park Service), Joseph Ray (Kentucky Division of Water), John Schmidt (NCAD Corporation), Ted Stumbur (Kentucky Office of Geographic Information Systems), Bernard Szukalski (ESRI and CRF), and Mike Yocum (CRF).

The meeting began with a demonstration by Szukalski of some of the possible uses of ArcView GIS, an Environmental Systems Research Institute (ESRI) software product, for managing, querying and analyzing data. Although hindered by a lack of sufficient cave and karst data to fully demonstrate the range of uses of the software, Szukalski's presentation was nevertheless impressive. Most participants were especially interested in the potential for data query, analysis and visualization in three dimensions, even though no GIS software is yet capable of full three dimensional functionality.

The demonstration occupied most of the morning. During the afternoon participants discussed the methods they currently use for managing cave and karst data. Computer hardware systems in use are DEC-VMS, Sun workstations, and Windows 95/NT PCs. Other hardware includes handheld GPS units, various Trimble backpack units, radio location devices, and traditional surface surveying instruments. Software included Arc/INFO, ArcView, Quattro Pro, Excel, Sigma Plot, AutoCAD, Access, FileMaker Pro, Advanced Revela-

tion, Sybase, SQL, Datatrieve, and the cave survey programs SMAPS, Compass, Walls, and CML. Paper was also a medium for data processing, analysis, and storage.

The types of data collected included date, time, yes/no (presence or absence of data item), feature type (e.g., swallet), matrix, x-y coordinates, x-y-z coordinates, flow velocity, discharge rate, solute concentration, temperature, specific conductance, pH, stage (level), relative humidity, wind speed, wind direction, evaporation rates, number (e.g., of a species), air quality indicators, and microgravity readings. In addition to the spatial, hydrological and geological data collected by most participants, Mammoth Cave National Park staff also collect a wide range of biological data for vegetation, fire management, and numerous other studies.

The use of the EPA's MAD (Method Accuracy Description) Information Coding Standards was mentioned as being required in some instances when collecting locational data. It was also noted and discussed that some commonly used USGS data types (DLGs, DEMs) are rapidly becoming available only in Spatial Data Transfer Standard (SDTS) format and that support for these formats is incomplete.

The following morning began with a discussion of participants' projects, and how the data types and processing methodologies discussed on the previous day are used in these projects.

The workshop concluded with a discussion of the requirements for developing a prototype CKIS project. Topics suggested for inclusion or consideration in developing a cave and karst information system were: 1) the questions that researchers seek to answer by querying data, 2) data layers (themes) that might be included, 3) existing types and formats of data, 4) a "candidate" list of suggested data fields, along with their source, 5) metadata, and 6) a need for systems management and support in developing cave and karst specific GIS applications.

# China Caves Project

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## China Caves Project Expedition to Guizhou Province Guado and Da Fong Area

*Paula Ledbetter*

A team of CRF cavers left from all parts of the United States on March 14, 1998 to begin the multi-day, multi-forms-of-transportation trip to the other side of the world. The team: Ian Baren, Roger Mortimer, Ann and Peter Bosted, Paul Massey and Paula Ledbetter. The mission: to work with Chinese scientists. The purpose: to assist the students and professors of the Geography Department of Guizhou Normal University in their cave research, to further the understanding of hydrogeology and geology of the local cave systems, and to apply that knowledge to issues dealing with agriculture and tourism.

The journey to Guiyang, the capital city of Guizhou Province in south central China was via New York City, Vancouver, Canada, and Hong Kong by plane, taxi, bus, and automobile. Our hosts greeted us warmly at the

airport. We were received at the university guesthouse with a customary banquet dinner

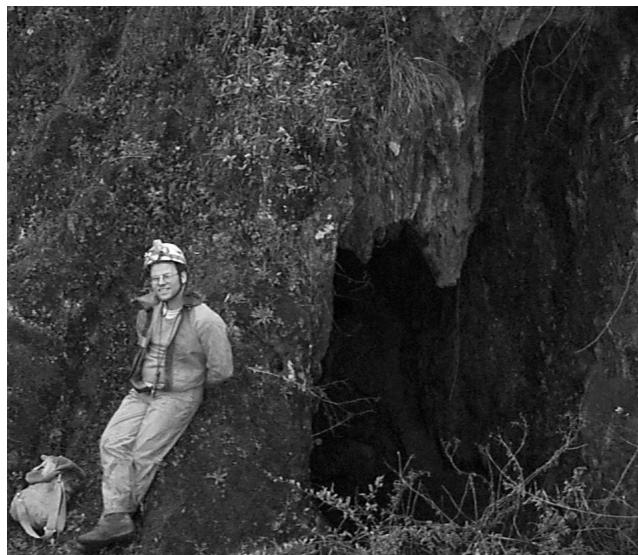
### Return to the Guado Area

We spent a day in the city making last minute purchases and doing a minimum of sight-seeing. We were anxious to get out into the field. Our Chinese hosts had rented a bus for our gear and us. We departed one overcast morning for the village of Guado, a region in which previous CRF expeditions had worked. We stopped in a town on the way to pick up the rented cotton mattresses for our beds for the next couple of weeks. We arrived in the village of Guado with another warm welcome from all of the village people.

This village had been host to four previous CRF expeditions and knows cavers' habits well. Our housing was the second floor of an old government building which was made of concrete block wall and floors, and a wood timber and slat framed roof with slabs of limestone for shingles.

We had five rooms, one of which was the kitchen. It had a stove cooking hearth and potbelly stove with wood benches around it. This was the gathering area for cooking, eating, reading, doing laundry and computer work. The rest room was an eight-holer across the street, which the entire village used. Water was brought to us in gallon plastic jugs carried up from the river. We boiled all of our drinking water and kept a thermos and wash basin in our rooms. The pallets on the floor were fairly comfortable.

The first week the weather was rainy and overcast, and the nights were cold. But springtime soon set



Roger Mortimer at Chiu Feng Dong.

Photo: Paul Massey

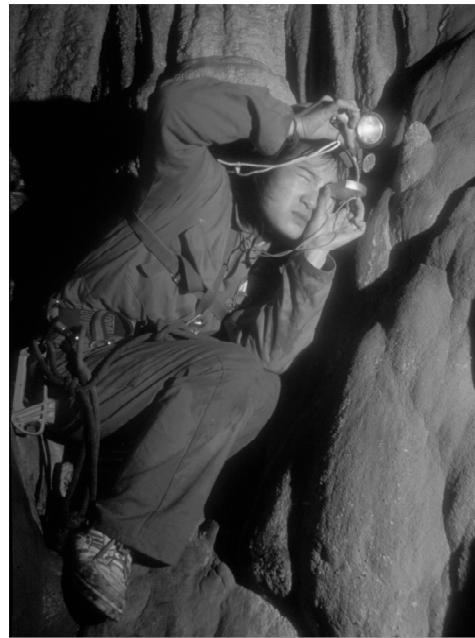
in and the days were sunny and nights cool. The cherry trees were in bloom, creating a touch of pink across the landscape. The fields were blazing bright yellow from the blooming rape seed.

Chui Feng Dong (Blowing Cave) is a multi-drop cave with two large lakes and lots of mud. There are large draperies at the entrance drop of approximately 120 feet. The cave passage cascades downward in flowstone and rimstone slopes. The first lake was rigged with a line traverse. The second lake did not require a traverse line. Beyond the second lake, the cave passage becomes drier, with large breakdown passage. There is a rappel through a narrow canyon into the connecting walking passage. The small walking canyon opens up into a junction room. It was at this junction on the last day of the previous expedition, in the spring of 1996 that Don Coons discovered the large, high passage, which was left for our expedition.

The obvious passage is straight ahead and down to the roaring river below. This is the connection point of Chui Feng Dong to Dou Bin Dong (Hiding Soldiers Cave). The large river cave resurges at the base of the river canyon. The locals had known about both caves, but did not know that they connected until our survey

Each morning we would get up, eat breakfast, grab our cave packs, and start walking to the cave entrance. We rigged the cave the first trip in. A couple of the trips we spent one or two nights in the cave to survey a large passage discovered the last day of the previous expedition. This passage was tied into surveyed passage and the cave was completed. In addition to the survey of Chui Feng Dong, several other caves were found nearby and mapped.

In addition to exploration and survey, we set up a couple of training sessions for the Chinese cavers who had never been on rope. This proved to be one of the greatest challenges. The gear that the Chinese have is all donated gear belonging to the university. So each person had to adjust their gear to fit them. The training involved overcoming the fear of heights, trusting the rope, trusting themselves, and the technical aspects of rappelling and climbing.



Teaching our Chinese hosts to survey,  
Photo by Peter and Ann Bosted

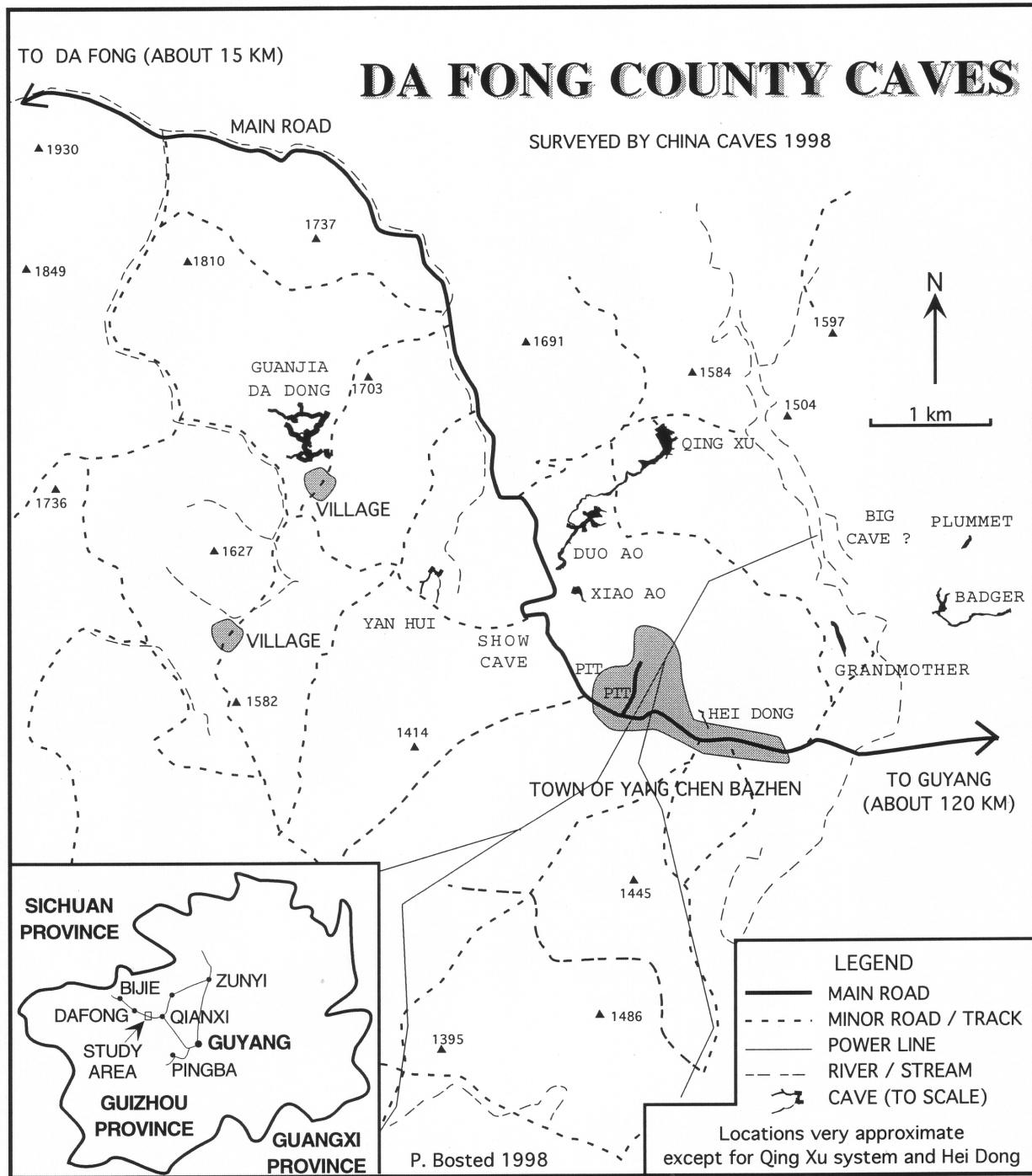
The language barrier becomes more critical in technical situations. Although most of the Chinese cavers spoke some English, only one of our team members spoke Chinese. Visuals, understanding, and patience become great tools in these situations.

The village people were very friendly to us. They showed us caves and took us to an area built around the remains of a castle fortress constructed during the Ming Dynasty. The children sang songs for us. And, yes, we sang a few for them. The food was delicious!

### New Frontiers

Our Chinese leader felt that we had completed our work in this area and that it was time to move on. He had been on scouting and politicking trips in the Da Fong region (Figure 1) located several hours north of Guadou.

When we arrived at the new area, the accommodations seemed like the Ritz compared to our previous stay. The building was a government structure, which had been built as a weekend home for Chaing Kai-shek, leader of the Nationalist Regime who is now in



Taiwan. We had several rooms on the second floor with wood frame beds, glass windows, and a door with a lock. The kitchen and bath were across the court-house on the lower level.

The first day we were to tour the area in jeeps with the local officials. They were going to show us

the caves. I did not have high hopes for this adventure, as the officials looked like they never walked farther than from their car to the house. I was to be proven wrong. The first stop was a 40-foot diameter pit in the village. It was overgrown making it difficult to determine the depth. We never got around to bottoming this pit.

The next stop was at a nondescript roadside with no remarkable features. Our hosts pointed up a small hill. We hiked up the hill and looked down approximately 500 feet into a beautiful canyon with two large cave entrances at either end. The next stop was a show cave. It was unlike our show caves – in particular, the power had gone out, so we toured most of the cave with our Mag-lites. The power came on near the end of the trip, exposing to clear view all of the electrical cables which were located on the cave floor beside the pathways. The lighting consisted of large spotlights, which our guides moved as we walked on the trail.

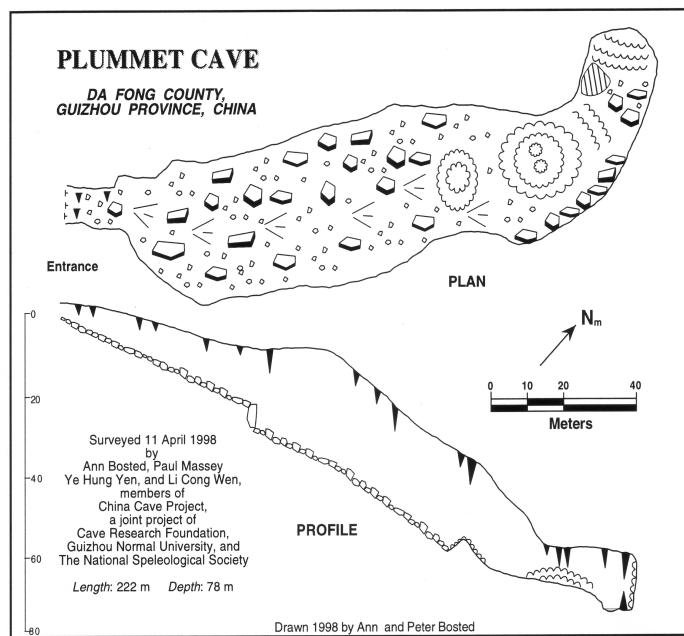
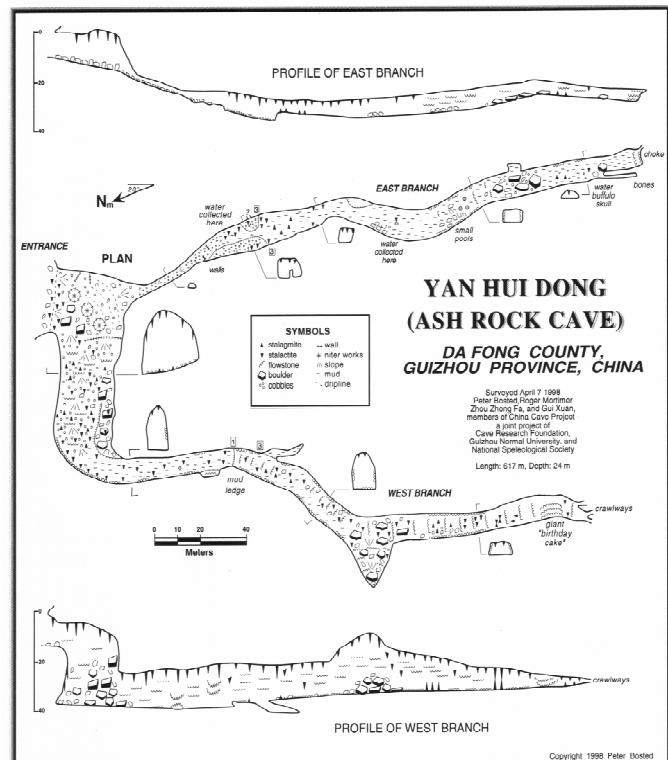
The next stop for the day was to a tall limestone arch. The outside height is approximately 300 feet, and the inside height probably 200 feet. Just past the arch is a 200-foot diameter open air, collapsed room. A stream flows under the arch, through the room, and into the cave entrance at one side of the room. The village people use this area for ceremonies. The cave is often toured by locals.

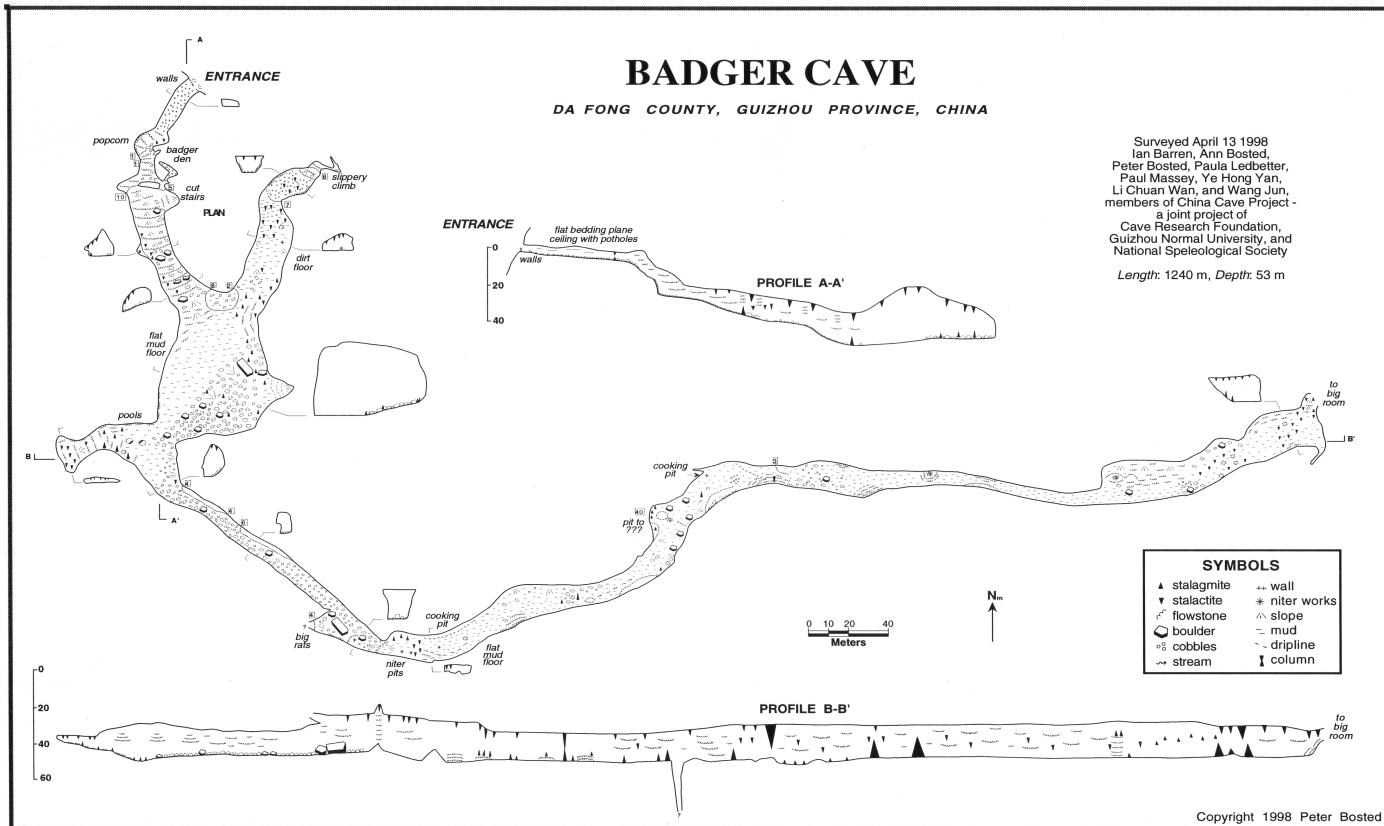
These three caves became our focus for the next few days. What we discovered is that the arch cave and the two caves in the collapsed canyon are one cave system. The character of this system varies greatly from walking passage with a stream and breakdown, to high dry passage with formations, to roaring river canyon passage. The people have used the cave for centuries for many applications. These included fortressing from the soldiers, mining nitrate, and mining cave formations.

### Epilogue

Ridge walking and talking to the locals was profitable. We surveyed three other caves, and one other large system. (Plummet, Badger and Yan Hui Dong) The total surveyed length in this region was approximately nine kilometers. None of the resurgences for these systems were surveyed. There are many caves in this area. I look forward to the next expedition.

We took one other tourist trip to the Hundred Miles of Flowers. This is a state park encompassing several hundred acres on hilltops with rhododendron bushes everywhere. These trips are important to the Chinese





to be good hosts. They also build strong friendships between the American cavers and our Chinese hosts.

The last day we packed up our gear, loaded onto the buses, and went to the city of Da Fang to present to the officials our findings and comments. We had been entering our cave data on the laptop computers every night (no matter how tired we were). We showed them our survey notes, how we used the survey equipment, and the plan and profiles of the caves on the computer. They were impressed. It was also important to them to hear our comments on their local show caves, how they could improve tourism, and the hydrological and geological reports on the caves of the area. They stated that they were pleased with our work and look forward to our return trip.

The last day in Guiyang was spent purchasing a few souvenirs, and discussing the exchange for the Chinese cavers to come to the United States for the Idaho Convention in 1999. A farewell banquet was given the last night, and our hosts put us on the plane to Hong Kong the next morning. We took a few days touring Hong Kong and relaxing.

The 1998 CRF China Expedition was a great success. There were a few mishaps that we overcame. There was a lot of huge, beautiful cave surveyed and photographed. Some strong, new friendships were established and old ones enriched. I feel fortunate to have been part of this expedition and look forward to future expeditions to China.



## **Cave Research Foundation Activities 1999**

## **Cave Research Foundation Directors**

**1999**

Patricia Kambesis President	Dick Maxey Hamilton Valley Project
Paul Cannaley Treasurer	Chuck Pease International Projects
Peter Bosted Secretary	Bob Osburn (through September 1999)
Phil DiBlasi National Personnel Officer	Chris Groves Fellowships and Grants Program (through February 1999)
Rick Toomey Fellowships and Grants Program	Harvey DuChene (April -October 1999)

## **Operation Area Managers**

Eastern Operations Area: Dave West

Southwest Operations Area: Barbe Barker

Lava Beds Operations Area: Janet Sowers

Ozark Operation Area: Scott House

Sequoia Kings Canyon/Mineral King  
Operations Area: John C. Tinsley

# **1999 Highlights** *Compiled by Patricia Kambesis*

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## **CRF Research and Field Station in progress**

A decade-long effort to secure land and raise funds for a CRF headquarters and Eastern Operations Field Station is now moving forward. On September 8, 1999, CRF President Pat Kambesis signed a Letter of Intent to begin construction of the Hamilton Valley facility. Pouring of the concrete footers and walls, laying out power lines, and septic system construction is underway.

A significant amount of work still remains and much of that will be done by CRF members. These tasks include building in beds, shelving, ad heating/cooling systems in the bunkhouse and furnishing the kitchen. Stan Sides and Randall Hatfield will install the well pump, water lines and pressure tank with the assistance of the Building Committee. Stan and Kay Sides also generously provided permission to run the electrical lines across their land which adjoins CRF's property. The utility building, constructed totally by volunteer CRF labor is now nearly completed.

## **Annual Members Meeting Held**

The 1999 CRF Annual Members' Meeting was held on October 23 at the Radisson Read Hotel in Chattanooga, Tennessee in conjunction with the 14th Annual Cave Management Symposium. Thirty CRF members attended a luncheon which took place following the Annual Board/Operations Council Meeting. CRF President Pat Kambesis presided. The guest speaker for the luncheon was Ronald Kerbo who provided an update on the National Cave and Karst Institute. CRF project and area reports followed the talk. Richard Maxey, Hamilton Valley Building Committee reported on the current construction. Dave West, Eastern Operations Manager reported on CRF projects throughout the Central Kentucky karst, including Hidden River Cave (in association with American Cave Conservation Association), Roppel Cave (in association with the Central Kentucky Karst Coalition) and about the ongoing activities within Mammoth Cave National Park.

Pete Lindsley reported on Fitton activities for 1999. Scott House summarized Missouri Operation activities in the Ozark Scenic Riverways and Mark Twain National Forest. Other cooperative activities during the year have been with the Missouri Department of Conservation and Natural Resources, the US Geological Survey, the Missouri Speleological Survey, and with private land owners.

Peter Bosted reported on activities in Sequoia and Kings Canyon National Parks as well at Lava Beds National Monument. The Lava Beds Operation held the first public showing of their virtual reality cave tour, currently being shown at the Oakland Museum of California in the Underground Worlds exhibit.

The next Annual Members Meeting will be held in St. Louis Missouri in October of 2000.

## **CRF Fellowships Awarded**

CRF Fellowships are given to CRF members in recognition of outstanding contributions to the study, conservation and interpretation of caves. This year, CRF Board elected Dave West and Karen Willmes for their long-standing contributions to CRF.

## **CRF Newsletter Editor Changes**

Candice Leek, who has served as CRF Newsletter editor for the past several years, has stepped down from that position. The Foundation appreciates her efforts in producing a timely and newsworthy publication. Paul Nelson, a CRF member from California will take over as the next CRF Newsletter Editor.

## **Arkansas and Missouri Operations Areas Merge**

In 1999, the Arkansas Operation Area and the Missouri Operation area joined and formed a new entity called the Ozark Operation Area. Scott House will serve as the operation manager for the

new entity. Pete Lindsley will continue to serve as project manager for Fitton Cave.

### **CRF and Missouri Department of Conservation Educational Program “On Becoming an Outdoors Woman”**

The Missouri Department of Conservation, under its program entitled “Becoming an Outdoors Woman” offers introductory education courses in areas such as archery, camping, and this year, caving. This was the first such offering and CRF was invited to participate. Sue Hagan served as CRF’s representative as a co-instructor for 3 days in August. Approximately 20 women signed up for the course which was held at MDC’s Presely Center on the banks of the Current River. Sue instructed on elementary caving and, along with Bill Elliott, gave an overview on cave biology. The three day course featured in-cave-hands on experiences for the participants.

### **CRF-CKKC Partnership**

In June of 1999, CRF and the Central Kentucky Karst Coalition (CKKC) entered into an official partnership in order to continue to support our mutual objectives (exploration, survey, research) in Roppel Cave and to develop more objectives and projects outside of Mammoth Cave National Park. CKKC will continue to provide objectives to Eastern Operation expeditions and will field their own expeditions from Hamilton Valley.

### **Fund-raising in Progress for Lava Beds Research Center**

In April of 1998, CRF signed a Memorandum of Agreement with the National Park Service and the Lava Beds Natural History Association to raise the funds to build a small research facility on NPS property at Lava Beds National Monument. In 1999 the fund-raising phase was in full swing with a deadline of April 2001. The proposed new facility will provide a base for research activities to be conducted at the Monument.

### **ESRI Grant Awarded to CRF**

CRF’s GIS Resource Development Program (GIS RDP) has been awarded a grant of software val-

ued at approximately \$16,400 from the Environmental Systems Research Institute (ESRI). The software includes: ArcView 3.1, Spatial Analyst, 3D Analyst, Data Automation Kit, Atlas GIS and ArcPress. The software will allow our GIS RDP to demonstrate and share with other agencies, organization and individuals the value of GIS technology for the purpose of cave and karst resource management.

### **14th Annual Cave and Karst Management Symposium**

The 14th Annual Cave and Karst Management Symposium was held in Chattanooga, Tennessee on October 19-22, 1999. The symposium was hosted by the Southeastern Cave Conservancy, Inc. (SCCI). CRF is one of the sponsors of the symposium which is held every other fall. The event brings together agency, academics and individuals involved with cave management, research and conservation.

CRF members who presented and/or coauthored papers included Ann Bosted, Rane Curl, Alan Glennon, Jim Goodbar, Chris Groves, Horton Hobbs III, Pat Kambesis, Ernst Kastning, Karen Kastning, Ronal Kerbo, Julian Lewis, Rick Olson, Bill Putnam, Patricia Seiser, Bernie Szukalski, Rick Toomey, and Mike Yocum.

The theme of this year’s symposium was “Living with Caves and Karst.” The keynote speaker was Ronal Kerbo, national cave management coordinator for NPS. His speech, “Conservation and Protection of Caves - a Retrospective,” stressed the importance of education of the general public.

At the concluding banquet, George Veni, a hydrologist specializing in caves and karst, discussed “Living with Caves and Karst: an Historical Perspective toward the Future.” The closing address was given by author-caver Michael Ray Taylor. His new book, *Dark Life*, discusses microbial life found in caves including the work of CRF member Diana Northrup.

### **CRF Session at the NSS Convention**

To increase visibility of CRF activities and to provide information on CRF research aimed at the gen-

eral audience, Pat Kambesis organized a CRF session at the 1999 NSS Convention in Filer, Idaho. This was the second year that CRF has held a session at an NSS convention. Peter Bosted chaired the session.

The first talk was given by Rick Toomey on "Paleontology at Mammoth Cave". Bernie Szukalski's talk on CRF's GIS Resources Program, outlined the work being done by Bernie, Mike Yocum and Aaron Addison. Peter Bosted talked about Lilburn Cartography. Patty Jo Watson gave a presentation on CRF's Archeology program. Bill Devereaux gave an update on Lava Beds Research and made a fund-raising plea for the proposed Lava Beds Research Center. Bill Frantz gave a Mineral King project update.

The last twenty minutes of the talk were spent answering questions about CRF and letting the audience know that CRF is interested in new members and new research projects. Rick Toomey gave an overview on our Fellowships' program and Roger McClure talked about Cavebooks. The session was very well attended, and CRF plans to continue holding the same type of session at future conventions.

### **GIS Resource Development Program**

Mike Yocum named the following individuals to the GIS RDP committee: Aaron Addison, Gary Fisher, and Bernie Szukalski. Yocum continues to serve as the director of the program.

At the 1999 NSS Convention, Bernie Szukalski gave a GIS presentation for the CRF session as well as giving a paper (coauthored by him and Mike Yocum), to the Geography and Geology Session of the Convention titled "Developing a Cave and Karst Information System using ArcView GIS." In July 1999, Yocum attended a week-long user group conference sponsored by the Environmental Systems Research Institute. During the Cave and Karst User Group meeting, he gave a brief overview of CRF's GIS activities. Later in the week, he gave a talk to the National Park Service User Group meeting. In October, Yocum also presented a paper at the National Cave and Karst Management Symposium in Chattanooga, Tennessee. The GIS RDP continues to provide consultation and GIS services to an archeological investigation of the former Collins property on Flint Ridge which is being conducted by Phil DiBlasi.

CRF's GIS display and demonstration were part of Kentucky's official GIS Day activities held at the Legislative Research Commission at the state capitol. CRF provided hard-copy handouts that the state Office of Geographic Information printed and made available to participants of the demonstration.

### **Educational Resource Development Program (ERDP)**

In July, CRF's ERD Program began working under a cooperative agreement with Mammoth Cave National Park to shoot video footage that will be incorporated by the Park's Division of Interpretation and Visitor Services into a display at the Visitor Center next year. The project, which will continue through Spring 2000, involves shooting selected sites on nine tourist routes with an emphasis on informing the public about potential safety issues. Mike Yocum is in charge of the project for CRF.

### **1999 Research Fellowships and Grants**

CRF received eight proposals for 1999 and all were funded: one fellowship and seven grants totalling \$9500 distributed as follows:

#### **High-Resolution Paleoenvironmental Record Since the Last Glacial Maximum based on Speleothems from California**

Kathleen R. Johnson, Department of Geology & Geophysics, University of California, Berkeley, CA  
Fellowship Award amount: \$3500

**Project Summary:** The researcher has collected speleothem samples from Moaning Caverns and California Caverns in the central Sierra Nevada foothills, California which contain a detailed, but as yet unexplored record of past climate change over hundreds to thousands of years. Geochemical variations along the growth axes of these samples reflect changes in climate at the time of calcite precipitation. My analysis of these variations combined with precise U-Th dating will provide a continuous high temporal resolution record of precipitation and temperature changes in California as far back as the last glacial maximum (LGM,) about 18,000 years ago. Oxygen (18O/16O), carbon (13C/12C), and strontium (87Sr/86Sr) isotopic compositions

will be determined for stream, drip and spring waters to test how they are recorded in speleothem growth bands. In addition, a high-precision three-dimensional digital map of the caves and surrounding geology will be created to aid in our understanding of the local hydrology. Oxygen isotopic variations will be carefully interpreted in terms of past temperature changes. A groundwater isotopic evolution model will be applied to the carbon and strontium isotopic data in order to reconstruct paleohydrologic environments. High-resolution time series such as these are very important in understanding the natural variability of the climatic, hydrologic, and ecologic systems in California on long time scales. This information may help lead to improved climate models and hence improved predictions about future climate changes. Speleothems potentially contain the most complete record of past environmental change in central California, and their study will provide a valuable complement to other climate records.

#### **The Yalahau Archaeological Cave Survey.**

Dominique Rissolo, Department of Anthropology, University of California, Riverside, CA,

Amount of award: \$1500

**Project Summary:** The Yalahau Archaeological Cave Survey was created to evaluate the nature and extent of ancient Maya cave use in northern Quintana Roo, Mexico, and to better understand the relationship between cave sites and surface sites across the region. Within the twenty caves located so far, the survey has identified evidence of ancient Maya activity such as: deposits of pottery and other artifacts, shrines, architectural features, breakage and removal of speleothems, quarrying, and rock art. Recent research efforts have focused on detailed mapping and the recovery of archaeological material. An upcoming analysis of the ceramic collection will reveal important chronological and functional information. This study hopes to provide new insights into the ancient tradition of cave use in the Maya area as well as contribute to the expanding corpus of archaeological and geographic data on the Yalahau region.

#### **Mechanisms and timing of trace metal transport in a karst aquifer: Impacts on spring water quality**

Dorothy Vesper, Penn State University, State College, Pennsylvania, Amount of award: \$1000

**Project Summary:** In karst systems, springs are one of the most likely locations for human and ecological receptors to be impacted by potentially toxic substances. Not only have springs been long utilized by humans, but they also form a unique freshwater habitat for flora and fauna. Knowing when, how, and at what magnitude trace metals are discharged at springs is vital in understanding the potential impact of metals on karst spring ecosystems: metal concentration and speciation must be considered because they control toxicity and bioavailability. To address this question, I have designed a field study which incorporates environmental chemistry at input (soils), transmission (spring water samples through a storm event), and output (spring sediments). The study will be conducted at the Fort Campbell Army Base in Kentucky-Tennessee. The springs chosen for the study have been traced from potential contaminant source areas and have well-documented flashy responses. The analytical techniques have been chosen to indicate the form of the metals as well as their concentrations. Analysis of water samples collected over a storm event will indicate temporal variability. The results of the study will help karst scientists to understand the links between karst hydrogeology, spring chemistry, movement of sediments in karst systems, and karst spring ecology.

#### **Use of Molecular Genetics to Trace Aquifer Interconnectedness.**

Jean Krejca, Zoology Department, University of Texas,

Austin Texas, Amount of award: \$1000

**Project Summary:** The goal of this project is to use the genetic relatedness of stygobitic organisms to determine the hydrological connections of the aquifer they inhabit. In regions such as the Edwards Aquifer, faulting makes it difficult to reconstruct aquifer interconnectedness from surface geology and well data. Dye tracing is impractical because of the large size of the aquifer. One technique that shows promise for sorting out the interconnectedness of the aquifers is looking at the genetic relatedness of certain stygobites. This project will test the use of the technique in both a fairly well-characterized setting (central Kentucky) and a more complex, less understood setting (central Texas and northern Mexico). One hypothesis that will be tested is that the Rio Grande River is a barrier to genetic and hydrologic connectivity between central Texas and northern Mexico.

**Sediment Composition and Preservation of Macrobotanical Remains at Mounded Talus Shelter (15LE77), Lee County, Kentucky**

Katherine Mickelson, Department of Anthropology, The Ohio State University, Columbus, Ohio, Amount of award: \$750

**Project Summary:** This research will focus on sediment composition and the preservation of macrobotanical remains at the Mounded Talus Rockshelter, Lee County, Kentucky. Mounded Talus Shelter is one of many documented rockshelter sites with unusual environmental conditions leading to the preservation of normally perishable remains, especially plants, that provide an important data set upon which inferences of past subsistence strategies and environment are made. Although previous research in the region has documented that the environmental composition of these rockshelters is highly variable and that there is a high degree of differential preservation within them, to date there has been no systematic attempt to identify the major environmental determinants of plant preservation. This research will 1) identify environmental (mineralogical, chemical and physical) properties of the sediments that affect the composition of archaeological and paleoethnobotanical assemblages, using as a test case the Mounded Talus shelter (15Le77) in Lee County, Kentucky, 2) Identify relationships between specific environmental variables and the preservation of paleoethnobotanical remains through statistical analyses, and 3) utilize these data to develop a predictive model of archaeobotanical assemblage formation. This is the first systematic research to identify important environmental variables affecting preservation of plant materials in rockshelter sediments in the Cumberland Plateau. The identification of these variables has broad implications to other cave and rockshelter archaeological sites and will provide data to be used in future research of environmental and subsistence change of the region. Furthermore, this research identifies variables and utilizes methods that have importance for archaeobotany by correcting for differential preservation. Processes involved in preservation of botanical remains will be identified and are needed for comparisons of taxa within cave and sheltered environment, between sheltered sites and between carbonized and non-carbonized remains. Inter and intra-site

archaeobotanical comparisons will make for more robust interpretations of past subsistence and environmental change.

**Systematics of the North American groundwater amphipod genus *Bactrurus***

Stefan Koenemann, Department of Biological Sciences, Old Dominion University, Norfolk, VA Amount of award: \$750

**Project Summary:** The crustacean amphipod genus *Bactrurus* Hay, 1902 (*Crangonyctidae*) is a comparatively small subterranean group. It is composed of only three described species, restricted to groundwater environments in parts of eastern and central USA. The research in progress will result in a badly needed revision of the genus *Bactrurus*, including redescriptions of three previously described species and descriptions of approximately six new species. Moreover, the relationship of *Bactrurus* to its apparent crangonyctid sister genus *Stygobromus* is being investigated. In order to augment several rare *Bactrurus* collection series and also to collect fresh animals for molecular analyses, the type localities of *Bactrurus* were revisited and sampled if still intact. Two series of collection trips were scheduled for eight days in March and a 3-4 week period during May 1999. The *Bactrurus* habitats include numerous caves, but also springs, wells, and drainage outlet pipes in the Appalachian karst, Interior Low Plateaus Region, Ozark Plateau, and even glaciated areas north of the karst regions. The re-sampling program covered approximately 80 localities in various counties of Alabama, Illinois, Indiana, Missouri, Ohio, Tennessee, and Virginia.

Arrangements for a cooperation project were made with the laboratory of Dr. J. Waegle at Ruhr University Bochum (Germany), where 18S rDNA sequencing of *Bactrurus*, *Stygobromus*, *Crangonyx*, and several bogidiellid genera were carried out. As part of this cooperative project, a graduate student from Bochum joined me during the May excursions and subsequent laboratory work on the collected animals. In exchange, I visited Dr. Waegle's laboratory during July/August, 1999, and took part in the molecular analyses of the collected animals. The data generated by these joint ventures will result in one or more papers. It will be the first publication of 18S rDNA sequence data for amphipods known to science.

**Comparative Biology of Epigean and Hyogean Banded Sculpins (*Cottus carolinae*)**

Ginny Adams, Department of Zoology, Southern Illinois University, Carbondale, IL, Amount of award: \$500

**Project Summary:** Banded sculpin (*Cottus carolinae*) occur in both surface streams and springs in the eastern United States (Pflieger, 1997). Occasionally, *C. carolinae* have been reported in twilight or dark regions of cave systems but these populations do not appear to be more than accidentals or troglophiles, exhibiting no cave adaptations. However, several populations of *C. carolinae* from Perry County, Missouri exhibit characteristics similar to other cave-adapted fish species. These unusual sculpin populations exhibit morphological separation with varying degrees of reduction; including reductions in eye size, pigmentation, and pelvic fin ray number. *C. carolinae* collected from the cave resurgence streams in Perry County also exhibit reduced pelvic fin ray counts compared to literature on other surface populations (Robins 1954). These three distinct habitats (cave streams, cave resurgence streams, and surface streams without cave systems) and their corresponding sculpin populations provide a unique opportunity to investigate associated changes in physiology and morphology in relation to habitat. The purpose of this study is to determine routine metabolic rates and life history characteristics for *C. carolinae* inhabiting epigean and subterranean habitats of streams in Perry County,

Missouri. Epigean *C. carolinae* will be compared to conspecifics inside the cave to evaluate any variation in metabolism, development, and morphology that could be attributed to the cave environment.

**Hydrological, Lithological, and Meteorological Controls on Temperate-Cave Heat Budgets and Cryptoclimatic Zones**

Toby Dogwiler, University of Missouri-Columbia, Department of Geological Sciences,  
Amount of award: \$500

**Project Summary:** The cryptoclimate of caves is a fundamental control on cave development, management, and ecosystems. Cave climate is directly linked to the local climate by meteorological and hydrological processes working at the surface and in the shallow subsurface. The proposed study will investigate the importance of the various sources of heat flux in caves such as: short and long term surface weather patterns, diurnal variations in temperature and humidity, cave stream water temperature, and storage and conduction of heat in the bedrock perimeter of the cave. Quantification of these parameters will allow a heat budget for cave environments to be developed. An improved understanding of heat flow in caves will enable current cave climate models, such as the three-zone model commonly used by cave ecologists, to be refined and improved.

# Operation Area Reports

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## Eastern Operations Area Report

*Compiled by Dave West and Patricia Kambesis*

In February, Dave West and Pat Kambesis had their first meeting with Jerry O'Neal, the new chief of Science and Resource Management (SRM) at Mammoth Cave National Park, and his staff. A number of new policies and issues were discussed including new requirements for key request letters, expedition objective lists, inclusion of a participant list with the key requests, updating SRM with an annual CRF members list, and the Parks safety and liability concerns.

In April, Eastern Operations (EO) hosted an Expedition Leaders meeting to discuss the new rules and policies and how they would be implemented. Issues addressed included party leader training, availability of back-up survey objectives, maintaining camp watch, and policies on overdue parties. NPS now requires that all of CRF's trips be composed of 4 people. Expeditions leaders have had to be much more creative in expedition planning (considering that expedition attendance is not always counted in fours).

Joyce Hoffmaster has taken on the job of EO Logkeeper. All original survey notes will be sent to her either directly or via one of the Ohio CRF members attending the expedition.

EO fielded sixty trips during the course of ten expeditions this year. Forty of those trips supported Mammoth Cave cartography, eight were for the Small Caves Inventory Project, eight focused on the Mammoth Cave Safety Video project, eight were for paleontology objectives and nine were to projects outside of the National Park.

*Mammoth Cave Cartography Program:* CRF cartographers provided objectives for various active quads throughout the Flint Ridge Mammoth Cave System. Areas of concentration included Brucker Breakdown,

Historic Mammoth, Sandstone Dome at the end of Black Chambers, Salts and Colossal, Unknown, Proctor, and Bransford Avenue. An interesting inventory note from the Bransford trip was an inscription at the Bransford/Logan junction indicating that this area was discovered in 1924 by Roy Gipson, Carl Hanson, Fred Doyle, Jack Chapman, and John Turpin.

In addition, a detailed map of Fossil Avenue (New Discovery) was needed for current biological and future paleontological projects. The teams were required to take exceptional care to leave no trace of their efforts (not even the scuff mark of a tape). This resurvey was finished in four trips during the July expedition.

*Small Caves Inventory Project:* Teams were sent to continue the push/survey on Wilson cave and to Bat Cave where more survey was added to the remote and difficult end of the B Survey. Other trips went to Long Cave, and Demundrum Cave, and Dixon Cave.

*Caves Outside the Park:* Eight survey trips worked various areas in Roppel Cave (seven survey and one restoration). A successful dig in Diamond Caverns which was started by Gorden Smith, produced 400 feet nicely decorated trunk. Survey and inventory work was also conducted in Cub Run Cave.

*Paleontology:* Paleo inventory continued in Proctor, Bedquilt, Long Cave, Dixon Cave, and between Black Avenue and Ranshaw Avenue in Mammoth Cave.

*Digital Video Project:* This project kicked off with several trips for equipment testing and storyboard development.

## Highlights at Lava Beds

*Janet Sowers*

Highlights of the year include the continuation of basic cave documentation (survey, reconnaissance inventory, installing entrance markers, and entrance GPS readings), ice level monitoring, gating another cave entrance, and the first public showing of our virtual reality cave tour of Valentine Cave. As of mid-October, we fielded fifteen expeditions in 1999 totaling 948 person-hours in the field. We also have spent a great deal of time on the fund raising drive for the Lava Beds Research Center. We held six meetings of the Lava Beds Research Center Campaign Committee and raised about \$65,000 as of late October 1999.

About 948 volunteer hours were expended in the field; 120 volunteer hours were invested in constructing the gates at home; Mike Sims spent 60 hours drafting cave maps. Hours for others including travel to and from Lava Beds are not reported.

**Cave Survey, Inventory, and GPS Location:** We have continued efforts in the area of basic cave documentation –cave location, survey and cartography, and inventory. Bill Devereaux continues to lead the cave location effort, working with monument staff to obtain high-precision cave locations with the monument's GPS system. He has also been installing brass markers at the cave entrances that serve as our GPS reference points as well as identify the cave by name and by number. This past year, we completed setting markers and taking GPS readings for all the caves in the Elmer's Trench system. Cave survey has continued at a somewhat faster rate this year primarily due to the efforts of Cindy Heazlit and dedicated survey crews that do not mind shredding their coveralls in spiky lava crawlways. In 1999 we completed the survey of fifteen caves, for a total of 1080 meters. Cindy Heazlit and Robert Mudry have put all the survey data they collected into "Compass" and have transferred some of that data on disk to Kelly Fuhrman, the Lava Beds Cave Specialist. Kelly was delighted with this. He will be exporting the data into the Lava Beds GIS. Kelly's

goal is a GIS layer of subsurface features that can be viewed with any above ground layer. We conducted complete resource inventories of a complex of three caves - Balcony, Boulevard, and Shark's Mouth. The inventories follow our 1991 protocol and include a survey of cave biology, geology, hydrology, cultural resources, paleontology, visitor impact, and management recommendations. Monitoring: We continued with long-term monitoring of ice levels in the ice caves, and winter bat population counts. Bill Devereaux has led the ice level recording effort, recording ice levels in six caves twice a year at the time of their expected minimum and maximum ice levels.

**Gating project:** The cave-gating project, headed by John Blum, Mike Sims, and Pete Gerhart, is being conducted on specific caves of concern at the request of the Monument. Last year a gate was installed at the lower entrance to Post Office Cave. This year a new gate was constructed and installed in Crystal Ice Cave to replace the old gate. The Crystal gate was built at home in the shop and six trips to Lava Beds were made in construction of the gate. John Blum also repaired the gate on Post Office, which was damaged by vandals. A gate on Gemini Cave will be constructed next year.

**Virtual reality tour:** Last year Peri and Bill Frantz conducted an experimental photography session at Valentine Cave, to begin developing the techniques needed for constructing a virtual reality (VR) tour of the cave. They shot pictures from five locations in the cave, taking 18 pictures at each, from which they constructed a walk around the first pillar. In early 1999, they shot additional pictures, and by the spring were able to put together their first virtual reality tour of Valentine Cave. The VR simulation is currently being shown at the Oakland Museum of California in the new Underground Worlds exhibit. This exhibit, showcasing caves of California, was put together by CRF member and museum curator, Christopher Richard.

## Lava Beds Research Center Capital Campaign

*Janet Sowers*

To recap last year's report, in April 1998, we signed a Memorandum of Agreement with the National Park Service (NPS) and the Lava Beds Natural History Association (NHA) to raise funds to build a small research facility on NPS property at Lava Beds. It states, briefly, that CRF will be responsible for design, fund raising, and construction. The NPS will assist with the design, handle environmental clearances, permits, and inspections, grade the site, install utility connections, and provide general support during all phases of the project.

The NHA will be responsible for collection and disbursement of the funds. We spent the remainder of the year finalizing the building design, writing, and submitting to the NPS our fund raising plan, and preparing fund raising materials. Joan Chaplick, of the National Park Service, served as our coach and mentor. The total cost of the project is estimated to be \$200k, with \$150k of this being actual construction costs. As you may recall, the architectural services, estimated value of 30k, have been donated by Minert Architects, Inc. and the site preparation work, estimated value of 20k, will be provided by the Park Service. Our fund-raising goal, therefore is \$150k

### **Activities:**

This year we began fund raising in earnest. We have held meetings of the Capital Campaign Committee about every two months.

Committee members include Janet Sowers (Chair), Peri Frantz, Bill Frantz, John Tinsley, Christopher Richard, Bruce Rogers, Pat Helton, Peter Bosted, Amy Ponsetti, and Richard Minert. At these meetings, we continued work on the fund raising materials, brainstormed lists of people and organizations who might be interested in donating, discussed who to ask next, and strategized publicity for caving conventions such as the NSS convention, the NCRC, and Western Regional. Peri Frantz has assembled a website to provide

basic information about the project and to keep people informed of our progress.

The website site is up for viewing at <http://www.pwpconsult.com/lbrc.site> -We hope to link into the CRF site soon. We tried to send out thank-you letters to all donors in a timely manner and do regret that the system failed this summer. We believe that we are back on track now. Building design drawings: At the September meeting, Richard Minert showed us the new drawings he had recently completed for the building. The drawings are at a scale of approximately. 1"=15' and include floor plans, reflected ceiling plans, roof plan, elevations, and cross sections. The dimensions of the building, not including the deck, are 52' x 32' for total interior space of 1,664 square foot. An eight-foot-wide deck wraps around about half of the building. These are not the final construction drawings, but are detailed enough to allow us to move to the next step, which is to find a contractor in the Klamath Falls area that can give us a pre-bid estimate of the cost to build. Our working estimate of \$150k for construction was based on an approximate \$100/square foot cost for a 1,500 square foot building.

### **Fund Raising Progress:**

We have been actively soliciting contributions since about the first of the year. Peri and Bill Frantz kicked off the campaign in December by handing over a check for \$5,000. Janet Sowers and Jerry Horn followed suit, as did Janet's mother. The other committee members and relatives also made substantial pledges. By the end of February, we had \$21,000 in the bank. In March, we finally got our fund raising packets together and sent them out to the CRF board and to others we felt we were ready to approach. We received donations or pledges totaling \$3,500 from five of the CRF board members, including the President. The caving conventions this summer and fall were a good opportunity to publicize the project and generate support. At the NSS Western Regional we raised \$1,910 in cash

and pledges including \$342 from the auction. As a publicity stunt, we gave away a lava lamp (yes, one of those 60s hippie icons) to the highest donor for the weekend! Our current total in cash and pledges, as of October 15, 1999, is about \$65,000. This represents donations from twenty eight individuals (including Superintendent Dorman), three organizations (CRF, NHA, and the Mother Lode Grotto), and one corporation that matched its employee's donation. Individual gifts break down into categories as follows: \$10,000 gifts (3), \$8,000 (one), \$5,000 (two), \$3,000 (one), \$1000 (seven), \$500-999 (twelve), and under \$500 (five). We are left with \$85,000 yet to raise.

#### **Plans for next year:**

In our Memorandum of Understanding we are allowed two years, or until April 2000, in which to

raise the money. If the money is not raised by then, we have the option of extending the campaign up to one additional year if it seems likely that we will be successful. I am guessing we will probably be close to our goal by April, but will need to extend the additional year. Our plans are to continue to approach the people on our still-lengthy list, and to start exploring corporate donors and grants now that we have sufficient money to demonstrate the worthiness of the project. With any luck we will be breaking ground in 2001. Please send your tax-deductible contributions to:

Lava Beds Research Center Fund c/o Paul Cannaley, II, Treasurer Cave Research Foundation 4253 Senour Road Indianapolis, IN 46239-9403

## **Missouri Operations Area Overview**

*Scott House*

#### **What is the Lower Ozarks Area?**

This is a term coined by The Nature Conservancy to describe one of the "last great places in the United States." Roughly, this area includes the southeast Missouri Ozarks including the drainages of the Current, Jacks Fork, Black, and Eleven Point Rivers. Most, but not all, of our projects lie within this area.

#### **Ozark National Scenic Riverways (National Park Service)**

We continue to have several ongoing projects on Riverways lands. The Riverways comprises approximately 80,000 acres of mostly karst land which have over 300 caves on them. Mick Sutton and I continue to participate in the Ozark Riverways Cave Management Team. There was one formal meeting in 1999 at a place convenient for Mick and myself. We continue to map caves and assemble data for the Riverways. The major challenge data-wise this year was incorporating data from a five-year archaeological survey into the cave database. This process is not yet finished and will require follow up trips to verify new caves reported. The

monitoring protocols and database developed by CRF continues to be used by the Riverways.

A survey and bio-inventory project along the Lower Current River has been completed and a report (by Mick Sutton) turned in to the National Park Service (NPS). The survey of one cave could not be completed due to the presence of a gray bat colony that we first identified.

The Riverways continues to financially support our work in the Lower Ozarks project area by allowing us to use a field facility at Powder Mill (Owls Bend). This year, we had year-round use of the facility which helped with summer work.

An ArcView extension to allow easy import and display of cave locational data was created by Eric Compas. This was transmitted to the NPS. The biological assessment of Round Spring Cave was completed and a report by Mick Sutton is in progress.

We provided interpretive services in the form of a field trip at Round Spring for students from Antioch College in Ohio.

## **Mark Twain National Forest (MTNF)**

The Mark Twain National Forest (1.5 million acres and at least 380 caves) continues to be our most time-consuming project. Virtually all of the field work has taken place on the Eleven Point District, an area where lead mining has been contemplated in the past.

Mick Sutton's Phase 2 report was completed. It has been delivered to the MTNF and is also slated for publishing in an upcoming issue of *Missouri Speleology*. Phase 3 of the project is well underway. It has been renewed for an additional year.

New areas for us to investigate were identified by the Forest. We will be looking at these areas this coming winter. The major impetus of this additional work is heavy ATV use in some of the Forest districts. The Forest is concerned with impacts on caves in those areas.

CRF continues to manage data for the Forest. New updates of the database were provided. This work is being done in cooperation with the Missouri Speleological Survey.

We have enjoyed working with a new Forest Service contact, Neil Babik, who came to Missouri from national forests in Alaska. He has met with us several times and has participated in several survey and inventory trips.

## **Missouri Department of Conservation (MDC)**

The Department of Conservation owns over 200 caves on various lands around the state. Doug Baker and crew continue the survey of Powder Mill Creek Cave which is now in excess of 7.5 miles in length. Draft copies of the map have been provided to the Department for management purposes and to the Missouri Department of Natural Resources for use -in a sedimentation study in the cave. In addition, the digital data was transferred to the Department. Eric Compas used this data to create an ArcView overlay which was also provided to the Department.

One trip to Shop Hollow Cave was taken to do some survey work, but the purpose was primarily to show the new bat colony to the MDC cave biologist, Bill Elliott.

The Hunter Cave project was halted due to a loss of personnel. The data is in process of being transferred to the Department in hopes of getting someone else to continue the survey.

Bill Elliott and I did a three-day cave workshop for teachers and other educators at the Presley Education Center in Shannon County. Bill, Bob Osburn, Mick Sutton, and I did a weekend speleology workshop (for cavers), also at the Presley Center. We had a waiting list for this workshop which we will plan on repeating next year. The workshop focused on two aspects: biospeleology or cave mapping. Participants were involved in one or the other of these activities.

## **United States Geologic Survey (USGS)**

We continue to cooperate with the USGS on a project involving geologic mapping of lands around the Ozark Riverways and Mark Twain National Forest. Bob Osburn has been leading this project and has cooperated in field work with Randy Orndort and others.

We continue to share database information with the ILISGS. The USGS has provided us with some funding for equipment needs.

The mapping of Sutherland Cave was completed with some USGS field help. -Several caves near the old Midco mine site were also surveyed.

## **Missouri Department of Natural Resources (DNR)**

We work with two divisions of the DNR. -in cooperation with the Division of Geology and Land Survey we are helping to validate and process incoming cave data for the state cave database. -in cooperation with the Division of Parks we have undertaken a new survey of Fisher Cave, a large show cave in Meramec State Park. Partially surveyed several times before, Fisher Cave is a well-decorated, historic cave that is show to visitors by lantern tour. We began the survey in September and after several trips have nearly 4000 feet of survey. Also in Meramec State Park Paul Hauck has been surveying a smaller, new cave.

## Pioneer Forest

This is a large, privately-owned forest in the Lower Ozarks. There are about 100 caves on Pioneer land. We continue to manage data for the Forest. -We have worked on management problems concerning a large Forest cave in Shannon County. We did confirm the presence of endangered species in this cave this past winter.

## Other Private Lands

Matt and Mike Beeson continue to work on caves within the area of the northwest Ozark Plateau. Steve Irvine and George Bilbrey have been working on the survey of Crocker Cave, a large (4000 feet) cave on private land adjacent to National Forest land. No trips were taken to Bunker Cave this year due to an injury to the project leader.

## Missouri Speleological Survey (MSS)

The MSS seeks to collect all cave data in the state. We cooperate fully. I continue to serve as MSS

Vice-President. -We provided two manuscripts to the MSS this year for publication. One of these, *The Wild Caves of Benton County* written by Matt Beeson, was published this year. The other is the Phase 2 MTNF Report by Mick Sutton which is scheduled for publishing this coming year. We have led the way in providing a cave database for use by the MSS as well as other agencies. Several CRF members are involved in the processing and validating of incoming cave data.

CRF members provided show and tell demonstrations at three MSS meetings this year. I demonstrated simple databases, Mick Sutton brought specimens and scopes, and Eric Compas brought ArcView demonstrations.

## Personnel

We continue to attract a good group of people. The workshops we did provided us with some new folks. Other new folks were attracted to the Fisher Cave resurvey. CRF interacts well with both cavers and agencies and several agency personnel worked with us in the field. Life continues to be good.

## Fitton Cave Survey Project Report Ozark Operations Area

*Pete Lindsley*

The Fitton Cave Survey Project in Arkansas fielded four expeditions during 1999, up from three in 1998. A total of five survey parties worked in the cave during 1999 with expeditions on July 16-17th, August 14th, September 11th and October 16-17th. A total of sixty one person-hours above ground and 223.2 people-hours below ground was expended at the cave. In addition, a Fitton Cave Cartography Workshop was cosponsored by the Park Service to help address our current goals of increasing output from the map factory and was part of several hundred additional hours of work.

The primary event this year was the Cartography Workshop. Although it was almost postponed due to lack of a proper facility, our Park Service sponsor,

Chuck Bitting was able to make last minute arrangements at a local college computer lab, and we had a first-class facility for the event. Because the goal was to make plans for carrying forward our map making efforts (rather than train and instruct new cave surveyors) the workshop was a high level presentation that the two or three new people who attended commented was like drinking from a firehose. The workshop was formalized on May 1, 1999. The first edition of the "Ozark Newsletter" was published May 5th following an e-mail announcement and a posting to the CRF Web site; and the event occurred on May 15, 1999.

Scott House was a big help with the workshop starting with a flurry of e-mails between Scott and Pete

two to three weeks prior to the event that helped to thrash out the agenda to everyone's satisfaction. Both Scott and Pete presented overheads, Scott presented a map drafting exercise, and several cave survey programs were demonstrated on the computers by Pete, Terry Holsinger, Mike Pearson, and others. Gary Schaecher, our project cartographer that drafted our original eight quadrangles in 1991, attended and also offered his advice.

An action plan was established by the attendees as follows:

- Change the North arrow alignment to the top of the page to facilitate drafting new quads directly from the computer printouts onto a gridded Mylar material. Chuck Bitting (NPS) will obtain a supply of mylar material for our use.
- Review the Quad layout and issue a new index featuring the new north alignment
- Use multiple quadrangle layers to show multiple cave levels
- Run the whole cave on the WALLS program to "fix" the main loops. Add information on GPS locations at appropriate cave entrance and radio locations. Record additional GPS locations as required. Terry Holsinger who is working closely with the author of the WALLS program will be reducing the data for the Project.
- Expand the current group of cartographers to include several new cartographers that will be recruited by Scott House.

We believe this is a viable action plan and is typical of what can be done on other cave survey projects that have fallen by the wayside and need a boost to start producing maps from a mound of in-cave data.

The first expedition to the cave area was held on July 16-17, 1999. We were fortunate to be joined by Lawrence Ireland (an NPS employee and caver) and the NPS Trimble GPS unit for the first day. Two days were spent recording numerous GPS stations. Chuck Bitting reduced the data. Because one of the problem areas with several surveys was Grand Central. The

single cave trip on August 14th was used to sort things out in this area past Jurgen's Leap. Essentially all the hanging surveys were recovered and new leads were noted. Then, on the October 16th trip, we took advantage of the low water and this area was "finished" for the time being. The September 11th trip was used to both introduce two new JVs to the cave and to resurvey some of the closure problem areas in the cave. A new tie was made to the start of the Tennouri Passage and the Crystal end of the Double Drop Pit complex was tied to the appropriate brass cap.

The October 16th trip was interesting with a total of seven new JVs and only four "old timers". A resurvey line was run through Tennouri all the way to the Alter Rock brass tack to correct some previous closure problems. An attempt was also made to continue the cross section at the Lower East end of Double Drop passage. This area is particularly complex and will require additional trips before completion. On October 17th seven of the JVs surveyed Cave X (a small one-room cave) with six individual sketches being made. Each sketcher will draw up their map as suggested by Scott during the Cartography Workshop.

The Cartography Workshop was so popular that one of the attendees asked CRF to help with a similar survey workshop on August 20 at Cave Without A Name in Central Texas. Pete Lindsley and Mike Pearson provided about half of the presented material and training at this workshop.

Cartography is number one on our list for 2000. The bulk of the major passage in Fitton Cave has been surveyed now and future work in the cave will address goals supporting drafting of the new quadrangles. At present we have an Entrance Room Profile quadrangle in work that will be different from the proposed new quads. In support of the new quadrangles discussed above, Lindsley is updating the whole cave database into several smaller sections which will allow us to correct some closure errors by areas. The next step is to provide suitable computer files that interface with WALLS so that the whole cave closure can be established prior to start of drafting.

The Fitton Cave Project is continuing to solicit scientists that may have an interest in doing work in the cave. We continue to invite geology and biology profes-

sionals to come to an expedition, but to date none have been able to attend. For a scientist with access to carbon dating equipment, we have some interesting carbon chips in the lowest 10-15 feet of the Lower East Passage. This material is possibly related to a major flood following a forest fire or perhaps represents flood water washing through campfire material in the Bat Cave entrance. But no known flood of this proportion has occurred in recent historical times. In addition there are several other potential projects including mineralogy, geology, hydrology, and biology that will be of in-

terest to qualified scientists and researchers. The present survey data base offers data on various water sources in the cave and there are several other small springs in the area in addition to the known Fitton Spring resurgence. A biological survey of the cave is needed and could be correlated with a previous survey done in nearby caves by CRF in past years. Interested primary investigators should contact Pete Lindsley, Project Manager or Danny Vann, CRF Arkansas Area Operations Manager, for additional information.

## Sequoia and Kings Canyon/Mineral King Operations Area Reports

### Lilburn Cave Diving Project

*Bill Farr*

The primary goal for the Lilburn Dive project is continued exploration in the "Upstream Rise," the most upslope emergence of subterranean Redwood Creek. Exploratory dives in the fall of 1997 reached the practical limit of exploration with a standard side-mount setup of two tanks and one cylinder of pure oxygen staged near the beginning of the dive for decompression. This resulted in a maximum penetration of about 1200 feet, pushing more than 900 feet beyond the northernmost known extent of Lilburn Cave, and reaching depths of about 160 feet below the dive entry point. Permission to continue dive activities was granted August 6, 1999, by Superintendent Michael J. Tollefson.

With high expectations for emergence into the "Great North Cave", exploration of the Upstream Rise re-commenced on August 22. However, re-traverse of previously explored passage proved to be much more difficult than expected, owing to sand movement, despite the seemingly mild winters. After three dives characterized by a general lack of Sherpa support, exploration was terminated for the season without having reached the limit of previous exploration. However, the sump is still open, and if the new dive line doesn't become buried this winter, conditions are promising. This past year saw the first mixed gas dive and the first stage dive in the Upstream Rise, and the removal of a large quantity of discontinuous old dive line segments. Description Access via the five-mile hike, the 5000-

foot altitude that extends decompression requirements, the seven degree C water temperature, a depth of >160 feet, two passage constrictions, and a relatively short season of high-visibility conditions all hamper cave diving at Lilburn Cave. Push dives now typically involve five or more tanks with three or more gas mixtures, and in Big Spring, depths reach about 250 feet, making Lilburn a world-class cave dive.

In 1999, push diving into the Upstream Rise was thwarted owing to sediment partly filling the phreatic passage and burying the dive line, at great inconvenience to the diver. The August dive revealed multiple discontinuous dive line segments, owing to partial burial of the line. New continuous dive line was run from the point of entry during near-zero visibility conditions. The October dive was dedicated to removing old dive line segments, as these represent a serious risk of entanglement. The dive was called after fifty minutes, owing to cold resulting from soaked dry suit undergarments that had been left in the cave in August. A push dive in November penetrated 310 meters into the sump, but was called on air (thirds). Much effort was expended in pulling the dive line free from intermittent places where it was buried in sand. Additional dives would have been conducted in 1999 had there been sufficient Sherpa support. Dives are now at the point where serious logistical support will determine the success or failure of this project. Assuming that sediment accumulation remains at about the same point this year as last, diving can continue.

Future push dives will benefit from staging tanks in-sump and in between dives, a step that cannot be risked late in the season. (Recall that an unseasonable July storm several years ago whisked away a dive tank near the Z-Room several years ago; the tank was recovered this past year. The risk of leaving gear in the cave is never zero, unfortunately.) We hope continued exploration in the Upstream Rise will surface into air-filled cave within the next few dives.

The depth and duration of these dives (over thirty minutes swimming one-way at 162 feet) and the extended cold-water decompression for even a one-way trip, plus small passage size and low visibility make this sump one of the most challenging ever attempted.

### **Cave Digging**

*Bradley Hacker*

Meatbug Sink has yielded some additional passage, but we will wait out the winter rains to see what more may come of it. This sinkhole swallows runoff from a small gully on the flanks of Big Baldy. It has been plugged for a couple of decades, but lately has shown signs of renewed collapse. Several short digs within Lilburn Cave have yielded additional passage to cartographers. (See the Bosted report on Lilburn Cartography, this section). Owing to the low stream flow reflecting the La Nina winters, we may attempt to extend Mays Cave toward Lilburn Cave via a short dig near the present limit of Mays Cave. Several years ago, fluorescein dye was used to establish that drainage into Mays Cave from Mays Creek (the Field Station's water supply drainage) reappears just upstream of Scumbag Dome, below the White Rapids area, in Lilburn Cave.

The potential of this significant connection beckons strongly, and exploration during low water levels will help make the potential connection a reality. Hope for a compliant winter that favors the success of this enterprise.

### **Hydrologic Activities at Redwood Canyon**

*William D. Howcroft and John W. Hess*

Hydrologic efforts in Redwood Canyon have seen diminished activity in 1999 relative to prior years owing to a number of factors including a redefining of the scope of Bill Howcroft's dissertation, and contin-

ued problems with the data loggers at Big Spring and within Lilburn Cave. Time has been used this year to collate and better organize the data collected over years past, rethink present and future research projects in Redwood Canyon and focus on compiling and eventually publishing the results of our work. In addition, Nizar Abu-Jaber, who is a visiting professor at DRI on sabbatical from Jordan, is examining the chemograph data from Big Spring and Redwood Creek.

As a result of repeated equipment failure, logistics caused by heavy snow years, and laboratory analytical problems, the hydrograph separation work previously planned for Redwood Canyon has been indefinitely postponed. At this time, only the data logger at Redwood Creek is fully operational. During the most recent Hydrology trip, the data logger at Big Spring was found to be inoperable. It was therefore removed from the site, sent back to the manufacturer for repair, and is now awaiting re-installment in early 2000. Similar problems occurred with a different data logger at Big Spring in 1998. The data logger within Lilburn Cave continues to be plagued by wiring problems; its future is currently being discussed. Cave survey data from the Redwood Canyon Caves, in addition to other caves across the U.S., including Lechuguilla, Carlsbad, Wind, and Jewel Caves, continue to be examined for self-similarity using fractal algorithms. The results of some of this work were presented at the Karst Waters Institute Karst Modeling Conference in Charlottesville, Virginia in February. The fractal studies and modeling now comprises the scope of Bill Howcroft's doctoral research, with completion anticipated later this year.

### **Cave Restoration**

*Bill Frantz*

One restoration trip was conducted and dedicated to continuing to clean up the area below the Jefferson Memorial. The area is extraordinarily delicate and is fairly dry, so water and other cleaning supplies must be packed into the area. The Cave Restoration project has sacrificed itself in past years by contributing personnel in support of other CRF projects, a role that the other P.I.s and the Project Coordinator appreciate very much.

## **Redwood Canyon Cartography** **October, 1998 through November 1999**

*Peter Bosted*

There have been nine survey expeditions to Redwood Canyon between October 1998 and Oct. 1999. There were twenty two survey trips into Lilburn Cave, netting a total of about 3400 feet of new passage in 340 stations, and 800 feet of resurvey in eighty stations. Lilburn is now about 17.2 miles long. The largest portion of new survey (1400 feet) was in the Southern Comfort area, first found in late 1997. Pushing through some tight crawls in late 1998 led to a series of larger rooms, which were pushed in 1999 to the top of an impressive pit. A rappel to the water filled bottom revealed that this is Slash-down dome, the southern-most point in the cave, only reachable from the bottom when water levels are extremely low. A lead heading south from the top of the pit will require a bolt climb to access.

Several side passages were also surveyed, including one that connects to the Mousetrack area. Also in the southern end of the cave, low water levels have permitted easier access to the Thanksgiving Hall area, where over 700 feet have been surveyed and several good leads remain heading away from known cave. The third biggest area of activity was the Schreiber Complex and Clay Palace, where the availability of newly completed quads allowed revealed several overlooked leads. Most of the re-surveys were done to improve on the originals sketches, but three were accidental, due to the paucity of permanent station markers and the extreme complexity of the cave. I still need the survey notes from the last survey trip (Carol Vesely, leader) to enter into the system.

The map of May's cave had been considered finished except for one small lead, which on a quick inspection trip in February led to a substantial new section. Survey marks indicated that at least part of this was known to the 1970s survey project led by Ellis Hedlund. A couple of rather tight squeezes are involved, but near the bottom of the cave, the passage can get as large as twenty feet tall and five feet wide. A small stream flows into a tight crawl that could be enlarged by removing rocks when the water flow is sufficiently low. This might lead to a connection with Lilburn, about 100 feet away. The new area was mapped in four sur-

vey trips for 680 feet in 81 stations, more than doubling the length of the known cave. Several leads remain.

Some progress was made on updating existing Lilburn quads with the new 1999 surveys, but not everything is finished yet. Progress was made on the F and G series quads. There are about seven quads (out of 80 total) that have no draft at all, about ten that need updating, and about sixty that are pretty much complete. I have made computer files for Lilburn, Cedar, and Mays caves in COMPASS format, all tied with surface surveys to A0 (Meyer Entrance). Mike Yocum is in the process of incorporating this in a GIS system. It remains to make a file for Big Springs. The surface survey is available, but I do not yet have the dive survey data from Bill Farr. For the year 2000, there are still many quads to be checked, and several leads to be pushed. Several of these involve aid climbing. I would like to increase the number of permanent station markers in the cave to aid in future research efforts, and to minimize accidental resurveys. This effort could be profitably combined with quad checking.

## **Sedimentology of the Redwood Canyon Karst**

*John C. Tinsley*

The 1998-1999 La Nina winter had a cool spring season that effectively limited the rate of delivery of snow melt to the karst of Redwood Canyon. There was effectively no flooding within the cave, even in areas that typically back up at relatively modest levels of discharge, despite the near-normal levels of precipitation this past winter. From an in-cave perspective, it could have been passed off as a drought year, as sediment transport this past winter was minor to nil. Consequently, the probability that sediment was eroded and re-deposited in volumes sufficient to impede Bill Farr's cave diving is believed to be very small. Farr reports that sediment is again accumulating in the Upstream Rise, where sand buried his dive line at several points. With luck, the sedimentation processes will continue at a slow pace, enabling further SCUBA exploration of this subaqueous route to the Great North Cave. In summary, it was another dull year at Lilburn Cave for sediment transport buffs. The peak rise in the cave stream above the White Rapids amounted to about fifty cm above the cave stream's low flow elevation.

Thirty years of observation of this reach of the subterranean course of Redwood Creek show it to be

one of the more flashy points in the cave's hydrologic system. A deposit of breakdown is located below the White Rapids. This downstream control impedes discharge and commonly impounds water at points above the White Rapids to depths of three to five meters in years with normal runoff. No new sinkholes were observed in the Redwood Canyon karst during 1999. Several sinkholes have shown signs of renewed collapse, including Meatbug Hole.

Incidentally, it was a banner year for ground-dwelling hornets, known malevolently and colloquially as "meatbugs", given their fondness for carrion and the calculated tenacious ferocity with which they defend their nests. The Pebble Pile Sink has aggraded fully, to the level of its downstream lip, although the sink still takes water near its lower limit. Thus, at high flow, Pebble Pile Creek again traverses Pebble Pile Sink and after about a decade-long hiatus, has resumed flowing along its former channel below the sink. As the one-hundred fifty-foot high north wall of the sink continues to retreat, it threatens to excise the Redwood Canyon trail. Ten additional feet of retreat of the lip of the sink will require the National Park Service to relocate the trail further up-slope, for safety's sake. There is plenty of area available for this land use, but this is not a part of the Park's trail system that is maintained regularly.

#### **Cave Rescue Preparedness Exercises, October 13-14, 1999**

*Roger Mortimer and John C. Tinsley*

Six rangers from Sequoia and Kings Canyon National Parks (SEKI), four joint-venturers of the Cave Research Foundation, and SEKI's Cave Management Specialist jointly conducted successful cave rescue preparedness exercises at Lilburn Cave. The objective of the two-day event was to introduce key NPS personnel to the cave environment and to make them aware of the kinds of problems that they could anticipate in the event of a search and rescue in a cave in their district. As Lilburn Cave is SEKI's largest and most complex cave, the experience predictably proved to be a sobering one for all hands. Tentative plans for future exercises were discussed, as this exercise was merely a beginning.

The first day, after a quick tour of the karst features in the Mays Creek tributary valley located

east of the Lilburn Field Station, we experienced the traditional Lilburn Cave tour as it formerly existed from about 1950 until the 1966 Sequoia NSS convention. Entering via the Lilburn entrance, we divided into two groups for convenience and proceeded to the Lake Room via the Double Skungy Chimneys, the Junction Room, and the Corkscrew. This route is presumably the most likely evacuation route from the bottom of the cave, as it is relatively non-technical and the passages are larger than most of the alternative routes. Everyone was impressed with the complexity of the cave, and with the myriad problems that would have to be solved by the rescue personnel in the course of conducting a rescue and evacuation by litter.

We also proceeded through the Curl Passage to the Hexadendron Room (the cave's largest air-filled room) and examined the architecture and connectivity among parts of the central portion of Lilburn Cave. The second day, we again split into two groups. We invested the morning examining in some detail, the route from the Junction Room to the Lilburn Entrance, and considered what approaches would be the best to employ during an actual evacuation. It was a solid exercise, enthusiastically pursued, with all hands contributing thoughts and perspective concerning the most efficient ways to conduct an evacuation along this relatively straightforward 400-foot-long section of cave. The morning concluded with Roger Mortimer demonstrating his SKED evacuation litter with its several bells and whistles. Then we cleaned up the cabin, stored the rescue cache's gear, and hiked out of the canyon, completing the exodus by about 5 pm.

NPS Participants were Joel Despain, Cave Management Specialist, SEKI; Jeff Monroe, Asst. Subdistrict Ranger, Grant Grove; Steve Klump, Kern Subdistrict, (Backcountry); Mike Cole, Mineral King Subdistrict; Bud Walsh, Ash Mountain; Mark Hehl, Ash Mountain; John Kamencik, Kern Subdistrict, (Backcountry).

CRF Participants were Roger Mortimer, Bill Frantz, Howard Hurtt, and John Tinsley

#### **Mineral King Area 1999 Activities**

*Roger Mortimer*

In 1999, CRF personnel conducted three expeditions to Mineral King. As the project has matured,

we have spent less time in the White Chief Bowl and more time exploring karst elsewhere in the district. This year, we did no significant hydrologic studies, but spent more time in pure exploration. We also began to implement the inventory tool developed by Carol Vesely and others to document the geology and biology of Mineral King caves. Information gathered is linked to survey stations to quantify findings in a geographic information systems (GIS) format. Jeff Cheraz's expedition in August focused on exploration of Mineral King valley. We explored the ravines on the east side of the valley as they crossed the two bands of marble that crop out there. Going up Cascade Creek, we found some areas where water emanated from the marble, but found nothing that was humanly passable. The next day, we surveyed Little Breeze Cave, located high up on the east side of the valley.

Over the Labor Day weekend, we returned to White Chief to continue our survey there. Bill Farr, Paul Nelson, and Jeff Cheraz donned wet suits to survey the breathing space insurgence "cave" into the lower stream passage of White Chief Cave. The rest of us stayed dry by doing re-survey in the historic entrance and mystic pools of the cave. Peter Bosted led a group that cleaned up high leads in the upper level passages. Our last day there, we did survey instruction and photography in Seldom Seen Cave, which was now completely devoid of snow. The White Chief survey now stands at 1.2 kilometers. A preliminary draft of the cave map is completed, but much clean-up work remains. The Columbus Day weekend expedition split time between White Chief and Timber Gap. On Saturday, five of us hiked to White Chief along with Ranger Mike Coles to survey the lower stream passage. Our goal was to link to the cairn left at the sump. The cold made us turn back after we stopped at the base of a pit in the entrance doline. This turned out to be about thirty feet from the cairn, down a lead that we had left on the prior survey. The next day, Bill Frantz and Kirk Hastings ridge-walked the Timber Gap marble while Carol Vesely, Jeff Cheraz, and Erin Lynch continued the survey in Jordan Cave. In addition, two joint venturers, Roger Mortimer and Jeff Cheraz, did a non-CRF trip south of Mineral King into the Golden Trout Wilderness. They found no caves, but did find evidence of karst at Upper Bullfrog Lake. The return hike allowed some exploration along the main stream of the valley. They found

several minor resurgences, but no passable cave.

### **Mineral King Karst Tagging Project**

*Jeff Cheraz*

The cave-entrance-tagging project will help CRF to complete a survey of the karst features in the valley. The task is seemingly quite simple. We need but to locate all of the known karst features so that the National Park Service will be able to locate their resources on a map using global positioning satellite surveys. We anticipate that we will place an ID tag at each cave entrance or group of entrances.

The caves and pits are to be tagged so as to eliminate the guesses by researchers, NPS personnel, and other users of the Parks while a field as to which resource is which, and if the karst feature is cataloged. The tags and anchors will be of stainless steel, cemented into the rock with epoxy, in order to exclude the elements and prolong the life of the tag. The ID numbers and letters will be assigned by the Cave Management Specialist and will also be the name for each file containing information about that particular cave or pit. Information gathered about each cave or pit will eventually be compared to data stored in other Mineral King files, using GIS or other means of study.

This project will help to minimize the impact of cavers on the caves and will save researchers time in locating additional karst resources and determining what additional work may need to be completed. Comparisons among cave systems will be enhanced owing to the growing body of improved location data. At present, most of the caves and pits known from existing cave files have been located.

We were fortunate to find a few new caves two years ago. One of those finds was determined to be among the larger caves of the valley. This last year was not so kind to the cave hunters, as the weather was inclement and winter came early. Mineral King is alive with many different types of interesting plant and animal life. Because of the bold nature of the animals in the valley, extra care must be taken to keep caver's food and products of civilization away from them. The animals are a great attraction, but in the Spring, the valley's wildflowers may be even more spectacular. The fields are carpeted with blue, purple, red, yellow, and

white wildflowers. One can only marvel at the beauty of this alpine valley and what it has to offer mankind as a spiritual refuge. A foundation of this abundance of life is the seemingly endless water flowing throughout the valley. Many creeks and streams find their way down the valley slopes and thereby give life to a variety of riparian habitats. It was not until I started work-

ing for CRF that I gained a deeper respect for the subterranean levels of Mineral King as well. All of the natural conduits or caves running through the hills deliver water to many different sections of the valley. So I am looking forward to continuing the process of trying to understand Mineral King's special ecosystem, one that continues to fascinate and enthrall enthusiastic cavers!

## Southwest Region Operation Area Report

*Barbe Barker*

CRF volunteer time at Carlsbad Caverns National Park (CCNP) for 1999 totaled 1118 hours.

*Survey & Cartography:* CCNP is putting all of the updated survey on their computer. CRF has ongoing projects, headed by approved sketchers, in different parts of the cave. All original survey data stays with the Cave Resource Office. Copies are distributed to each individual sketcher and to the area manager.

*Scientific & Geology Inventory:* Approved Scientific and Geology Inventory personnel are on each survey team and training continues in this area.

There were a total of four expeditions this year which focused on survey and restoration. Survey work was conducted in the F-Fissure Area in Lower Cave, Nicholson's Pit below Mabel's Room and below National Geographic Pit (under the Big Room). Approved

Scientific and Geology Inventory personnel are on each survey team and training continues in this area.

Ongoing projects continue in the Rookery, Guadalupe Room, Lake of the Clouds and the Big Room. New projects are accomplished as per the Park requests.

*Insurance:* We signed a "Volunteer Agreement" with the Park Service which covers all volunteers under their workers compensation insurance and also enables them to count our volunteer hours.

*Expedition Fees:* We have stopped providing food for each expedition and therefore, reduced our costs dramatically. Currently, charges for an expedition are a minimum of five dollars to cover costs.

The Cave Resource Office Personnel and Management are very pleased with CRF efforts and contributions.

## Cave Research Foundation Lincoln National Forest Capitan Peak Study Area

*Dick Venters*

### April 1999, LNF-CPSA Expedition

Attendees for the project were: Dick Venters, David Sherrow, Lloyd Swartz, John Corcoran III, Dorothy Corcoran, Randy Cabeen, Marty Cabeen, Dennis Worthington, Jeffery Worthington, John McLean and Rick Lytle. Total volunteer hours expended on the project were: 398.

#### April 17th

The dig crew (attendees) went to Doc's Gastropod Cave dig on Baca Ridge. After a preliminary excursion into the dig, ideas were discussed as to our next plan-of-attack. The dig entrance was blowing cool-moist air at about 6 mph. The dig crew cleaned up some debris that had fallen into the entrance and the dig was continued until late that afternoon. The total depth from the entrance to the dig area is now 22 feet.

#### April 18th

After a restful night's sleep, our dig crew went to Dick's Blowfly Cave (DBF). After a preliminary check within the cave and dig area, the crew got together to re-assess the dig, it's potential and the direction of the proposed cave passage. It was decided to continue the dig into the NW wall area, where most of the good air seems to be blowing. This area also has the easiest digging potential; mostly loose gravelly dirt (soil), without large boulders. The soil is slightly moist, and rock debris is fairly rounded. The passage with this type of soil constitution may possibly have been a flood wash-in type of debris flow from the surface and could have covered the cave passage we are looking for. The dig continued until late in the afternoon.

#### April 19th

Our crew returned to the DBF dig site. Most of the debris being removed this time seemed to be in a multi-layered, humic, light brown calciferous type of soil with minimal (large) rock debris. The dig is following the same trend, NW, toward and central to the main

ridge. The dig continued until late in the evening. Total dig depth: 44 feet.

#### April 20th

Dig crew was dispatched to Doc' Gastropod Cave dig. The dig is continuing through calcareous-boulder debris, some breccia and following the path of "good" air. Total depth/length: 33 feet.

#### April 21st

Break Day! Some of the crew wanted to go to Serpentine Root Cave for a tour and picture taking expedition. They returned to the campsite about lunchtime. After lunch, we decided to do some ridge walking and surface geologic survey work on the Hydrothermal Hill (HT) and Three-Paleo-Sink ranch (3PSR) area near the camp.

While searching for marker beds in a canyon between HT Hill and 3PSR, we located an excellent fossil bed (assemblage) within the San Andres FM. John Corcoran III and Dick Venters completed a photographic record, of some of the best fossils and lithologic layering in the Limestone within this area. This area was georeferenced for future work.

#### April 22nd

"Short Day", we returned to the HT Hill/3PSR fossil area for more paleo-study. We followed the marker bed of fossils to the north until we lost it in the Capitan Granite float. (This marker bed was also noted to the south of the L57 forest road previously.)

### October 1999 CRF-LNF-CPSA Project Area Expedition

Attendees for the project were: Dick Venters, David Sherrow, Dennis Worthington, Jeffery Worthington, John McLean, Lloyd Swartz, John Corcoran III and Dorothy Corcoran. Total volunteer hours expended on the project were 384.

#### October 9th

Dig crew (all attendees) were dispatched to Dick's Blowfly (DBF) cave dig. Dig is continuing in moist-humic soil toward the NNW center of the ridge. Cool-moist air (approximately three MPH) continues to come out of the entrance. Dig continued until evening.

#### October 10th

Dig crew continued at DBF dig. Approximately mid-afternoon, the crew broke through, into what seems to be the lower part of a boulder-breakdown-room (dome room). The room contains very large breakdown boulders blocking the main passage. The air movement, through the breakdown, seems to have increased at this point.

After a bit of discussion and summarizing this new situation (mid-afternoon-break), we decided it would require a larger crew size than what we have now, to remove the (larger) boulders from the passage. Being close to the pack-up time, we decided to return to camp for more in-depth discussion on this situation.

#### October 11th

Our dig crew was dispatched to Doc's Gastropod Cave dig. Digging continued in an area of highly brecciated LS and passage seemed to continue to the SW (not good!). Large blocks of LS (2-tons plus) were cemented-in on each other and over-hang the digging area. As the dig continued, the area was looking less promising and more dangerous. Digging continued with diggers trying to stabilize the area to no avail. We decided to break off the dig until the next day and possibly re-evaluate the site.

#### October 12th

The dig crew started anew at Doc's Dig. After a brief period of stabilizing the dig area, the crew continued the dig. Material being removed from the area now consisted of larger loose rock, calciferous dark dirt (soil) and numerous tree roots. As the digging continued, the area is becoming more precarious and needed to be re-evaluated for safety again. Noticeably, there was no air movement in this part of the dig area (that had previously been felt in the early part of the original dig). Most of the digging seems to be in a highly brecciated limestone fault zone, without a real "cavy" look or passage.

During the lunch break, all diggers made a unanimous decision to move the dig area back to an area on the north end of the dig. There were small (3 to four inch) "phreatic" worn zones, where you can look into known cave, has good air movement and is a potentially safer digging environment. After lunch, the crew started on this new area, using the debris they were removing to fill the old dig. Digging continued until late in the afternoon. That evening, at the campfire get-together, our dig crew decided (unanimously) to move the campsite to a new area. The new area is near a dig (Crash Cave); we had started in August 1999, in the LNF just south of Ft. Stanton Cave. The new campsite area will be located on top of Water Tank Hill.

In August, on the last day of the Ft. Stanton Bat Cave dig, John McLean, Lloyd Swartz, and Dick Venters ridge walked this area and re-located Crash Cave. Most of the afternoon, we had time to dig the crawl (Ball Mill Crawl), and were able to see a small room (Recovery Room) with more cave beyond our sight. At that time, we decided to continue the dig (at a later date during the October 1999 Expedition).

#### October 13th

"Campsite Moving Day!" Moved our camp to the new campsite location on Water Tank Hill. All attendees did some reconnaissance of the area near Crash Cave and the surrounding area. After lunch, we decided to ridge-walk an area to the SW of the cave. We located a large sink (60 feet in diameter) near the camp, georeferenced the location and continued recon of the area. John and Dorothy Corcoran, Dennis and Jeffery Worthington and David Sherrow had to leave to go back to work, so we lost some of our dig crew.

#### October 14th

John McLean, Lloyd Swartz, and Dick Venters continued dig in Crash Cave. After a couple of arduous hours of digging in Ball Mill Crawl, Lloyd broke through into a small terminus room (Recovery Room, 15'X8'X5'). This room continued through a left hand passage to a larger room (Arch-Canyon Room, 70'X12'X15').

The Recovery Room has some very interesting features. The SW wall has corroded-gypsum rind on the upper part of the wall. As you enter the Arch-

Canyon Room (ACR), you can see a massive drilled gypsum block in the center of a ten foot-pit in the middle of the room.

The ACR gypsum block is a (approximately fifteen to twenty feet thick) lenticular-shaped block within the upper-San Andres Limestone FM. The gypsum block has multiple drill-holes at varying parts of the room, some go all the way to the floor, others only partially into the block.

ACR also has large limestone break down blocks in the NW portion of the room. Along the east and west sides of the room, we noted the same type of gypsum rind seen in the Recovery Room. It is multi colored, has nicely crystalline structure and similar drill holes.

We continued to look for a passage to the NW on the north and south walls, down below the breakdown blocks, but with no luck. Finally, we saw a small breakdown hole at the NW end of the room. John McLean volunteered to move the blockage. When the breakdown was removed, we broke into another room (Boulder Crawls). John and Lloyd pushed forward through the "V-Notch Crawl" down a right-hand crawl into the "Hall-of Pain". The Hall-of-Pain leads to a bifurcated passage. This passage continues in two different directions to the NNE and NW.

Dick pushed a lead to the upper left of Boulder-Crawls. This lead goes up and back about twenty-five feet to an area with perpendicular passages. The left hand passage goes to a solution breakdown crawl into a stooping/walking passage. The right hand passage goes to more crawl/breakdown passage.

It was getting late in the day and all three of us were getting pretty tired and ready to call-it a day! We still had to go through the Ball Mill Crawl (thirty feet of narrow, sharp debris filled) passage to the main entrance. We exited the cave in the late afternoon, tired, hungry, and sore and relishing the wonderful sights, we had seen.

October 15th

After our long day in Crash Cave, the journey through Ball Mill Crawl (4X), bruised, bumped and beaten-up, we decided to ridge walk some of the ridges to the SW of the campsite. To our luck, Lloyd found three good-sized caves! One of the caves had been over-brush in the area). This cave, Dug Cave, looks as if it may not have been previously pushed, the openings were rather small openings, and has lots of moist-cold air coming from the entrances. The other two caves look very doable, nice air and look as if they were not pushed in the past.

We continued the ridge walk to the south and located two more sinks (dig gable), three caves (small), and four blowing-holes. They all look good and "dig gable" for future trips. As we continued around the east side of the ridge, we "scoped" the opposite ridges. Lloyd eyed a (pretty) good-looking hole on the opposite ridge and as we continued the walk up the main ridge, Lloyd decided to check out this area. John and Dick continued up the ridge and told Lloyd to meet us back at camp about 6PM.

When Lloyd returned that evening, he told us of five new large cave openings on that opposite ridge. His original hole did not pan out, but the new ones were blowing good air, diggable and need more study (April 2000). We also need to georeference the new finds and check the area for more potential caves.

This year's October CRF-LNF-CPSA expedition was an excellent, educational and new experience. The weather was excellent for cave digging/hunting and the caver-volunteers made this project one to remember. As coordinator, please accept our thanks to all of the LNF-CPSA people who made this expedition such a success. Thank you for your friendship, understanding, camaraderie, and the supreme-effort you all put into our project. Without these generous qualities, there would not be a CRF-LNF-CPSA Project.

# Archeology

## Progress Report: Excavations of Pine Crest Rockshelter (15LE70), Lee County, Kentucky

*Elizabeth Monroe  
Washington University*

Pine Crest rockshelter (15LE70) is a multicomponent site located in the Big Sinking Creek Oil Field of the Daniel Boone National Forest (Stanton Ranger District), Lee County, Kentucky (see Figure 1). It was first recorded in 1983 and, like nearby Cold Oak Shelter, was one of five heavily looted sites excavated by the U.S. Forest Service in 1984 (O'Steen et al., 1991). The purpose of the 1984 testing was to determine whether the evidence of looting observed on the surface of these sites accurately reflected the state of the deposits. It was found in a few cases that sites badly disturbed by pothunters actually had intact deposits adjacent to looter pits or under backdirt piles.

Pine Crest shelter has the preservation and deposits necessary for examining issues related to agricultural origins and faunal resource selection and use. Some of the earliest evidence for plant domestication in the Eastern Woodlands is from rockshelter sites in the Cumberland Plateau, such as Cold Oak shelter and Cloudsplitter shelter (Gremillion, 1993a, 1993b; Cowan, 1985). With the development of agriculture, I expect to see changes in species representation (decline in deer and rise in numbers of small fauna; Speth & Scott, 1989:71; Linares, 1976; Szuter, 1994; Szuter & Bayham, 1989), increased modification due to processing (Enloe, 1993), and deer body part representation would increasingly emphasize high utility parts through time (Emerson, 1993; Lyman, 1991; Marshall, & Pilgram, 1991).

The shelter is located in Town Hollow, which is drained by Big Sinking Creek, a tributary of the Kentucky River. This area is known as the Cumberland Plateau, a portion of the Appalachian Plateaus physiographic province (Fenneman, 1938:333; McGrain, 1983:23). The western edge of the Cumberland Plateau is the Pottsville Escarpment, which is characterized by deeply entrenched streams and narrow, steep-

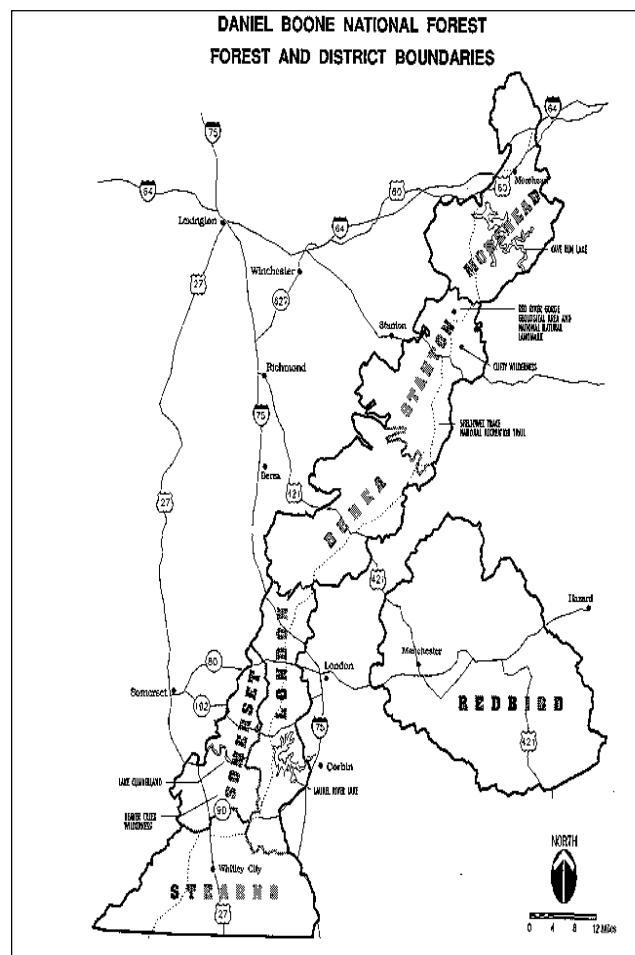


Figure 1: Daniel Boone National Forest  
(from <http://www.uky.edu/Agriculture/Forestry/AppalFor/forntel.html>)

walled valleys. Farther east, relief, altitude, and ruggedness increase, culminating in the Cumberland mountains (McFarlan, 1943:177-178). Resistant Pennsylvanian sandstone is underlain by softer marine limestone. Differential erosion of the sandstone has created numerous rockshelters and natural arches in this area, such as those found at nearby Natural Bridge

State Park and the Red River Gorge Geological Area. The excellent state of preservation of organic materials at rockshelters in this region has helped to advance our understanding of plant domestication in the Eastern Woodlands of North America.

Pine Crest is a large rockshelter situated in an east-northeast facing cliff of sandstone at the head of a steep and narrow hollow about 1000 meters above mean sea level. There is an intermittent waterfall to the north, and the dry shelter floor, measuring c. twenty by twenty-five meters, slopes down to a wet area fed by a spring to the south. Another, shallower overhang is adjacent to the south of the shelter. To the north, the overhang of Pine Crest continues, sheltering the course of water fed by the waterfall. At the base of this trickle of water is a barrel, probably the remains of a historic period still (O'Steen et al., 1991:133). The spring to the south meets this intermittent trickle on the northeast side of the talus slope to form a creek that flows into Town Hollow. The back wall of the shelter, which is rough in texture due to interleaved bands of more and less resistant sandstones, exhibits fractures and a ledge with a small hollow or room.

Signs of looter activity in the shelter are apparent, including graffiti on the walls of the room above the ledge, although none seemed recent in 1996. Although pits and backdirt piles can be found throughout the shelter, the heaviest looting activity is confined to the back wall. Some of the pits are quite deep: a sawn tree stump was found buried upside-down in one of the looter pits in the southwest corner. Other pits on the periphery of this area, including pits in the grotto to the south, are fairly shallow and often appear to be in sterile sediments. Perhaps looting was curtailed because the shelter seemed to have been depleted of desirable artifacts.

In the course of my project, two one-by-two meter units and a one-by-one meter unit were excavated. These units were placed adjacent to the Forest Service's units in the hope that results from the earlier excavation would help to interpret the complex stratigraphy in the shelter. The original Forest Service datum, arbitrarily labeled 400N/400E, had been placed on high ground in the northern portion of the dry shelter floor. By matching the edges of the previously excavated units, I was able to find that datum, and superimpose the earlier grid on the current excavation. Units were labeled



Figure 2: Photograph of Unit 386N/400E, north profile.

according to the grid coordinates at the southeast corner of each unit. The units were excavated in natural levels when possible. Thin lenses or irregular intrusions within levels were given secondary designations by letter (e.g., 4a) and excavated separately. Features were originally labeled by number, starting with the number after the last one used by the Forest Service archaeologists (e.g., Feature 20). Eventually it became clear that many features were merely shallow lenses that disappeared as soon as they were given a number, so they were also labeled by level number and letter (see Figures 2 and 3).

All excavation was performed by trowel. Each unit had a datum from which level elevations were measured using line levels and folding rules. Detailed plan views were drawn at the base of every level, and profiles were drawn of each wall, once excavation of a unit was completed. In addition, profiles were drawn of features, following excavation of half the fill. One liter sediment samples were taken from every level and feature for botanical analysis. To avoid damaging uncarbonized plant remains, samples were carefully screened through .6 millimeter mesh to remove the matrix. Kristen Gremillion, of Ohio State University, examined samples of the plant remains from unit 385n/406e. When possible, a second sample was taken for the recovery of small animal remains. The rest of the sediment was screened through 1/4-inch mesh. All flakes, ceramics, bones, and possible tools were collected and bagged by level. In addition, historic materials, such as plastic utensils, bottle glass, or aluminum foil, were kept to delineate possible contamination. Plant remains were abundant, extremely so in some instances. Diagnostic

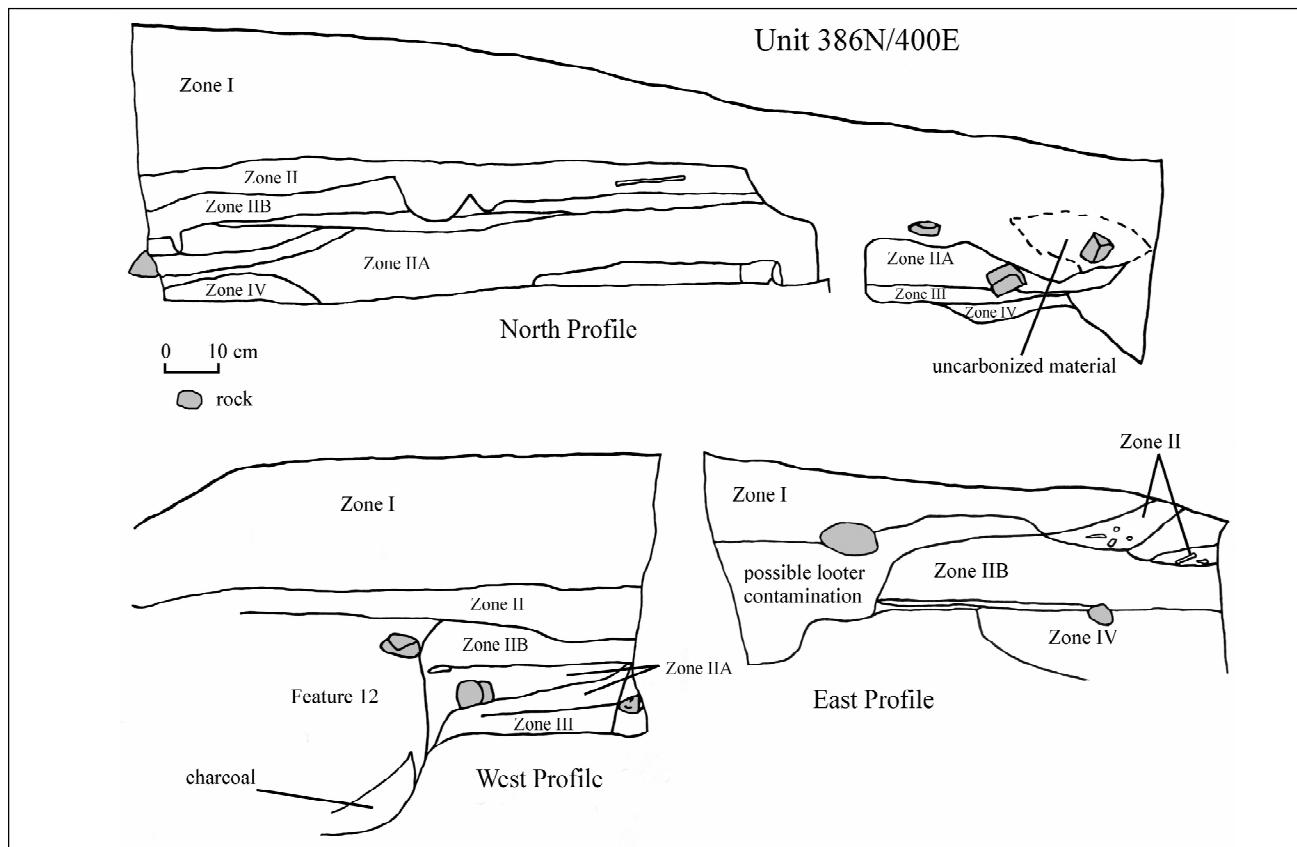


Figure 3: Drawn profiles of Unit 386N/400E

examples, such as the occasional chestnut or acorn hull, were collected. Cultigens were collected when encountered. It was impossible to collect every bit of charcoal (although the temptation was compelling), but sampling (i.e., one liter of sediment per level or feature) should be more than adequate. Sandstone fragments were not kept, but were described in the fieldnotes. Each bag and sample was given an invoice number to prevent mixing levels or units in the lab. Once in the lab, all materials except for botanical remains, fibers, and fragile mussel shells were washed and sorted. A summary of materials recovered from the excavation, with emphasis on the faunal remains, follows:

**Ceramic Artifacts:** Several plain and cordmarked limestone tempered sherds were found, but they are almost exclusively from disturbed contexts (84%). Of the twenty five ceramic fragments, only two were rim sherds, and both are from disturbed contexts.

**Lithic Artifacts:** Only two identifiable projectile points are present in the assemblage: a Ft. Ancient triangular, and a Brewerton-Eared Notched (Justice :119-124). There are also a few biface fragments, including a flared base. Almost all the rest of the lithic artifacts are flakes. The material is locally obtained Newman formation cherts, with a few pieces of Ste. Genevieve. Most of the flakes are thinning flakes rather than primary or secondary flakes, suggesting that few tools were being made in the shelter.

**Botanical Remains:** Kristen Gremillion examined several samples of the botanical remains from Pine Crest. Unfortunately, she found few examples of cultigens. I suspect this is a sampling problem rather than a real absence, due to materials recovered from the screens, and the presence of cultigens from the 1984 excavation (O'Steen, 1991). Items were found in the screens include abundant hickory, acorn, and chestnut shell fragments. Four cucurbit seeds were also found in the screen. One was from a Woodland Period context; the rest were from disturbed levels. There was

evidence in some areas of piles of leaves and grass. We found a handful of scorched, but not burned, holly leaves at the top of one of the features. Two strands of cordage were recovered. The material appears to be inner bark (Patty Jo Watson, pers. comm.).

*Faunal Remains:* A total of 3555 fragments of animal bone were recovered from the excavation, of which 1382 were identifiable to class and came from good context (see Figure 4). The latter group forms the assemblage discussed here. There are not many bird remains in the assemblage. Only forty fragments are identifiable to class, two of which are wild turkey (*Meleagris gallopavo*). The tibiotarsus of a perching bird (Passeriformes) was also recovered. It is likely that the specimens identified only as "large bird" are also turkey.

The bulk of the reptilian fauna (107 of 127 fragments in total) are turtle remains. All specimens that can be identified to genus are box turtles (*Terrapene* sp., 15 specimens). In addition, twenty snake (Serpentes) fragments were recovered. Three specimens are identified as frog or toad (*Rana/Bufo*), and one salamander (Caudata) vertebra is in the sample. The assemblage contains a single fish specimen: a cleithrum from a sucker (Catostomidae). Only two other fish fragments were found (from disturbed contexts), and they were also from a sucker. It is interesting that almost all the animals in the sample are terrestrial. The only other aquatic materials are mussel shell and crawfish remains, neither of which has been analyzed in any detail. The crawfish could have been collected quite close to the site, but it is unlikely that they are intrusive; the majority of remains are claws, and some show signs of burning. One feature contained over 50 fragments of crawfish (see Figure 5). The mussel shell probably came from a distance, where stream size would be large enough to support them.

Taking the sample as a whole, 88% of specimens are mammal remains (1211 specimens). Most of these remains are large mammal longbone shafts, which is to say probably deer (*Odocoileus virginianus*). Deer do make up the largest portion of those identified to family (64% of mammals identified to family, 86% of mammals identified to genus). The other large mammal specimen identified in the sample is a mountain lion humerus (*Felis concolor*).

Medium sized mammals (twelve specimens at the family level, five at genus level), include beaver (*Castor canadensis*), porcupine (*Erethizon dorsatum*), raccoon (*Procyon lotor*), and fox (*Urocyon cinereoargenteus* or *Vulpes vulpes*). With the exception of a fox radius, all of these specimens are from the cranium, either teeth or skull fragments. I am not sure what this means, but it is possibly a preservation issue, or perhaps a recognition issue (beaver teeth are very identifiable, for example). Small mammals, which include woodrats (*Neotoma floridana*), flying squirrels (*Glaucomys volans*), squirrels (Sciuridae), groundhog (*Marmota monax*), rabbits (Leporidae), shrew (Soricidae), and a big brown bat (*Eptesicus fuscus*), are represented by post-cranial fragments as well as teeth. There were twenty three small mammal specimens identified to the family level (eight specimens at the genus level).

How do the faunal assemblages of these two components compare? At first glance, they seem identical except for sample size. Looking at the distribution of fauna by class (see Figure 4) shows that the proportions in both samples are very similar, with mammals as the largest group. A comparison of the species lists for the two components shows that there are more species identified in the Woodland assemblage. The Woodland sample is larger, however, so this may be a function of sample size, or merely of preservation. In addition, species lists obviously do not take into account the fragments that are identifiable to part or class or body size. If all specimens are lumped into body-size categories, smaller animals do seem to increase in the Woodland component. Chi square tests indicate that this difference between samples is significant. Hence, there may be a trend towards procuring more small vertebrates, or at any rate the large mammals (deer) become less prominent in the assemblage.

Class	Archaic Component	Woodland Component	Total
<i>Birds</i>	8	32	40
<i>Mammals</i>	331	880	1211
<i>Fish</i>	1		1
<i>Amphibians</i>		4	4
<i>Reptiles</i>	32	95	127
<i>total</i>	372	1011	1383

Figure 4: Pine Crest fauna distributed by Class.



Figure 5: Feature 9B, a pit containing ash, burned wood, and over 52 crawfish claw fragments.

Turning to bone modification, quantification results for cutmarks and percussion marks or flake scars are nearly identical between the two assemblages. Cutmarks are, as is often the case, rare in both assemblages. Fewer than 3% of fragments had evidence of cutmarks. Flake scars noted on bones can be a sign of intentional bone breakage. If flake scars that seem to be due to carnivore gnawing are excluded from the sample, then one half to 1% of the fragments have at least one flake scar. Chi-square testing confirms that the two assemblages are not significantly different as regards flake scars. An examination of the degree of completeness of the specimens again shows little difference between the two assemblages. Less than 10% of fragments in either sample was more than 25% complete. Most longbone shaft fragments measure twenty millimeters in length or less. Additionally, a larger proportion of the Woodland assemblage falls into this category. This difference is significant according to chi-square testing. So it seems that the Woodland assemblage displays greater fragmentation.

A preliminary examination of deer body part distribution again shows the great similarity between the two assemblages. The Archaic deer assemblage is composed primarily of low utility items (71%), such as metacarpals, phalanges, and antler. Metatarsals are mid-utility, as are thoracic vertebrae, ribs, and the radius. The Woodland deer specimens are also mostly low utility elements (73%), but some, such as a femur

fragment and two tarsals (both are astragali), are high utility. The absence of any high utility elements in the Archaic sample is puzzling. It is important to note, however, that there are many specimens in both assemblages that are probably deer, but cannot be identified as such, and many of these are longbone shaft fragments. Further analysis may clear up this picture.

The faunal assemblages conform to my expectations, albeit weakly. Why are the differences not more robust? First, the two assemblages are not widely separated in time. I perceive the changes in subsistence as a continuum; perhaps these assemblages are too close temporally for the changes to be robust. Alternatively, similarities between these two assemblages may

have more to do with seasonality and a perpetuation of settlement practices. Walthall (1998a, b) has suggested in recent articles that rockshelters served as dispersed, short-term residential locales for small family groups during the late fall and winter seasons, from early Holocene to early historic times. While groups became steadily more sedentary in the warmer months, winter was a time of dietary stress, and dispersion would have been the most efficient strategy. Thus, the two samples may be broadly similar due to a perpetuation of winter dispersal to rockshelter sites.

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## Biology

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### **Speleogenesis of Movile Cave, Southern Dobrogea Romania: A Continuation of Studies about a Place Lost in Time and Space**

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#### **Project Summary**

Movile Cave, located in southern Romania, has imprinted itself on the scientific community with its delicate ecosystem not dependent on photosynthesis but instead on microbial chemolithoautotrophy. Portions of funding provided from the Cave Research Foundation (CRF) were used to finish my Masters thesis research in the Department of Geological Sciences, and start a Masters project in the Department of Biological Sciences, both from the University of Cincinnati, Ohio. My initial project goals were to determine the origin and age of sediment in Movile Cave in order to describe its speleogenetic history. From sediment mineralogy, stratigraphy, and paleomagnetism analyses, I determined that the sediment was closely related to surface soil, and loess deposits, and was transported into the cave via free-flowing streams that may have been associated with a nearby sinkhole. Fossil terrestrial and aquatic vertebrate taxa collected from the sediment belong to a Late Pleistocene assemblage, and sediment paleomagnetism supported deposition within the last 770 thousand years.

Following cave sediment deposition, the cave was sealed and abandoned by surface water. Deep, sulfidic groundwater inundated the region and the lower levels of Movile Cave approximately 10 thousand years ago (kya), initiating modern speleogenesis due to sulfuric acid dissolution. I continued the project in microbiology by investigating speleogenetic processes potentially impacted by microbial activity, with an emphasis on the integrating geological and biological methodologies. I found that microbially-produced sulfuric acid from sulfur-oxidizing microorganisms from Movile Cave, and other sulfidic cave systems, increased calcium carbonate dissolution rates compared to abiotic rates. The resulting work was one of the first geomicrobiological in-

vestigations done in a sulfidic cave system that quantified the contribution of microorganisms to sulfuric acid speleogenesis.

Funding from the CRF (\$2500.00) was used for travel expenses getting to and within Romania in 1998 (amounting to \$1500), radiocarbon dating of material from a swamp near Mangalia (\$900), as well as scanning electron microscopy work (\$200). Due to changes in research logistics beyond my control in Romania, modifications were made to my research proposal, allowing me to capitalize on detailed microbiology research.

#### **Research Results: The Potential for Microbially-Enhanced Sulfuric Acid Dissolution of Movile Cave**

Carbonate caves typically form from carbonic acid dissolution of limestone rock. In contrast, less than 10% of the Earth's caves probably formed by sulfuric acid (Palmer, 1991). In this process, limestone dissolves in the presence of sulfuric acid, created by abiotic oxidation of hydrogen sulfide at the air-water interface, as well as by oxidation of sulfide or other reduced sulfur compounds by sulfur-oxidizing bacteria.

Prior to the discoveries of microorganisms thriving in active sulfidic caves, karst formation due to sulfuric acid was thought to be the result of strictly chemical oxidation reactions (e.g. Egemeier, 1981; Hill, 1990), although sulfur-dependent, acidophilic microbes had been found in acid mine drainage systems and hot springs, and were known to generate sulfuric acid and cause rock corrosion (Pochon & Jatton, 1967; Mosser et al., 1973). Documentation of sulfur-oxidizing microbial populations in karst was limited until the discovery of sulfur bacteria from microbial mats in Movile Cave (Sarbu & Popa, 1992). The sulfur-oxidizing, chemolithoautotrophic

bacterium *Thiobacillus thioparus* strain LV43 was isolated from Movile Cave and characterized by Vlasceanu et al. (1997) and *Thiosphaera* sp. was also identified (Sarbu & Popa, 1992). However, no studies were conducted on the ability of these microorganisms to weather the carbonate host rocks due to the production of sulfuric acid. Therefore, my research goals were to isolate strains of sulfur-oxidizing bacteria and to screen them for their ability to lower the pH of their surroundings. Additionally, the ability to dissolve calcium carbonate ( $\text{CaCO}_3$ ) was tested. Dissolution rates were calculated for individual strains, and rates were compared to chemical reactions rates determined for strains of bacteria isolated from other sulfidic cave systems and abiotic dissolution rate estimated by previous investigators (Engel, 1999).

#### *Movile Cave Microbial Mats*

The microorganisms in the Movile Cave form a dense mat that floats on the water surface. The mat is mostly anaerobic, and Sarbu (1996) proposes that methanogenesis, not sulfur oxidation, is the most important metabolic pathway. Romanian colleagues gathered microbial samples from the lower levels of Movile Cave using SCUBA diving techniques. Due to the configuration of the cave passages with respect to groundwater levels, floating devices were setup in the cave airbells to encourage growth of microbial biofilms. These areas proved to be very useful when large amounts of samples were necessary.

#### *Strain Isolation and Characterization*

Chemolithoautotrophic, sulfur-oxidizing bacteria were enriched for using liquid media, modified from Brierley (1966), Postgate (1967), and Kuenen et al. (1992). All liquid enrichments were incubated aerobically in the dark at 28°C. Liquid cultures were allowed to grow for 1 week and once bacteria were observed microscopically, 2% solid agar plates were inoculated in order to isolate colonies of sulfur-oxidizers. Colony-forming units (CFU) were counted on plates after 2 weeks and isolates were sub-divided based on morphology. New plates and liquid media were reinoculated until pure strains were obtained. Thiosulfate-based media were the most successful for achieving enrichment diversity, although growth was also noted on all media and pH combinations. Thirteen short or long rod isolates were isolated.

The rod-shaped microbes were probably related to the genus *Thiobacillus*, characterized as Gram negative, short rods that form small, rounded, clear to white colonies. Thiobacilli require a reduced form of sulfur and most lower the pH of their surroundings due to the generation of sulfuric acid. Because there is not one media that can enrich for all bacteria, it is possible that microbes that grow fast, such as the thiobacilli, are "weedy" and out-compete other microbes in liquid or solid media. Therefore, the thiobacilli from Movile Cave may not be dominant in the microbial populations and may not be important contributors to sulfuric acid dissolution. Additional work, particularly with molecular techniques, needs to be done to substantiate these findings.

#### *Microbial Acid Production*

Isolated strains were classified as acid-producing and non acid-producing by plating on media containing 0.01 g bromocresol green, a pH indicator dye that could not be readily degraded by the microorganisms for heterotrophic growth. Above pH 5.4 plates were blue, at pH 3.8 and below plates were yellow. Acid production and potential to corrode  $\text{CaCO}_3$  were also tested using plates with disseminated  $\text{CaCO}_3$  powder within the medium. Sterilized  $\text{CaCO}_3$  was added to the agar solution at 1% (w/v) prior to aliquoting into standard petri dishes. These plates were made a pH 6 to reduce dissolution of  $\text{CaCO}_3$  by chemical acidification. As acid-producing colonies grew on the plates,  $\text{CaCO}_3$  was cleared and crystals of gypsum may or may not have appeared. Bacterial lawns were allowed to grow on the plates and the amount of time to clear  $\text{CaCO}_3$  from the plates was recorded. Control plates were also incubated, whereby no  $\text{CaCO}_3$  dissolution was observed following a three week incubation period. The thirteen strains were isolated from Movile Cave microbial mats, with six being able to generate acid on both plate types. Similar research experiments were done with isolated thiobacilli from other sulfidic cave systems (e.g. Cesspool Cave, Virginia, Engel et al. 2001). For all the strains, dissolution rates were calculated from the volume of the media, approximately 25 cm<sup>3</sup>. One of the strains from Movile Cave had an estimated 4.8 mg/cm<sup>3</sup>/day dissolution rate. Dissolution times from other cave isolates ranged from 7 to 36 days, corresponding to dissolution rates of 14.4 mg/cm<sup>3</sup>/day and 2.8 mg/cm<sup>3</sup>/day, respectively.

### Microbial Karst?

Regardless of problems associated with culturing or identifying microorganisms, being able to detect for acid production from isolated strains was an important part of this work. Abiotic sulfuric acid dissolution rates for the Frasassi Caves, Italy, (Galdenzi *et al.*, 1997) were calculated by weighing carbonate tablets before and after exposure to the cave atmosphere for a limited amount of time. Surface area-based acid dissolution rates were calculated at 15-20 mg/cm<sup>2</sup>/yr. Galdenzi *et al.* (1997) also report that microbial mats colonized the tablets, suggesting that the rates they measured may have been higher than expected. However, strains I isolated from the Frasassi Caves could dissolve as much as 839.5 mg/cm<sup>2</sup>/yr (Engel 1999). This rate is significantly faster than the dissolution rates from abiotic experiments, and significantly faster than those from Movile Cave, perhaps attesting to the nature and diversity of the microbes in each setting. Attempts to estimate weathering rates in Movile Cave were made by Sarbu (1996) based on gypsum accumulation due to carbonate replacement. Because this technique has not been standardized, and there is potential for misinterpreting replacement mechanisms, correlation of their results to strain rates is not possible.

It should be noted that the laboratory rates for microbially-enhanced rock dissolution are probably underestimates compared to what is actually occurring in the caves. Although this study provided cursory evidence for microbial carbonate weathering in the subsurface, this work is still just a first approximation of the biogeochemical process. Therefore, more detailed studies are underway in another sulfidic system, Lower Kane Cave, Wyoming, involving in-cave dissolution experiments and comparative analysis of bacterial populations (Engel, unpublished data; Stern *et al.*, 2002).

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## Geosciences

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### Sedimentology of the Redwood Canyon Karst

*John C. Tinsley*

The karst of Redwood Canyon lies in the Grant Grove section of Kings Canyon National Park. It contains more than sixty sinkholes, three caves including Lilburn Cave, and a major Vauclusian ebb-and-flow spring (Big Spring). These elements comprise a single karst system containing a three-dimensional maze more than eighteen miles in mapped length. The karst is developed as a mantled karst, situated wholly within the eastern part of the Redwood Mountain roof pendant, a highly metamorphosed suite of rocks intruded by Mesozoic plutonic rocks of the Sierra Nevada mountains. Scientists of the Cave Research Foundation have conducted research, monitoring, and mapping studies of the sediments of the karst for more than twenty five years. Several aspects of the karst's sedimentology have been studied during the past couple of decades. These topics include studies of the rates of sediment yield to the sinkholes above ground during the past 700 years, the provenance or source characteristics of the sediment mapped in the channels of surface streams and subsurface deposits in Lilburn Cave, the impact of a single sinkhole collapse on the hydrology of the cave and spring system, and the response of the cave to various levels or intensities of runoff events.

The studies of sediment yield to sinkholes depend on the presence in plugged sinkholes of a volcanic ash deposit that was erupted about A.D. 1240 from the Deadman Dome area of the Inyo Craters volcanic chain in the eastern Sierra Nevada near Mammoth Lakes resort. Owing to westward-directed winds that prevailed at the time of the eruption, this tephra made it across the Sierran crest where it is preserved in alpine meadows as a distinct layer, and it comprises a buried identifiable marker bed in some sinkholes of Redwood Canyon. Hand-powered auger equipment readily intersects both the tephra and its post-depositional sediment cover in the sinkholes, and the volumes of tephra and post-tephra sediment are readily computed from isopachous maps of the sinkholes, and the

results compared to aspects of the karst including drainage basin area and slope. Sinkholes that have been "leaky" or that have collapsed since the tephra was deposited do not yield reliable results. About ten of the sinkholes have a decent stratigraphic record useful for the purpose of this study.

Contrasts in rock types within Redwood Creek basin provide useful keys indicating the source of sediment within the passages of Lilburn Cave. The main surface stream, Redwood Creek, flows mainly south towards the Kaweah River. Redwood Creek's tributaries from the north and west drain a basin that is dominantly underlain by non-carbonate metamorphic rocks (mainly schists, hornfels, and quartzites) of the Redwood Mountain pendant; tributaries from the east side of the drainage come off Big Baldy mountain, an 8000-foot-high Cretaceous granite pluton. Consequently, sediment along Redwood Creek's modern channel contains 70% metamorphic lithologies, in contrast to the nearly pure granitic sand and gravel deposits of the drainages that emanate from Big Baldy.

Within the cave, these lithologic contrasts are preserved and enable investigators to determine which passages have received water and sediment from Redwood Creek, which passages have retained apparently an exclusive eastern tributary association, and which passages preserve an interplay between the two source rock associations.

In 1989, a portion of the bed of Pebble Pile Creek, a westward-draining tributary to Redwood Creek, dropped into Lilburn Cave in the general area of the Yellow Floored Domes. The minimum volume of sediment dumped into the cave was estimated to amount to 140 cubic yards by surveying the volume of the new sinkhole preserved in the bottom of Pebble Pile Creek. The estimate is a minimum because an undetermined volume of sediment was shed from the precipice along

the north side of Pebble Pile sink. The effect within the cave was to cause subterranean Redwood Creek to aggrade vertically about ten feet from the Z-Room to the South Seas. There was a corresponding 10-foot rise in the standing water level of the South Seas sump during episodes of low discharge in the late summer and autumn. These new conditions persisted for nearly eight years, until the El Nino winter of 1996-1997. At that time, substantial early season snow was melted by warm intense rains (the proverbial "Pineapple Express" condition in California weather parlance), and the cave was filled with water such that about 130 feet of head was applied to Big Spring. This was sufficient to construct a low fluvial terrace in Redwood Creek downstream of Big Spring; the sediment was derived mainly from Lilburn Cave via Big Spring, on the basis of grain size, composition, and spatial association. Within the cave during the 1982-1983 El Nino winter, a sediment wave at least 10 meters in amplitude went through the Z-Room area, as recorded by a static sediment sampler. During the next two years, the aggraded sediment in lower Lilburn Cave that was derived from Pebble Pile sink was eroded

progressively away. By 1999, conditions within the cave were back to pre-1989 conditions. In 1999, the Pebble Pile sink also was re-filled such that water flowing into the sink could flow out the lower end of the reach, once again displaying an integrated thalweg. For the preceding decade, the entire water and sediment discharge of Pebble Pile creek had been trapped by Pebble Pile Sink. Thus, we have documented an example of a sinkhole "cycle" that has had a duration of about ten years. Other subdued scars along Pebble Pile creek probably record similar sequences of geomorphic events, but these have not been dated or studied in any detail. The wall of Pebble Pile sink continues to decline, and headward migration of the sinkhole lip is threatening to excise the present course of Redwood Canyon trail. Several mature conifers have contributed their undermined carcasses to the sinkhole, with more to come.

Lilburn Cave is a wonderfully dynamic natural laboratory in which to study, monitor, and document sinkhole development and evolution, and sediment transport processes above and below ground.

## Paleontology at Mammoth Cave

*Rickard Toomey*

Starting in the Fall of 1997, the Illinois State Museum (ISM) has been involved in two paleontology projects at Mammoth Cave National Park (MaCa). The principal investigator on these projects has been Rickard Toomey. The projects are being undertaken under cooperative agreements between the ISM and the NPS. In addition to providing important data to the projects, CRF has been actively involved in supporting the projects through both mapping activities and contributing personnel to assist in locating paleontological remains. Although there are formally two projects, with somewhat different goals and timelines, the methods, data, and CRF participation are the same in both projects.

The first project is a study of the Past Bat Usage of the Historic Entrance Area of Mammoth Cave. This project is a portion of MaCa's larger Historic Ecotone restoration project under the direction of Park Ecologist Rick Olson (NPS, CRF). The Historic Ecotone

Project seeks to reverse much of the damage that has occurred to the Historic Entrance Area during the 200 years the cave has been utilized for saltpeter mining and tourism. The types of damage that are being targeted include airflow changes, increased condensation, fungus growth on archaeological materials, loss of bat habitat, lint and dust, and increased ceiling spall. The project also seeks to protect the cave from future damage. Other components of the Historic Ecotone Restoration Project include replacing the old entrance gate with a batfriendly gate and construction of a boardwalk to reduce trail maintenance damage, lint, and dust.

As noted above, two of the goals of the Historic Ecotone Restoration Project are to restore past bat habitat and past airflow conditions. The Past Bat Usage Project contributes to these two goals. In order to restore past bat roosts, it is necessary know where those roosts are, what bats used them, what season they used

them in, and when they used them. The Past Bat Usage Project is determining these kinds of information. These data are also the main data being used to reconstruct past airflow patterns. Hibernating bats choose specific climatic conditions. By locating past hibernacula, we are able to help determine the past temperature and humidity of these areas.

CRF has been extremely active in supporting the Past Bat Usage Project over the last year. The CRF map of the Historic Entrance Area is vital to the project. Doug Baker, the CRF cartographer in charge of the Historic Entrance sheet, has allowed us to set the priorities for his drafting on the sheet. He has also worked with us in completing survey of areas that we needed sketched.

In addition to the mapping support, CRF has also contributed to the Past Bat Usage Project with personnel assisting in locating paleontological remains in the Historic Entrance Area. In order to locate material that provides information on past bat usage (bones, mummi-

fied bats, guano, raccoon scat) we have been performing an intensive hands-and-knees survey of the area. CRF personnel have been participating in this survey/inventory on numerous expeditions.

In addition to the remains in the cave, the Past Bat Usage project has also focused on historical accounts of past bat usage in the area. CRF has contributed significantly to this aspect of the project, as well. We have been given free access to the Mammoth Cave Bibliography and Gazetteer being complied by Mick Sutton, Sue Hagan, and Ray Mansfield (CRF). Other CRF members, such as Stan Sides and Gordon Smith, have also suggested important historical accounts of bat use.

The Past Bat Usage project is coming to an end. We are now assembling the final report for the park. However, the project has highlighted various questions, that we will be continuing to explore with CRF's help.



## **Cave Research Foundation Activities 2000**

## **Cave Research Foundation Directors**

**2000**

Patricia Kambesis  
President

Paul Cannaley  
Treasurer

Peter Bosted  
Secretary

Phil DiBlasi  
National Personnel Officer

Rick Toomey  
Fellowships and Grants Program

Mick Sutton

Chris Groves

Dick Maxey  
Hamilton Valley Project

Chuck Pease  
International Projects

## **Operations Area Managers**

Eastern Operations Area: Dave West

Lava Beds Operations Area: Janet Sowers

Ozark Operations Area: Scott House

Southwest Operations Area: Barbe Barker

Sequoia and Kings Canyon  
/Mineral King Operations Area: John C. Tinsley

*Page 85 photo credit: Cockscomb formation in Emesine Cave, HI  
Photographer: Dave Bunnell*

# 2000 Highlights *Compiled by Patricia Kambesis*

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## Annual Meeting

The CRF Annual Meeting was held in St. Louis, Missouri during the weekend of November 10-12. The meeting started on Friday with closed sessions of the CRF Board and Operations Council. Member activities included a Saturday morning tour of the Anheuser Busch Brewery. The open meeting was held at the Powder Valley Nature Center. The meeting began with CRF President Pat Kambesis announcing the completion of the Hamilton Valley building and with the recognition of CRF Fellows and Certificate of merit recipients.

Talks followed on aspects of CRF work in Missouri by Scott House and Bill Elliott, project reports from CRF's various operation areas and projects, and a slide presentation on project caving in Hawaii by Don Coons. Don Kurz from the Missouri Department of Conservation was the keynote speaker, his topic covering the five biomes that exist in Missouri. The meeting was followed by a banquet. Sunday activities included survey trips to Fisher Cave.

## Board /Operations Council Additions

Mick Sutton and Chris Groves were elected to the CRF Board during 2000. Both Mick and Chris have previously served on the Board. Their past experiences will be an asset to the current Board.

At the Missouri Board meeting, the Operations Council voted to include Elizabeth Winkler on the Operations Council as the Hamilton Valley Director.

## Hamilton Valley

In anticipation of CRF's final move to Hamilton Valley, Pat Kambesis appointed a steering committee to put together a facility management plan and to also determine the necessary supplies, equipment, furniture etc. to get the facility up and running. Elizabeth Winkler was appointed to head up the first Hamilton Valley facility management group.

Alliance Contractors finished the Hamilton Valley construction project in September of this year. Once

the building was ready to be occupied, Elizabeth coordinated the efforts of many CRF members who volunteered their time and donated supplies, equipment, furniture and other items to make the facility functional. Cavebooks donated bunks, mattresses, tables, chairs and a refrigerator. Mel Park donated a new stove for the kitchen.

Eastern Operations moved all of their belongs to the new facility during the first week of October. On Friday, October 7, 2000, CRF hosted its official Open House which took place after the 8th Annual Mammoth Cave/CRF Science Conference and right before the October expedition. There were sixty plus in attendance which included many CRF members and researchers, our partners from the Division of Science and Resource Management, and friends and neighbors of CRF. An excellent meal was catered by CRF member Al Welhausen.

The Open House and Inauguration was a grand event. With a view of Hamilton Valley from the main hall as a backdrop, CRF acknowledged the Hamilton Valley Project's biggest benefactors: Roger McClure, Patty Jo Watson, and Red Watson, for their vision and support of the Hamilton Valley Project. Red and Roger were given the honors of conducting the actual dedication. A piece of webbing was strong across the fireplace: Roger cut the webbing and Red lit the first fire. Don Coons presented Red and Roger with handmade porch-worthy rocking chairs. Gordon and Judy Smith continued the honors by presenting Roger, Red, and Patty Jo with a plaque mounted with the door of the first stove used by CRF during the Flint Ridge days in the Park. Though the initial phase of the Hamilton Valley Project has drawn to a conclusion, it is just the beginning of what CRF will accomplish from the Hamilton Valley Research Station.

## NPS/CRF Science Conference

The Eighth Annual Mammoth Cave National Park Conference was held on October 5-6 2001. Co-sponsored by CRF and the National Park Service, the conference provided a forum for presentation and discussion of karst research in Mammoth Cave National

Park as well as in the surrounding area. Superintendent Ron Switzer and CRF President Pat Kambesis gave welcoming remarks.

A number of CRF members gave papers at the conference including Stan Sides, who talked about 18th Century tuberculosis treatment experiments conducted in Mammoth Cave; Rick Toomey discussed his ongoing paleontological inventory; Patty Jo Watson presented Ken Carsten's paper on archeological research over the past 200 years in Mammoth Cave area; Chris Groves discussed the broad-based implications of his global carbon project. Pat Kambesis presented the Mammoth Cave digital base project that Don Coons has been developing using all of CRF's digital data, and Bob Osburn summarized CRF's history of survey standards, status of map production, and developments in cave cartography techniques.

A Friday evening banquet was held at the Hamilton Valley Research Station. This also served as an Open House for the new facility.

### **CRF Member Recognitions**

Certificates of Merit were awarded to the following CRF members: Mike Yocum, for his work in the GIS and Educational Development Programs; Bernie Szukalski, for his contributions to the GIS Program; John Fry, for the great job he as done as liaison between CRF and park Management at CRF; Karen Willmes for her efforts at editing the Eastern Operations Personnel Manual; Bill Devereaux, for his work at Lava Beds National Monument, and to the Hamilton Valley Building Committee (Cheryl Early, Dave Hanson, Daniel Greger, Sheila Sands, Joyce Hoffmaster, Dick Maxey, Elizabeth Winkler, and Richard Zopf.)

### **China Caves Project**

Cave Research Foundation and Western Kentucky University have expanded the China Caves Project with Scientific Exchanges in 2000. In June 2000, Chris and Deana Groves and Alan Glennon, visited the Karst Dynamics Laboratory in Guilin. They gave a three-day workshop on Geographic Information Systems (GIS) tools for study of karst geomorphology, hydrogeology, and resource management, led by Alan. Chris presented results of the Mammoth Cave Working Group of Project

379. In addition, a joint Chinese-US team participated in field research into landscape evolution of the Li River Valley using newly developed methods of cave sediment dating by isotopic analysis being pioneered by Darryl Grainger. (See detailed report in this issue).

### **CRF Fellowship & Research Grants**

In 2000, CRF Awarded eight grants totaling \$7000 under the Karst Research Fellowships and Grants program. The following projects were awarded Karst Research Grants.

#### **Local Landscape Evolution and the Emergence of Cultural Complexity in the Central Mississippi Valley: A Case Study in the Mid-Holocene History of the Midwestern Uplands**

Kristen Arntzen, Department of Anthropology, Washington University, St. Louis, MO

Amount of award: \$1000

*Project summary:* Funding from the Cave Research Foundation will support a detailed archaeological study of the robust mid-Holocene deposits at the Allscheid Rockshelter in southwestern Illinois. The shelter preserves a rare, long post-glacial upland depositional sequence in the broader American Bottom region. Due to a limited sediment catchment, sedimentological and radiocarbon analyses will enable a fine-scale reconstruction of the history of sediment regimes. With its proximity to the well-studied, bluff base Modoc Rock Shelter, the Allscheid Rockshelter presents an excellent comparative study for Modoc's long sequence of post-glacial riverine deposition. Furthermore, like Modoc, the Allscheid shelter shows evidence of long-term use by prehistoric human groups through the mid-Holocene. This time period is known to be critical for understanding subsequent developments in social and economic complexity, but archaeological work has so far emphasized the importance of human adaptations to the evolving configuration of large interior river floodplain settings. Thus, the fine-scale evaluation of sources and timing of the Allscheid deposits, along with comparison to the Modoc deposits, will mark an important contribution to both the study of post-glacial geologic history in the Midwestern uplands, as well as the exploration of mid-Holocene cultural change and landscape evolution in a generally poorly understood setting.

**The Karst Hydrology of Boiling Spring, Mill Creek, and Surrounding Basins, Phelps and Pulaski Counties, Missouri**

Jim Kaufmann, University of Missouri, Rolla

Amount of Award: \$1000

*Project summary:* Although Boiling Spring along the Gasconade River in Pulaski County, Missouri, is one of the largest springs on the north flank of the Ozarks, very little is known about its recharge area. A large karst upland to the south and east of Boiling Spring supplies recharge to Boiling as well as several other second and third magnitude springs located in the Mill Creek, Spring Creek, and Little Piney watersheds. Dye tracing and flow measurements will be used to delineate the recharge areas for several of the larger springs. Initial results indicate that the karst hydrology of the region is very complex with Boiling Spring sharing recharge areas with most, if not all, of the other large springs. Previous flow measurements of Boiling Spring have been taken at extremely low flows. The discharge of the spring has been reported as 65 cubic feet per second (cfs) which is an underestimate of its actual average discharge. A more realistic estimate of the average discharge will be calculated using a combination of long-term flow measurements, flow duration curves, and precipitation events for other large second magnitude and first magnitude springs and surface rivers in the Ozarks, and comparing them to previous Boiling Spring and Gasconade River measurements.

**The Effects of Timber Harvest upon Sedimentation in Caves and Karst in Southeastern Alaska**

William Curry, Western Kentucky, University, Bowling Green, KY,

Amount of award: \$1000

*Project summary:* Sediment samples collected from caves in Prince of Wales Island, Alaska are being prepared and analyzed for Cesium 137 at WKU Applied Physics Institute. Cesium 137 is not natural to soils or caves but it was added to soils around the Northern Hemisphere as a result of the atmospheric nuclear testing beginning in the last 1940's and early 1950's. The Cesium 137 is useful as a tracer in soil erosion studies involving recent erosion and sedimentation. It is being used to trace soil transport into caves and sinkholes in Central Kentucky and Southeastern Alaska where recent timber harvesting and development has taken place

and caused erosion. If the soil samples are positive for Cesium 137, this indicates that the layers were deposited as a result of post 1954 erosion (likely resulting from timber harvest or development). Negative results could mean that the soils in the caves are older than 1954. Additional, carbon dates of wood fragments or sediments can be used as controls in this study.

**Genesis, Paleoenvironment, and paleogeomorphology of the Mississippian Redwall Limestone Paleokarst, Hualapai Indian Reservation, Grand Canyon Area**

Mr. Tony Troutman University of Texas at Austin,

Amount of award: \$1000

*Project summary:* pending

**Foraging Strategies of Cave Crickets, Mammoth Cave, Kentucky**

Kurt Lewis Helf, Ecology and Evolution Group, Biological Sciences, University of Illinois at Chicago

Amount of Award: \$1000

*Project summary:* I decided to use CRF funds to focus on two aspects of predation rates on *Hadenoecus subterraneus*. I will examine the effect of crop fullness on predation rates on *H. subterraneus* by the white-footed mouse (*Peromyscus leucopus*). I predict crop full crickets will suffer increased predation rates relative to crop empty crickets due to their decreased escape ability. I will carry out experiments in 2m x 2m x .6m plexiglass enclosures of my design. An experimental run will consist of two different treatments: 1) 2 arenas with a mouse and 20 crop full crickets; 2) 2 arenas with a mouse and 20 crop empty crickets. After a few hours I will remove the mice and gather the remaining crickets and determine the rates of predation in the two treatments. I will perform at least 5 iterations of the two treatments. I will compare predation rates between the treatments using a t-test. Further, I will examine the effect of moonlight on predation rates on *H. subterraneus* in the field. I predict predation rates on *H. subterraneus* will decrease on moonlit nights relative to moonless nights. I will attach cave crickets to large spikes in the ground with 2 lb. test with 50cm of slack and leave them out overnight.

I will check the crickets every 3 hours and note any missing individuals. Individual crickets will be secured with a noose in a 50cm piece of 2 lb. monofilament with the free end anchored by a nail in the ground. Twenty tethered crickets will be placed along a transect line and spaced 1m apart. Transects will begin just outside the cave entrance because this is where GUFs were lower and where use of baits decreased at the population level. Tethering locations will be examined several times each night and presence/absence of all individuals will be recorded; any missing individuals will be replaced. In addition, any observed predator-prey interactions will be recorded. Experiments will be run on moonless and moonlit nights at three cave entrances (i.e. Great Onyx, White, Frozen Niagara). We will attempt to identify predator type based on available evidence at the tether site. For instance, mice usually leave feces and discarded body parts after preying on crickets and salamanders might be 'hooked' to the monofilament. We will use chi-square analysis to test for significant differences in predation rates between moonless and moonlit nights.

### **Environmental Disturbance of Oligotrophic Bacteria and Effects on Water Quality in a Deep Karstic Ecosystem**

Andi Hunter, University of New Mexico, Albuquerque, Amount of award: \$750

*Project summary :* The human population is at risk of loosing its water supply due to contamination of surface and ground water resources. This problem extends to remote areas such as the Lechuguilla Cave system where coliform populations are endangering the health of its visitors. My work in the Water Resource Program at The University of New Mexico specifically addresses hose materials used in Lechuguilla Cave exacerbating the growth of harmful microbes. Currently, Lechuguilla Cave uses Tygon tubing that supports high levels of slime which in turn promote pathogenic coliform colonies. This overabundance of microbial activity, particularly *E. coli*, threatens Lechuguilla's drinking water supply. My research aims to identify alternative plastics such as Teflon, vinyl, Nalgene, and rubber products which prohibit excessive coliform development. Hosing improvements coupled with visitor impact reduction will alleviate further water contamination problems. In addition, the identification of safer

plastics will prevent contamination in other cave systems worldwide.

### **Role of Suspended Sediments in the Transport and Fate of the Pesticide Atrazine in the Hawkins and Logsdon Rivers, Mammoth Cave, Kentucky**

Michael Anderson, Western Kentucky University,

Amount of award: \$750

*Project summary:* pending

### **The Caves and Rockshelters of the East Obey River Basin, Tennessee: An Archaeological Survey**

Jay D. Franklin, M.A., Department of Anthropology, The University of Tennessee, Knoxville

Amount of award: \$500

*Project summary:* The caves and rockshelters of the East Fork Obey River Basin possess a rich archaeological record, one that reflects several thousand years of human prehistory. I am conducting a systematic archaeological survey of these caves and rockshelters and adjacent uplands in Fentress County, Tennessee. The purpose of the survey is to locate important sites that will define the culture history of this karstic region and elucidate unique prehistoric human-land relations there. This survey is the focus of my doctoral dissertation research at The University of Tennessee, Knoxville. This prehistory remains obscure because this area has never been systematically surveyed. Culture histories applied to this region, however, were developed in other physiographic regions and primarily from large cultural resource management projects conducted under contract with the Tennessee Valley Authority (TVA), for example. As such, these projects were focused in large river valleys and floodplains. The culture histories of karstic regions have never been directly assessed. The proposed project represents a significant and unprecedented departure from mainstream regional archaeological survey practices. It is expected that existing culture histories are inadequate for the East Fork Basin and the Upper Cumberland Plateau (UCP) generally, and that the UCP possesses its own unique culture history, one that will contribute new, original, and important information concerning prehistoric human history. My doctoral research centers on the unique culture history of this karstic region.

# Operation Area Reports

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## Eastern Operations Activities

*Compiled by Dave West and Patricia Kambesis*

Eastern Operations officially moved to the Hamilton Valley Facility during the first week in October 2000. It took multiple trips and an energetic group of volunteers to vacate Maple Springs of CRF gear and equipment. Eastern Operations' "new" home is situated in the map/researchers room located just behind the main meeting hall. Half of the space in the map room is dedicated to Eastern Operations. The Columbus Day expedition was Eastern Ops first out of the new facility.

Mammoth Cave National Park has welcomed a new manager for the Division of Resource Management, Mr. Mark Depoy. He seems very receptive to the efforts of CRF, and we look forward to working with him.

During the year 2000, Eastern Operations fielded 63 parties. Thirty seven of these supportive the Cartographic Program with trips to Mammoth, Colossal/Unknown, Bedquilt, Salts, Proctor and Crystal sections of the Flint Ridge-Mammoth Cave System. Seven trips went out in support of the Small Caves Inventory Program with work conducted in Wilson Cave, Swallows Cave, Poison Ivy Cave, Smiths Valley Cave and Coyote Crescent Cave. Twelve trips began or continued work outside of the Park in Roppel Cave, Diamond Caverns, Dogwood Cave, Backyard Cave, and in Monroe Sink.

The Cartographic Program is working on incorporating all of CRF's Mammoth Cave survey data into one digital format. Don Coons is leading the effort by compiling all of the existing data into a COMPASS-format database. Mike Yocom will be converting that data into Walls format. This is the beginning of efforts by the Cartographic Program to convert all of its data and projects into a totally digital format.

Chief Cartographer Bob Osburn is working with various CRF cartographers towards converting all their work from hard copy to computer drawn format. The ultimate objective is for all CRF cartography to be done digitally.

### Mammoth Cave Video Project

It took twelve trips to complete the Mammoth Cave Tours Safety Video project. This project was completed as part of a cooperative agreement with Mammoth Cave National Park. It involved creating videotape sequences of 39 features or activities in various tours of Mammoth Cave. The goal was to incorporate these sequences in an interactive computer display to be set up in the Visitor Center at Mammoth Cave National Park (MCNP) in the summer of 2000. The display shows highlights of tours, and provides tourists with vital safety information about each trip. The project began in July 1999 and was completed during Cave Research Foundation's (CRF) Memorial Day 2000 expedition.

Features taped included Albert's Stairway, Audubon Avenue, Big Break, Booth's Amphitheater, Bottomless Pit, Carmichael Entrance, Cleaveland Avenue, College Heights, Drapery Room, the Elevator entrance, Fat Man's Misery, Fox Ave, Frozen Niagara, Gerta's Grotto, Grand Canyon, Grand Central Station, Historic Entrance, Kaemper Hill, Kathleen's Crawl, Keyhole, Mammoth Dome, Mummy Ledge, Onyx Colonnade, Rafinesque Hall, Rainbow Dome, Rotunda, saltpeter vats, Side Saddle Pit, Storm Drain, various travertine features, and Violet City

In all but one instance, each sequence was shot at least three times. In some instances there were as many as six takes. Side Saddle Pit required eleven takes before a satisfactory shot was obtained.

A total of thirty five CRF members contributed over 637 hours to this project. CRF's contribution in time, mileage, per diem, and materials was \$57,345. Thanks are due to all members who helped out, all expedition leaders who organized video crews, and the Eastern Area Operations Manager for support. Steering the project from the National Park Service side was Chief of Interpretation Mike Adams. *Source: Mike Yocum, Project Coordinator*

### **Paleontology work**

Rick Toomey's project, "Characterization of Past Bat Usage of the Historical Entrance Area, Mammoth Cave" continues to be supported in terms of logistics and manpower. In 2000, eight CRF teams provided cartographic and manpower support for these projects.

Paleontology work led by Rick Toomey in Cyclops Way and Gothic Avenue. The teams flagged resources for future data recording.

Long Cave was added to the list of caves in which paleontologic work was instituted. An accompanying re-survey will provide a detailed base map for the paleo work.

Paleontology reconnaissance was done in Sturgeon Cave to evaluate its paleontologic potential and to identify past bat colonies. Sturgeon Cave was occupied by a colony of thirty to forty Rafinesque big-eared bats (*Corynorhinus rafinesquei*). The cave was also rich in other biota including crickets, frog, rabbit, surface land snails and a Rhagidid mite, a dipluran and salanders. Very little paleontologic material was found.

## **Lava Beds Area Report**

*Janet Sowers*

An important event this year was the retirement of Bill Devereaux, freeing him up to do what he loves, be at Lava Beds. He worked for the Resources Management division all summer as a volunteer, putting in over 575 hours. He spent much of his time on the 438 cave files, specifically, reviewing the existing files for completeness and bringing all the files up to standard, including visiting many of the caves to complete their reconnaissance inventory, numbering and monumenting. This was a monumental task and a great service to Lava Beds. Bill says there is still more to do!

Cave survey continues at a steady pace. A total of 13 caves were surveyed this year. However, cave map drafting has not kept pace with surveying. To help with this problem, we have initiated the following steps:

1) Copies of survey notes are now left at Lava Beds in the Resources Management office before going home. This way the resource managers will know what was done and will have the raw data if the book person does not follow through.

2) Cave survey data is entered into Compass and line plots printed by the book person.

3) The cave maps are drawn up in pencil by the book person. The map should be laid out neatly with cross sections, profile, and scale properly placed. A copy of this interim product may be given to LABC as a place holder in the cave files until the inked version is prepared.

4) The inked version may be prepared by anyone with computer drafting or inking skills that can trace the pencil drawing. Bruce Rogers has offered his services.

Bruce Rogers has been computer drafting some of the cave maps that we have been preparing. He is now experimenting with enhanced, annotated and illustrated maps in which he adds photographs, captions, and text in the margins that help describe and interpret the cave.

### **Monitoring**

We continue with long-term monitoring of the ice levels in the ice caves and winter bat populations.

Bill Devereaux led the ice level recording effort, recording ice levels in six caves twice a year at the time of their expected minimum and maximum ice levels. Bill and Janet Sowers have both periodically monitored the rapid loss of ice at Merrill Ice Cave.

### Gating project

The cave gating project, headed by John Blum and Mike Sims, is being conducted on specific caves of concern at the request of the monument. This year the

gate on Post Office Cave was repaired, and a new gate was installed at Gemini Cave.

### Personnel

**Janet M. Sowers:** co-Project Manager, Technical Director, **William C. Devereaux:** co-Project Manager, Field Operations **Mike Sims:** Principal Investigator for cave gating projects **Bruce Rogers:** Principal investigator for cave mapping **Bill and Peri Frantz:** PI's for virtual reality cave tour

## Ozark Operations Area

*Mick Sutton*

### Mark Twain National Forest (MTNF)

During the year 2000, survey work continued in Crocker Cave, Howell County, where a party returned to the downstream lead. It was felt that this section could be completed, as the passage was only a couple of hundred feet from a surface ravine that has terminated all other passages in that direction. After 160 feet of survey, the party entered a 40 feet by 50 feet room devoid of footprints but with several exits. The lead at the downstream end of the passage appeared too small to allow further penetration, but an inlet passage continued, and the crew began a survey heading upstream into the opposite ridge from where they started. In all, 300 feet of survey was completed. A follow-up trip mopped up a small amount of survey in the downstream lead, resulting in a total cave length just in excess of a mile.

Much of Little Hurricane Creek was acquired by the Mark Twain Forest relatively recently, as part of the Greer Spring purchase, and there were four reported caves in that section of the creek, with no information other than names and vague locations. An overnight float trip to the mouth of Little Hurricane was the springboard for the search. We succeeded in finding three of the four caves, but Little Hurricane Cave remains a mystery. Muddy Cave and Prickerbush Cave were both short (c. 30 feet) and hard to find—the anonymous author of the earlier reports evidently did a thorough job of checking the valley. Further upstream, Beaver Spring

Cave was longer and more interesting. As the name suggest, the cave is beaver habitat. Although no beavers were presently in residence, the large quantities of sticks and shredded bark had a profound effect on the cave's biology, with large populations of terrestrial invertebrates and unusual stream fauna, including the only example we have seen of mosquitoes breeding within a dark zone. The survey extended into what seemed to be previously unentered territory along a very wet crawl interrupted by standing-high domes, for a total of about 300 feet

The biggest job on the Mark Twain during this period took place at the Chadwick Motorcycle Area on the MTNF in Christian County, a section of the Ava District given over to off-road vehicle recreation, with an extensive network of developed ORV/ATV trails in addition to, as we discovered, a prolific network of unofficial trails. We met with Neal Babik to assess the caves for adverse impact, especially to the caves' biology, due to the heavy ATV use. None of the ten caves known within the ATV area are very large; the largest is Rattlesnake Cave at about 250 feet. Rattlesnake Cave has a bike trail right outside it, and casual visitation is encouraged. The wall-to wall coverage of the entrance bluff by graffiti was impressive, but the cave apparently gets cleaned of trash periodically. The most notable biological finding was that use of the cave by hibernating pipistrelles is significantly reduced compared to the Gene Gardner inventory of 1979. Other caves were surveyed and inventoried in the area.

Fieldwork in July and August of 2000 consisted of a single weekend-long trip to the MTNF Cassville district in Barry County in far southwestern Missouri. As in the case of the Chadwick area of the Ava District, heavy off-road vehicle has the potential for increased visitation and vandalism of the area's caves. Chimney Rock Cave was mapped and inventoried (400 feet). It was historically an Ozark big-eared bat site, but heavy visitation eliminated this colony some years ago (the species is now considered extirpated from Missouri). As far as we could tell, this cave, although well-known, is not receiving extremely high visitation, and seems to be beyond the present illicit ORV road network. It was good to get some baseline data, though, as the ORV road net is undoubtedly expanding. Biologically, the cave is quite rich. Highlights included an unusual sighting of a hoary bat (*Lasiusurus cinereus*) in deep twilight, two species of stygobitic amphipod, and a tiny eyeless spider. The latter needs to be more closely examined, but it may extend the known range of the rare undescribed troglobite *Indiana sp.*

Other surveyed caves included Lohmer Cave and short and dry Sweet Potato Cave in the Radium Creek area. Lohmer Cave featured a troglobitic isopod species, *Caecidotea stilocdactyla*, reported only once before in Missouri. Onyx Cave is probably the most heavily visited cave in the area, and within the current ORV zone. The entrance is marked on the USGS topo and an old Forest Service trail leads directly to it. Again, vandalism does not seem to have increased notably, although there is a great deal of old speleothem breakage and graffiti. The main entrance is a sink, and the resulting forest debris washed into the cave makes for a richly-populated cave with a high diversity of terrestrial invertebrates.

There was one field trip during this period to the Rolla-Houston District, to do biological inventory in Hanley Cave (Phelps County). The air flow induced by the multiple entrances will be a factor to consider during planned prescription burns in the area, especially since the cave is a summer bat roost. In addition, Hanley Crawl Cae was mapped for all of twenty five feet.

Work in the Eleven Point District continued, with a trip to map and inventory Slave Cave, in a remote and beautiful setting along Little Hurricane Creek.

The cave was short (150 feet) but interesting. The most obvious biological feature was a remarkably high density of hibernating pipistrelles: 93 in this small area, along with a few other bats. Although aquatic habitat consisted of only one tiny drip pool, it was inhabited by numerous small isopods and amphipods. The other biological feature impossible to ignore, unfortunately, was a recently deceased skunk.

### **Missouri Department of Natural Resources**

Fisher Cave is the large, well-decorated show cave in Meramec State Park. The CRF resurvey resumed when a party mapped 300 feet to the Waterfall Room, the terminus of the "Cave Explorers' Paradise" arm of the cave. Through November of this year a total of over 1600 feet of passage was mapped in this cave.

### **Pioneer Forest**

The Pioneer Forest is the largest privately owned woodland in Missouri; for many years, CRF cavers have been assisting Pioneer's managers, who have a strong conservation ethic, with assessment of cave and karst resources. There was a trip to assess the condition of Cookstove Cave, a large and well-known "party cave" in Shannon County. Although the cave has been signed to bar winter visitation, ATV traffic in the area is very frequent and visitation continues to be heavy. This is a big concern, as two winters ago, CRF parties had documented a significant colony of hibernating bats, tentatively identified as Indiana bats. Traffic in nearby Holmes Hollow Cave was also extremely heavy, with ATVs riding more than 500 feet into the cave, not too difficult to do, as the cave is a large, level "railroad tunnel." Finally, a small 25 feet long crawl, George Cave, was relocated and mapped.

A return trip to Cookstove by Mick Sutton along with Rick Clawson, bat specialist with Missouri Department of Conservation and Greg Iffrig, manager of Pioneer confirmed our supposition that the resident bats were Indians. We counted 1000, about the same as our estimate from two winters ago, although the distribution was different, with most of the bats now in the remoter of the two roosts. Holmes Hollow Cave also housed a couple of dozen Indiana bats, probably overflow from Cookstove as Holmes Hollow is not cold enough to serve as a prime hibernation cave. The Pio-

neer manager is pondering ways to reduce illicit motor vehicle traffic into the cave area.

### **Arkansas-Buffalo National River**

Since the last Missouri report in 1999, CRF's Missouri and Arkansas operations have been merged into the Ozarks Area.

There were two expeditions to map small caves within the Buffalo National River in March. Horseshoe Cave and Christmas Candy Cave, both along Indian Creek were mapped. Caves along leatherwood Creek were also surveyed. (Great Disappointment Cave – 43 feet), SF7, a small natural bridge, and a previously unreported cave (150 feet).

During the April trip, three teams mapped small caves along the Buffalo downstream from Ponca. The Survey of Ivy cave proceeded for a total of 135 feet. A second team mapped 130 feet long Spider Cave, well named as it was full of *Meta ovalis* spiders. Team 3 mapped Azalea, Sandstone and Toga-toga Caves. The first two were small, but Toga-toga Cave was 3-dimensionally complex and involved significant vertical work. It is developed at the contact between the limestone and overlying quartzose sandstone.

### **Ozark National Scenic Riverways/ Missouri Dept. of Conservation**

A party checked out several archeological sites which may or may not constitute caves in the Jerktail Landing area of the Ozark National Scenic Riverways (ONSR). The CRF crew joined NPS ranger Becki Bulls. Archeological reconnaissance was conducted in several rocks shelters while CRF survey crews mapped and inventoried other small caves in the area.

Scott House and Bob Osburn worked with ONSR staff on reconciling archeological reports with the cave files. They then checked out another archeological site-Partney Farm Caves turned out to be two entrances to a single small seventy-five-foot long cave overlooking the Current River. The next day, a larger crew went to a pit lead near Red Bluff on the upper Jacks Fork. Cedar Pit was supposedly only twenty feet long at the bottom, but it turned out to have a side passage. The crew mapped the pit to a climb which they

could not get down due to the narrowness of the crack and lack of footholds below. Rymer Spring was then visited, and six small caves and shelters mapped.

A small shelter, Brandyweide Shelter, was located and mapped between the Log Yard and Powder Mill on the Current. Red Cave was located and renamed Red Shelter. There was a brief trip to locate Owls Bend Cave and to search the Little Bloom Creek valley.

A large crew, including visiting paleontologists Rick Toomey and Mona Colburn, paid a visit to remotely-situated Mose Prater Cave (aka Chimney Cave and numerous other synonyms) for mapping and inventory. The 55 feet entrance pit gives access to a trunk passage extending in either direction for a total of about 600 feet. Work progressed on mapping and documenting the rich assemblage of live fauna and faunal remains. The cave is most notable as a gray bat summer colony and Indiana bat hibernation site. The date of the visit was chosen to accommodate these constraints. About 1000 gray bats were still in residence, and guano piles covered the entire floor of the eastern arm of the cave.

The Powder Mill Creek Cave survey advanced further into the unknown with three long, wet trips. The first two knocked off the last remaining inlet passage, the "ultra-wet lead," a low crawl off the third watercrawl. Water levels had moderated by several inches since the last trip, and the first crew mapped 500 feet, ending in a breakdown room with near-surface indications. The cave appeared to end here, but as has often been the case with this cave, a wet crawl continued. The follow-up team mapped through several more small breakdown rooms in relatively comfortable passage, 3-4 feet high, then excavated the entry to a crawl, which led back to the continuing low airspace stream passage. This led through another small dome before effectively ending in a near-siphon. The total surveyed on that trip to complete the inlet was about 500 feet. On the same day as the Mose Prater trip, another Powder Mill crew continued up the main passage, now the only remaining lead in the cave. The survey started 12,000 feet upstream from the entrance and advanced under "rather nice" survey conditions (three feet high passage with up to a foot of water) for another 550 feet without reaching an end. The cave is still trending well under the ridge and shows no sign of ending soon. It is just short of eight miles long.

## **Missouri Department of Conservation (MDC)**

### **Education**

There was a visit to Susan Cave, a fairly long and austere cave in Washington County, to assess the cave for use during the MDC "Beyond Becoming an Outdoors Woman" program, which CRF personnel are assisting. The cave features plenty of mud and water but few technical difficulties, making it a good beginner's cave. In fact it's regularly used for this purpose by a local YMCA camp and a Boy Scout group. A biological inventory showed that the cave is rich in terrestrial invertebrates, fueled by a huge input of dung from raccoons and/or other small mammals. Also of considerable interest, we discovered a small Indiana bat roost (a State and Federal endangered species) within the twilight zone. The "Outdoors Woman" course will take place in April, with Sue Hagan leading the group on behalf of CRF.

We have also been cooperating with the MDC as part of a small-grant program to add CRF biological data to Bill Elliott's state-wide Missouri Biospeleology Database. In partial fulfillment of the program, we are depositing representative cave invertebrate specimens at the Entomology Museum at the University of Missouri, Columbia.

## **Miscellaneous**

CRF crews have been involved in mapping and paleontological work in a large, privately owned Pulaski County cave. The cave is notable not only for its large trunk passages, but also for the well-preserved remains of a short-faced bear. The articulated bones were in a deep cave site protected by a fairly large amount of crawling. Paleontologist Blaine Schubert and project leader Jim Kaufmann patiently excavated the remains and encased the bones *in situ* in plaster before transporting them out. The project has been very labor intensive, and there were a total of eight trips during this period, the last one involving a large number of porters to remove the last of the bones. A small amount of survey sketch and biological inventory was also accomplished during this trip. The remains of the bear are being studied and curated by Blaine Schubert at the Illinois State Museum in Springfield, Illinois.

A two-person crew mapped 125 feet of smallish, dampish passage to complete the survey of Catholic Church Cave, owned by the Lesterville School District, Reynolds County. The cave contains an exceptionally large population of long-tailed salamanders.

There was an educational trip for a local Audubon Society chapter to privately owned Bunker Cave, where CRF has been conducting a cave survey. The ten participants were shown primarily cave biology, but we also extended the survey for a couple of shots in a demonstration of cave mapping technique.

## Sequoia and Kings Canyon Operations Area

*John C. Tinsley*

The SEKI operation has seen a banner year in terms of cartography, with new discoveries mainly in the southern portion of Lilburn Cave that have a lot of folks excited, to the point that three additional expeditions have been conducted to date, in addition to the eight regularly scheduled expeditions.

**Cartography:** Chief Cartographer Peter Bosted reports that Lilburn Cave's surveyed length is about 29.5 kilometers (18.3 miles, if you're scoring). At least a half dozen new CRF members have attended the expeditions this year, and have proven to be solid performers. Additional exploration and cartography operations have been conducted intermittently in Mays Cave, but small cavers are required.

**Sedimentology:** Tinsley reports that the mild winter and prolonged cool spring season limited peak runoff to low levels. Consequently, little in-cave sediment movement occurred. GPS locations are being obtained on the karst features of Redwood Canyon, including sinkholes and swallets and creeks, in order to check the surface karst map being prepared by Tinsley.

**Cave Diving:** Bill Farr conducted an exploratory dive of the Upstream Rise and discovered that his dive line was not buried by sand, confirming Tinsley's assertion that little sediment appeared to have moved last winter. Weather and balky SCUBA regulators permitting, Bill plans a push dive of the Upstream Rise during low clear water conditions that persist in the autumn months in Redwood Canyon. Bill also found an air-filled bell that had been overlooked during previous dives. He may endeavor to explore that area further, although it isn't far from the entry point for the dive.

**Exploratory Digs:** Under Brad Hacker, leads have been pushed in Pebble Pile Creek, Redwood Creek, and at several points within Lilburn Cave. Air movement suggests promise, but the boulders are large and the bedrock cracks are too small for cavers.

**Hydrology:** The hydrology project is on hold while Jack Hess serves in his new capacity as anthrax experimental animal in Washington, D.C. Tinsley will re-establish the datalogger at Big Spring this November, to maintain the long-term monitoring study of the karst system.

**Cave Restoration:** Bill Frantz has continued cleaning of the Jefferson Memorial area, with other areas being temporarily deferred.

**Mineral King:** Jeff Cheraz and Roger Mortimer coordinated a major expedition on Labor Day weekend, to check the emerging map of White Chief Cave. Roger Mortimer returned to California for that weekend to help lead the effort. Roger will be returning to California from his year in Indiana, to his old job in the teaching program at Fresno State's medical program. We will welcome him and his bride Amanda with great relief, as they are an integral part of our effort, and small projects are intrinsically fragile entities. Bill Frantz led a trip to the caves of the Timber Gap area, and Jeff Cheraz led a trip to the Cascade Creek area for ridgewalking. These trips were run as day trips out of Cold Springs Campground, located near most of the trailheads that depart from Mineral King.

## Southwest Region Report

Barbe Barker

### Status at Carlsbad Caverns National Park (CCNP)

CRF volunteer time at Carlsbad Caverns National Park from September 1999 through October 2000 totaled 1464 hours.

There is a new Superintendent, Mick Holm, whom I have not yet met. Dale Pate has been named Acting Chief of Resource Management after Gary Vequist transferred to another park. CRF SW has been working more with Stan Allison (Cave Resource Technician) for the past year. He is very easy to work with and supports the efforts of CRF. He also has expressed that we are the best restoration group that comes to the Park and talked to me about holding a workshop for their Maintenance Department in order to educate them on maintaining the restored areas and show them how they impact the cave without being aware of it.

In the May/June 2000 issue of the National Parks magazine, an article entitled "Guardians of the Parks" recognized five individuals or groups of individuals, who have stood out as contributors to our national parks. The only caver featured was one of our own CRF SW cavers. CRF and CCNP were exceptionally highlighted in the article and the Park was very pleased with the national recognition and picture of the Soda Straw Room.

In 1996, CRF SW expeditions began signing an "Agreement for Sponsored Voluntary Services", Form No. 10-86 by the United States Department of the Interior, National Park Service Volunteer in the Parks Program. Basically, this form entitles us to Worker's Compensation Insurance benefits for anyone on a CRF Expedition. This includes getting hurt out of the cave as well as in the cave. This is particularly significant as one of our volunteers had an accident during Restoration Field Camp this last June. The Park had asked if they could borrow Walter Feaster and Bill Bentley to go out to Lechuguilla and help bring the culvert out that day. Mr. Bentley slipped on wet rocks before getting to the cave entrance resulting in a spiral fracture of his tibia. In addition to paying his medical bills, NPS also paid him weekly worker's compensation benefits while

he was off work from his "normal" job. I would strongly recommend that any of our CRF areas who work in a National Park look into this since it is a U.S. Department of the Interior, National Park Service form and you should be able to get coverage for your volunteers.

Also, by signing the *Agreement for Sponsored Voluntary Services*, CCNP is able to show our volunteer hours to support their needs and the financial rewards from a national basis. The equivalent of thirteen full time employees were credited to the volunteer efforts last year. Since 1996 when we started signing this Agreement, CRF SW has contributed 4,327 volunteer hours to CCNP. We are second only to LEARN in contribution hours (since we don't camp in the cave).

**Survey and Resurvey:** The Survey Standards set by Dale Pate are very high. Approved Sketchers are precious and few; especially when it comes to all three day holiday weekends. Everyone in the area and beyond are vying for them. CRF SW continues to attract them and each expedition has either two or six with no happy medium! However, ongoing survey projects have been completed and new ones are beginning.

**Restoration:** Ongoing projects continue, Lake of the Clouds, Guadalupe Room, Dome Room, Texas Trail, The Rookery - stopped until they install bridges over water. They ask us to take on another project almost every time we go.

**Data Management:** All original survey data stays with the Cave Resource Office. Copies are distributed to each individual sketcher and to me. I now have all the old CRF data that Pat Helton had before. My intention was to inventory and somehow copy it before archiving it at the Park in the temperature controlled environment. My recommendation for the old data is to find a technical type person who will scan the old documents onto CDs and I make a typed inventory of what each document was. However, I will not let the documents leave my possession to an entity or outside person. This will be a goal for this year.

# Archeology

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## Sediment Composition and the Preservation of Macrobotanical Remains at Mounded Talus Rockshelter, Daniel Boone National Forest, Lee County, Kentucky

*Katherine R. Mickelson*

*The Ohio State University, Department of Anthropology*

The sandstone cliffs along the western edge of the Cumberland Plateau in eastern Kentucky contain numerous rockshelters in which unusual environmental conditions have resulted in the preservation of normally perishable organic remains. The exceptional preservation of ancient plant remains has stimulated much of the archaeological research that has been conducted in the region and has provided important evidence for environmental and subsistence change, including the development of an independent eastern North American agricultural tradition. Archaeological research in the region has predominantly focused on the Late Archaic to Early Woodland (ca.3000-800 BP) transition to and development of food production. In contrast, subsistence practices in the period just prior to the archaeological appearance of domesticates, the Middle Archaic period (ca.6000-3000 BP), have received little attention. However, only with an understanding of Middle Archaic subsistence can the subsequent origins of plant cultivation be properly understood.

The lack of water and the presence of nitrates are often cited as causal agents for the exceptional preservation of plant remains beneath some of the overhangs in the region. Although previous research in the region has documented that the environmental composition of these rockshelters is highly variable and that there is a high degree of differential preservation within them, to date there has been no systematic attempt to identify the major determinants of plant deposition and preservation. The present study addresses plant deposition and preservation, and Middle Archaic plant exploitation, by examining the physical and spatial attributes of the archaeobotanical assemblage and the geochemical properties of sediments from the Middle Archaic

period rockshelter, Mounded Talus, in order to assess relationships between plant preservation and their environmental context. Subsequently, more robust interpretations of Middle Archaic subsistence can be made.

The results of botanical and sediment analyses indicate:

- 1) The primary source of plant remains at Mounded Talus shelter are anthropogenic rather than biogenic or geogenic.
- 2) Prehistoric use of the rockshelter led to changes in the geochemistry of sediments in the shelter, namely through the introduction of organic material and ash which acted to increase levels of nitrates. These changes in the micro-environmental composition of the sediment are the primary environmental determinants of plant preservation within the shelter. In addition, the prehistoric occupants of Mounded Talus rockshelter deposited a thick ash layer across portions of the shelter. This ash lens effectively 'capped' portions of the deposit resulting in two distinct environmental zones within the deposit. The upper deposits were driest and associated with the highest levels of soluble chemicals, especially nitrates; the ash lens buffers the upper deposits against moisture that enters the shelter through capillary action in the basal deposits. Below the ash zone, organic remains are subject to faster rates of decay because of increased moisture.

- 3) Despite the dry environmental conditions of the shelter there is differential preservation among carbonized and non-carbonized remains, between categories of plant remains (i.e., nuts and seeds) and among specific taxa of plants (i.e., hickory nut and acorn). Standard analytical protocols used by paleoethnobotanists would have failed to detect these differences in preservation. This study illustrates how slight modifications in the analysis of archaeobotanical remains resolved this problem.

Botanical remains indicate that the Middle Archaic inhabitants of Mounded Talus followed a generalized mode of plant exploitation from all landforms in the region and used the rockshelter as a central place for processing and preparing plant foods. The presence of wild/weedy undomesticated seeds of gourd (*Cucurbita*) and sumpweed (*Iva*) at Mounded Talus, both of which show evidence of being domesticated in subsequent millennia, may represent the initial stages of the domestication process. In any case, their presence in the Middle Archaic period deposits at Mounded Talus is important in filling a temporal gap in the record of wild progenitors of both gourd and sumpweed in Eastern North America.

This research is important for several reasons. First, this research is the first systematic attempt to identify environmental variables affecting the preservation of plant materials in the Cumberland Plateau. This study has demonstrated that the presence of potassium nitrate in sediment with low moisture content is the primary environmental determinant of archaeobotanical

preservation at Mounded Talus rockshelter. However, even slight increases in sediment moisture content reduce potassium nitrate levels and the preservation potential of plant remains is subsequently reduced. The identification of these variables has broad implications, not only to rockshelters but to other sheltered environments, such as caves. Specifically, it has important implications for a) understanding how *all* organic artifacts, such as plant remains, textiles and wooden structural remains, preserve in a given environment and, b) considering how human activities, both prehistoric and modern, can affect sediment geochemistry and results in differential preservation of organic remains. The results and methods used in this research can be used to facilitate the conservation of perishable materials at both rockshelter and cave sites, especially those that are open to the public. For instance, capping sediments - which is often done to protect archaeological deposits or to facilitate public access - may trap moisture in sediments resulting in the decay of organic remains; precautions need to be taken to ensure that organic archaeological materials preserve.

Second, this research identifies variables and utilizes methods that have important for archaeobotany by correcting for differential preservation. Processes involved in the preservation of botanical remains were identified and were used for comparisons of taxa within the sheltered environment. Methods used to identify these processes will enable researchers to make more robust comparisons between sites in sheltered environments (rockshelters and caves) and between sheltered sites and non-sheltered sites.

# Biology

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## Comparative Biology of Epigean and Hypogean Banded Sculpins

Ginny Adams

Department of Zoology, Southern Illinois University

Banded sculpin (*Cottus carolinae*) occur in both surface streams and springs in the eastern United States (Pflieger, 1997). Occasionally, *C. carolinae* have been reported in twilight or dark regions of cave systems but do not appear to be more than accidentals or troglophiles, exhibiting no cave adaptation. However, populations of *C. carolinae* exhibiting characteristics similar to cave adapted species have been found in several caves in Perry County, Missouri. These unusual cave sculpin populations exhibit variable reductions in eye size, pigmentation, and pelvic fin ray number. *Cottus carolinae* collected from the resurgence stream for these caves also exhibit reduced pelvic fin ray counts compared to similar streams in Perry County and to literature on other surface populations (Robins 1954). These three distinct habitats (cave streams, cave resurgence streams, and surface streams without cave systems) and their corresponding sculpin populations provide an excellent opportunity to investigate changes in morphology, physiology, life history, and genetic structure in relation to habitat. By taking an integrative approach to the study of these unique populations, we will have a better understanding of the evolutionary forces that shape troglobitic organisms.

### Study site

Perry County, Missouri, is located in the Salem Plateau of the Ozark Uplands and contains 630 known caves, making it one of the densest concentrations of caves in the United States. Perry County also contains the four longest caves in the state of Missouri: Crevice Cave, Moore Cave System, Mystery Cave, and Rimstone River Cave. Karst in Perry County is thought by several researchers to be derived from the Pleistocene Epoch (Vandike, 1985), implying ingress of sculpin into the caves occurred somewhere between 1.8 million to 10,000 years ago. Figure 1 shows the distribution of caves and surface streams which are

known to contain populations of *C. carolinae*. An anticline located between Crevice Cave and Moore Cave System is thought to create a drainage divide between the two systems (Vandike 1985). Hydrologic divisions between major cave systems containing sculpin populations implies *C. carolinae* have entered caves numerous times and provides natural replication for this study. The study sites for this experiment were selected based on ease of entry, density of *C. carolinae*, relative location to other sites, and current landowner relations. They include Mystery Cave, Rimstone River Cave, Running Bull Cave, Cinque Hommes Creek, Moore Cave System, and Blue Springs.

### Research Background

External morphology of the *C. carolinae* populations both in Perry County and throughout the species range was completed and published in Environmental Biology of Fishes (Vol. 62:279-296) (Figure 2). Significant separation of all populations was based on morphological characteristics, with the highest loading factors being measures of head shape, eye size, and caudal peduncle (Discriminate Function Analysis and Canonical Variates Analysis). The first canonical variate provided separation primarily of cave from surface populations. Cephalic lateralis pore size varied significantly between cave and surface populations using Analysis of Covariance (ANCOVA), with those on the surface having pore sizes two to three times smaller than those in the cave. There was also separation based on one meristic character (number of pelvic fin rays) that was found to be significantly reduced in populations from Perry County (3-3 or 3-4 elements) compared to banded sculpin found throughout its range ("normal" sculpin have four elements on each pelvic fin). Although banded sculpin have frequently been reported in cave environments (Burr *et. al.* 2001), even when collected several kilometers from a surface stream, none

of these populations have shown evidence of cave adaptation. An albino specimen reported from Buckeye Creek Cave, Greenbriar County, West Virginia, may be an exception. However, only a single "abnormal" specimen has been collected despite numerous attempts to document a viable troglomorphic population in this cave.

To compare metabolic rates of sculpin from cave and surface habitats, I tested three sculpin populations—two from caves and one from the resurgence stream. I measured *in-situ* metabolism of fifteen individuals from each population in the fall of 1999. In addition, to determine if photoperiod and/or food could alter metabolic rate, sculpin were collected from each study site and brought back to the laboratory where they were placed into three treatment groups. This aspect of the study was completed in conjunction with an undergraduate student (Linda Roman) with funding provided by the Cave Research Foundation Karst Fellowship (which also provided support for the study of the morphology of the laboratory held individuals). In the *in-situ* study, significantly different metabolic rates were observed between cave and surface populations; however, there was no significant difference between the two cave populations. For the laboratory study, water temperature was maintained at approximately 15° C during acclimation to photoperiod and testing. Oxygen consumption was measured for each treatment (twenty four hour dark/ high food, twenty four hour dark/ low food, twelve hour light: twelve-hour dark/ high food, twelve hour light: twelve hour dark/ low food) after eight weeks of acclimation. There was no significant effect of treatment on metabolic rate ( $P = 0.1885$ ). However, we detected a trend for higher metabolism in high food treatments compared to low food treatments. This may imply that either the laboratory acclimation period was not sufficient to allow metabolic alterations or that this trait is not "plastic" in this species, and the decrease in metabolic rate observed in the cave habitat (*in-situ* study) may have more of a genetic component.

Currently, I am completing data analysis on measures of gross brain morphology (measures of volume of each lobe relative to the total brain volume), melanophore counts, and histology of the eye on the same specimens for which external morphological data

were examined. Preliminary analysis indicates a significant difference in brain lobe volume between cave and surface populations, with those in the cave having significantly smaller optic lobes and larger telencephalon compared to surface populations (Figure 3). The overall size of the eye and lens of the eye in the cave populations is greatly reduced compared to surface populations and ongoing histological analysis of the retina will help to elucidate these differences. Specifically, I will be examining the relative numbers of rods, cones, and size of the lens among populations. In addition, morphological analyses (both external and internal) are being conducted on sculpin (collected from a surface stream in Illinois) held under two photoperiods for one year (12 light/12 dark and 24 hours dark) to determine if habituation to a constant dark environment could elicit significant changes in morphology.

### Future Directions

In the next year, I will be completing a project on population genetics of the troglomorphic sculpin populations in Perry County to determine if these unique populations are divergent morphologically and genetically. Based on the geologic separation between Tom Moore Cave and Mystery Cave, sculpin in Perry County appear to have invaded caves on several separate occasions; however, the source population for each of the caves lies within the same drainage. Genetic comparison of populations within the same drainage may provide pertinent data about factors influencing divergence. In addition, it will allow for development of a management plan that seeks to conserve the maximum amount of genetic variation present in these populations.

We have recommended that these populations be considered for listing under the U.S. Endangered Species Act (Burr *et al.*, 2001) based on their status as the only example of cave adaptation in cottids. In addition, these populations may be jeopardized from surrounding land-use practices in Perry County. Many of the caves are located downgradient of the city of Perryville and are surrounded by agricultural fields. Recently (1999) we observed a fish kill in one population (Running Bull Cave) that may have been linked to the above threats. It is our hope that Missouri Depart-

ment of Conservation will incorporate data collected during this project into a management plan conserving these unique fish and habitats.

### Acknowledgements

As with any cave research there are many people to thank for their time and help with the field research. Most notably, I would like to acknowledge the tremendous amount of time devoted to this project by Cindy Lee and Richard Young. In addition, the members of Little Egypt Grotto and many graduate students at Southern Illinois University have contributed time and ideas. I would like to acknowledge the Cave Research Foundation for research support through the Karst Research Grant (a grant that really helped “get the ball rolling”). Other sources of funding for this research include Raney Award (American Society of Ichthyologists and Herpetologists), Missouri Speleological Survey, Explorer’s Club, and National Speleological Society.

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# Cartography/Resource Inventory

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## Resource Inventory of Less-Extensive Caves: Mammoth Cave National Park, Kentucky

*Scott House*

The world's longest cave is located in and around Mammoth Cave National Park. However, within the park itself are entrances to over three hundred other, less extensive, caves. Most of these caves lie south of the Green River; however, a large (and largely undetermined) number are on the north side of the river. Despite, or because of, the fact that Mammoth Cave has been extensively studied, mapped, and written about, little is known about the majority of these less-extensive caves. Management of these resources could not be accomplished without first obtaining a great deal more information about the resource. A cooperative project between the Cave Research Foundation (CRF) and Mammoth Cave National Park has established an inventory system that should produce usable data about these caves on an ongoing basis.

The project got underway in late summer, 1994 and was due to expire in 1997. The original objectives were finished well within this time frame. Due to increased opportunities for additional work the project was extended until 1999.

### Objectives

The project has had two encompassing objectives: 1) to develop the materials and methodology, and 2) to test the system by inventorying the caves within the study area. Field materials and equipment to be developed include simple field guides, instructions, inventory sheets, Global Positioning Satellite (GPS) hardware, monumenting tools, biological inventory gear, etc. A database suitable for recording the data was to be investigated and tested. The methodology was planned in advance but was to be refined over the course of the project, particularly the first year.

### Study Area

An initial study area, selected by the National Park Service (NPS), consisted of several drainage ba-

sins on the north side of the Green River. Included within this area were at least five caves longer than 1000 feet and approximately 35 other, mostly unverified, locations of smaller caves. Previous work in the study area included surveys done by a group of Louisville cavers called the North Shore Task Force, a few cartographic surveys and locations from CRF files, and locations of caves and hydrologic studies by NPS personnel. This study area was scheduled for a three year project.

Later, the study area was unofficially enlarged by CRF and the NPS to include all of the caves on the North Side. This more than tripled the geographic area to be considered. The reason for this expansion of effort was simple: the project was being more productive in its work than was initially assumed. This expansion was done at little or no cost to the Park.

### Previous Work

A serious study of the resources of the small caves of the park, particularly of the North Side has never been undertaken. Previous work in the area includes work done by CRF (mostly cave surveys but including one inventory of Ganter Cave), a group of cavers called the North Shore Task Force (cave surveys, locational work, and geological studies), and the NPS (informal resource evaluations of certain caves.) This material had not been synthesized into a usable form.

Additionally, geologic and hydrologic investigations of certain drainages on the North Side had been done by Joe Meiman and Marty Ryan. These studies were extremely useful in this project.

### Philosophy and Training

In this project, we tried to develop an approach that would be flexible enough for many purposes. As



A “less-extensive” cave in Mammoth Cave National Park, photo by Mike Lace

part of this development, we rejected several older methodologies that we felt would not be as conducive to good data retrieval as the one adopted.

Particularly we shied away from a checklist approach for several reasons which are discussed further in this document. But, it should be understood that this approach was carefully considered before rejecting it. Basically, we felt the background strength of the available workers allowed us to go much farther. In our approach, the burden for inventory is not on the form or checklists but on the individual doing the inventory.

As part of this approach, it was necessary to insure that the data retrieved were of high quality. To insure this, we instituted a variety of training approaches: there were formal, classroom sessions, field training sessions, and on-the-job training during which people learned to inventory as they accompanied a more-experienced inventorier. Further, having people with a strong background in speleology enter the data insured a further filter of data. Lastly, several sites were inventoried more than once as a check on the quality of work. We feel confident that the quality of this inventory work is very high.

## Results

### *Work Accomplished*

Field work. During the course of this project, approximately 168 trips into the field were taken by

CRF personnel. These trips were for survey, inventory, field checking, photography, brass-capping, and GPS. Some of these trips were taken with NPS personnel, most were not. Over 120 CRF members participated in the field work aspect of this project, spending over 4500 hours in the field alone. This figure does not include any lab work, support services, travel time, or preparation time.

The work accomplished amounted to a very great deal; although some material remains to be sorted out. At a minimum: seventy five caves were cartographically surveyed; seventy one were inventoried for interior contents; sixty eight entrances were photographed; sixty GPS locations were obtained (mostly by the NPS), and sixty two entrances were monumented with brass caps. Over 450 individual stations had inventory records filled out for them.

Lab work: A good rule of thumb in cave work is that for every hour spent in the cave, one hour will be spent in project management, lab work, data entry, etc. In this project it is conservatively estimated that double the field man-hours were spent in administration, management, cartography, data entry, report writing, etc.

Databases: Several databases were developed by and for this project.

- The first database developed was to track the locations of cave entrances, their names, numbers, management classifications, work done on the caves, and other information. The database is called CAVES and, like all the other databases, is written in FileMaker Pro.
- A second database is called CONTENTS and tracks the features found within the caves during the course of the inventory process.
- Another database (SLIDES) was set up to record the photographic slides taken as part of this project.
- The CRF Trip Report database (TRIPLOG) was rewritten and enhanced as part of this project. A subset of that database is included with these project materials.

A database for showing the CRF standard map symbols was created by this project.

A database for tracking CRF maps at Mammoth Cave National Park was also created by this project.

- A monitoring database written for the Ozark National Scenic Riverways was modified for this project. Called MONITOR, its purpose is to provide a useful platform for the constant monitoring of caves within the National Park.

Over forty two reports (CAVES database) have been completed; thirty three maps have been finished; fifty nine sets of inventory data have been entered in the databases; and fifty sets of survey data have been entered into a cave survey reduction program.

Copies of this database are included with the project materials. Further explanations of the major databases are contained in the manual.

## Work Remaining

Not all of the caves on the North Side of the park have been completed; some need cartographic surveys; some require brass caps and locations; some lack photographs of their entrances; indeed, some have not yet been located. Finishing this work should be a very high priority for the park and CRF. Much work remains to be done in entering the entire inventory data - probably 100 stations remain to be entered. Additional material needs to be entered into the CAVES database, particularly cave descriptions. Several maps need to be drawn up; this includes some of the largest caves on the North Side: Ganter, Bat, Buffalo Creek, Lulu Mart, and Wilson.

## Findings

**Geological.** The caves are mostly formed in two geologic units: the Girkin and the Haney limestones (each accounted for about one-third of the caves found). Haney caves tend to be low, wet, and generally on the shorter side. The exception to this is Lulu Mart Cave which is over 2000 feet long. Girkin caves, on the other hand, follow the pattern of caves south of the Green River with dry upper levels and wet lower levels. Some

caves are also formed in primarily sandstone rock units such as the Big Clifty and Hardinsburg. Most of these are collapse or corrasional features rather than solutional. One typical pattern that became apparent was that sandstone collapse caves were formed through solution of the underlying Haney formation. Once the supporting rock layers were undermined, collapse of the overlying Hardinsburg occurred. Over thirty of the caves were springs whereas another fifteen or so served as swallets for surface water. Some were both.

**Biological.** Biologically, the caves are quite diverse. The large Girkin caves inventoried (Running Branch, Buffalo Creek, Forts Funnel, Ganter, Bat) are very similar biologically to Mammoth Cave with beetle and cricket communities in the upper levels (particularly in Running Branch and Bat) and typical aquatic life (cavefish and crayfish) in the lower levels. The sandstone collapse caves tend to be dry and their biologic communities are fueled by leaf litter, bat droppings, and wood rat nests and latrines. The Haney caves are the most active with streams rich in organic materials.

Nearly half of the 450 plus inventory records include crickets, either *Hadenoecus* or *Ceuthophilus*. Species of harvestmen were found at twenty eight stations; beetles were noted fifty times; spiders were found at 110 station; beetles were noted at six stations. Isopods and amphipods were the most common aquatic invertebrates noted, although a number of crayfish were identified as well as were occasional beetle and fly larvae.

Salamanders were noted at thirty two stations. Some caves had several cave salamanders (*E. lucifuga*) but other species of Eurycea (*E. longicauda* and *E. bislineata*) were also found. One cave was found to harbor red salamander larva (*Pseudotriton ruber*). This was an interesting find; red salamanders are not very common in caves. Only one frog was noted. This is probably due to the fact that relatively little inventory work was done in the dead of winter when frogs are most likely to be found.

Nests of the eastern phoebe were noted at nineteen caves. Bats, usually pipistrelles (*P. subflavus*) were found at ninety two stations; this included small numbers of Indiana, Gray, and Big-eared bats as well. Nests, usually fresh, of the rapidly-declining wood or

cave rat *Neotoma* were found in a number of caves a total of sixty four times. Easily the most interesting biological note was the identification of one short cave as being utilized as a deer lick by, apparently, a large number of deer. The cave is developed in a shale interbed of the Big Clifty sandstone; the deer are licking mirabilite hair crystals which periodically grow out of the clay residuum that results from the weathering of the shale bed.

Cultural. More than thirty of the caves were noted as potential archaeological sites. This project did not have access to archaeological survey records which probably would have confirmed some of these findings. Interesting cultural remains were identified at over 100 stations. Most of these were writings and historical graffiti but there were also a large number of artifacts found. Some of these artifacts were more-or-less rubbish but

others included: a possible pestle, whiskey bottles, square nails, distilling equipment, fire rings, and burnt cane torches.

### Continuation

Currently, work is continuing on the project, albeit at a greatly reduced level. The databases have already shown themselves to be useful tools even without full GIS integration. Survey data on caves in the project will be provided to the NPS as part of this final report. In addition, the inventory features (CONTENTS) and cave entrance data (CAVES) have been provided to the NPS.

One of the objectives of this project is to spread the inventory system to all the caves of the park and, based on our experiences thus far, there seems to be no reason that this cannot be done.

## Digital Database Project of the Cave Research Foundation

*Don Coons*

The beginning of the new millennium marked the end of the forty fourth year that the Cave Research Foundation had been collecting cave survey data in and around the Mammoth Cave area. Beginning with the Ohio Grotto efforts during the National Speleological Society sponsored Collins Crystal Cave epic, the grid of ever increasing survey lines has expanded outward to include Unknown, Salts, Colossal, and finally, the link to Mammoth Cave. Ongoing efforts now include Proctor, Lee, Logsdon-Hawkins River and most of the smaller caves within the park boundaries. Together with the efforts of the Central Kentucky Karst Coalition (CKKC) in Roppel, this work now includes more miles of connected survey within a single cave than any other caving area in the world. More than three fold-longer than the nearest competitor.

In total, nearly 5000 individual survey books have been generated in this effort to document the world's longest cave. With an average of 35 stations per book, the total number of individual survey points within the system has passed the 100,000 mark. Managing a data base as large as this one has become a truly monumental effort. It was realized several decades

ago that using paper as an archival medium was quickly going to become an unwieldy proposition.

In the early 1970s, Will Crowther and Bill Mann pioneered the effort to begin entering this mountain of material into the large mainframe computers available to them at the time. Original efforts were stored on punch cards. Since that time, the technology has progressed from large format magnetic tapes, to 5.5-inch floppy discs, to 3.5-inch floppy discs and today to zip discs and CD-Roms. CRF volunteers have made a valiant effort for nearly four decades now to keep pace with these changing technologies. Through the work of Lynn Brucker, Dave Hanson, Mel Park, Paul Hauck, Richard Zopf, Scott House, Bob Osburn and many others, much of the CRF data generated throughout this ongoing effort has been entered into a computer base.

One problem arising as a result of the changing technologies has been the inconsistency in programming and hardware available to the successive generations of CRF cartographers. Over the years, they have worked in at least twelve different software formats on an untold number of ever increasingly sophisticated

machines. It has only been the advent of the Pentium class PCs coupled with today's software developments that have finally brought the technology to a level that is capable of handling the entirety of the Mammoth Cave System on a single home computer.

The current phase of CRF digital data development is, then, an effort to combine this accumulated work of the past forty years. The first step was to find all of the individual copies of data archives, find equipment and programs to read them, and begin the process of converting everything into a single compatible format. The program chosen for this effort is named COMPASS. Its primary features of robust dependability, readily available support, and ease of conversion to other formats have proven it to be a very successful platform for this effort. This original phase of the project has now been completed. Everything ever entered is now running in one format.

The next step was creating an index to list all of the information that we have running and, more importantly, all the information that is still sitting in the original survey books and has never been entered into any program. File Maker Pro was chosen as the format for this information in order to be compatible with the CRF trip report data base. This index is now complete and reveals that more than 90% of the entire data collection is now running in a computer format. Data entry is currently being done by a team of CRF volunteers. In addition, the majority of all written trip reports will be linked to this survey database. It should be possible to store virtually all the CRF raw database on a single CD.

The first phase of this project has focused on the collection, entry and organization of 100% of the survey data. The second phase will be proofing, editing and correcting the database to bring it to as high a level of accuracy as possible. Work on the second phase is already underway. Thankfully, this effort is proving to be a much easier chore than the first phase. Header information (area names, dates, surveyors names) and survey designations have already been proofed for accuracy and consistency. Declination data is entered and corrected for all survey entries. Compass corrections have been edited for more than half of all entries.

Reaching this level of completion within the overall database has also made it possible to begin the process of checking for internal accuracy. Two steps are taken in order to generate a line plot of the survey with the best overall accuracy. The first step is based on the accuracy of the instruments in use during the collection of the raw data. Our compasses and inclinometers are expected to read within two degrees of perfect for each fore and back sight taken in the cave. Our tapes are incremented to the nearest tenth of a foot. Using these numbers as a standard, the computer program in which the data is entered calculates the maximum expected deviation for each individual survey loop. This Standard Deviation is used to predict just how far off a survey loop may wander. Most survey loops will fall within this predicted error value. A few will not.

A single linear survey line ending in a cul de sac has no specific check to determine if it lies within a predicted Standard Deviation. Surveys that loop back to known cave do have a tie to known space and can be better checked for accuracy, thus the importance of closing loops within the cave survey. Loops that close within the expected Standard Deviation are known to be recording the cave passage within the tolerances of the instruments in use. Loops that close with errors larger than expected have a Standard Deviation greater than 2.5 and probably contain one or more blunders hidden within the loop. Locating these mistakes is a strong point of today's generation of computer programs. By using their features, it is possible to identify and correct many of the outstanding errors within our base and tighten up our overall representation of the cave.

Data for older generation surveys were collected primarily to learn where the cave goes. Compass readings were done with no backsights and inclination readings were taken only if an angle was high enough to obviously distort the true horizontal distance. Later generation surveys were intentionally chained level and vertical distances from station to station were estimated as delta H records. With an overall vertical extent of a little more than 300 feet within the entire system the vertical component of an individual survey was largely ignored. For these two reasons, the older generation surveys are normally not as accurate as the resurvey efforts. The X, Y, and especially Z coordinates will wander.

In order to prevent the older data from "corrupting" our resurvey efforts the two data sets are maintained in separate files; two files for each area of the cave. The sets are named Original and Resurvey. The entire data base is divided into these two sets, old and new, for one primary reason: accuracy. Closures in the Resurvey effort are analyzed in a three-D reference. The Original work is analyzed in a two-D reference. Using this standard, our Resurvey loops are closing within an average error value of less than .5%. The Original work closes on average within .75%.

The final step in producing a high accuracy plot is to use the loop closing auxiliaries to adjust each individual shot so that the plot returns to exactly its starting point. In a loop with a twenty-foot closure error, this will mean that the final station is moved by the maximum error. The initial point will not move at all. Each

station within the loop will be moved an average of 10 feet from its original placement. If the maximum error was accumulated as a sum of many small errors, this closed plot will be more accurate than the original. If the maximum error is primarily the result of one blundered shot, then the closed plot will be less accurate for any stations in the string that follow the location of the blunder.

Finding survey blunders, then, is the preferred method of closing a loop. At some point, however, all of the blunders have been fixed and the plot must be closed by using the loop closing algorithms within the cave reduction program. A Standard Deviation less than 2.5 or a closure error less than 1 percent is a reasonable level at which this step can be taken.

Practical applications of the accumulated base are already being produced. A composite collage of computer generated images representing the cave was presented to Mammoth Cave National Park last year. It was titled *The Mammoth Cave of Kentucky* after historic maps of the same name.

# Geoscience

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## An Important Interglacial Fana from Sediments of the Frozen Niagara Entrance, Mammoth Cave National Park, A Preliminary Report

*Mona L. Colburn, Rickard S. Toomey III, Rick Olson, Jeff Dorale*

Recent work on paleontological remains contained in sediments at the Frozen Niagara Entrance of Mammoth Cave indicates that the area contains a fauna from the Sangamonian Interglacial. The diversity and taxonomic range of the fauna, combined with the ability to accurately date the deposit, indicate that this may be one of the most important Sangamon Episode (i.e., Sangamonian Age) sites in the central United States.

Discovery of the bone-bearing deposit was fortuitous. During the Cave Research Foundation's (CRF) Thanksgiving 1999 Expedition, Toomey went on a trip into the Frozen Niagara Entrance area as a party member on a trip supporting the CRF-National Park Service Digital Video Project. The party leader and project director, Mike Yocum, loaned Toomey one of the video lights to examine sediments while Yocum set up the video shots. While examining travertine and sediment banks along the trail, Toomey identified several areas with small bones. Later Olson located several more bone areas while evaluating potential impacts of scheduled trail improvements. Toomey, Colburn, and Olson sampled the deposits for bone in January 2000 to evaluate the deposits before any possible impact. In addition, they collected samples of flowstone for Uranium-series dating. The results of the sampling indicate that the deposits are very significant.

The sampled deposits consist of sediment and travertine that are exposed on both sides of the paved tourist trail; they extend from approximately the bottom of the entrance steps to about thirty five meters into the cave. The sediments and travertines that make up the deposit are exposed where they have been cut through during trail construction. The exposed section is about 1.5-meters thick, but this may

only represent the top of a much thicker sediment and travertine deposit. Together the travertines and sediments represent a mass that was deposited near an ancient natural entrance of the cave system. During the 1920s, the area was artificially re-opened, exposing the ancient sediments along the trail. The sediments consist mainly of red clay-rich matrix with abundant chert pebbles and small bones. The travertine consists of masses of cave popcorn and thin to massive carbonate crusts. Overall, the section is dominated by the travertines, with sediments occurring mainly pockets in the travertine mass. The generally fine-grained sediments, the small size of bones and bone fragments, and the amount of travertine suggest that the entrance in the area was probably small.

Some of the clay-rich sediment pockets had abundant bone, whereas others had little to no bone. Analysis of the bone is only in a preliminary stage; however, a few comments are possible. The bone represents a wide taxonomic range; amphibians (both frog and salamander), reptiles (turtle, snake, and lizard), birds, and mammals are all represented in the deposits. Most of the animals represented are small, with bats and rodents dominating the assemblage. Several larger animals are also present including deer (*Odocoileus* sp.), raccoon (*Procyon lotor*), flat-headed peccary (*Platygonus* sp.), and beautiful armadillo (*Dasypus bellus*). Of greatest interest are the extralimital species (extant animals not found in the area today) that are found in the deposit. Pocket gopher (*Geomys* sp.), for example, does not occur in Kentucky today, but it is very abundant in the deposits. Pocket gophers indicate open habitats in the area. One of the most interesting rodents in the deposit is the water rat (*Neofiber* sp.). At this time we are not able to identify whether the water rat represents an extinct species or the modern one. However, modern water rats are sub-tropical

animals, found only in Florida and extreme southern Georgia. The presence of *Neofiber* provides strong evidence that the deposit represents an interglacial assemblage. Their presence indicates marshy habitats in the area.

Uranium-series dating of the carbonate crust that seals the top of the deposit provides information on which interglacial is represented by the deposit. Initial analysis of this carbonate provides an age of 125,000 to 126,000 years. If this carbonate represents a flow-

stone layer that formed at about the same time as the bone-bearing portion of the deposit, it indicates that the deposit formed during the last interglacial (the Sangamon Interglacial).

If the fauna is indeed Sangamonian in age, the deposit is potentially very important from a paleontological standpoint. Relatively few well-dated Sangamonian faunas exist in the central United States. In addition, none has the diversity and taxonomic range exhibited in the Frozen Niagara fauna.

## The Ice Cavity at Merrill Ice Cave

*Janet Sowers and Bill Devereaux*

Beneath the solid ice floor of Merrill Ice Cave, located in Lava Beds National Park in California, unbeknownst to visitors or monument staff, lay a large bubble-shaped cavity, contained wholly within the layers of ice that underlie the floor. How long it lay there we do not know, but it was growing. The ice created gave us a view into the ten-foot diameter chamber below. The cavity appears to have formed naturally, the result of air flow in the breakdown beneath it. It is unknown when the cavity began, but unfortunately, it continues to enlarge.

### Background

In the spring of 1997, Janet Sowers and Peri Frantz of CRF took a short trip into Merrill Ice Cave to give a tour to the new Lava Beds interpretive staff. We noticed that there was an air gap of an inch or so beneath a thin ice crust in the middle of the ice floor. It looked as if the top of layer of water had frozen, then the rest of the water had drained out from beneath the frozen crust. We thought that was at little strange, but quickly forgot about it.

In November of 1997 Bill Devereaux took a CRF party into Merrill Ice Cave to make routine ice level measurements. They discovered a one foot diameter hole in the center of the ice floor just at the edge of the walkway. Looking down the hole they could see airspace of about ten feet below and a dry chamber.

They reported the phenomena to Barney Stoffel that evening.

Bill returned to Merrill in January of 1998 measured the ice hole that had been found during the Thanksgiving trip. It had increased in size by a factor of four. Cold air could be felt going into the hole, carrying their breath mist with it. The area below the breach is an air dome where the ice has been sublimated away, leaving a reverse 'igloo' dome under the ice floor. There was one stanchion of the catwalk floating free- with no support except for the bracing posts from the adjacent uprights. Later that day they went to see Terry Harris in his office to report their findings. They concluded that descending into the hole or walking on the ice floor above would not be safe, and that a survey should be made by qualified people into the hole to look for artifacts that may be there from earlier times. The monument temporarily closed the cave, then reopened it after posting warning signs on the railings above the ice.

In February of 1998, we revisited the cave with several other CRF and Lava Beds staff to thoroughly document the ice chamber. Two teams consisting of Bill and Peri Frantz, and Peter and Ann Bosted, photographed the floor and cavity. Janet, Jonah Perez, and Peri measured cavity dimensions and made a sketch map and profile. Bill Devereaux measured ice levels on the floor above. Kelly Furhman and Janet measured the depths of historical artifacts found (wood, flash-

bulbs, paper, etc.) embedded in the ice (Table 1). These depth measurements were made by hanging a tape vertically from the lip of the hole in the ceiling, and sighting a level line to the wall with an inclinometer.

### Description of the Cavity,

As of February 1998, the ice cavity measured fifteen feet in diameter, approximately round in plan view, with a dome-shaped ceiling about six feet high. The floor generally slopes toward the Northeast with the deepest part of the chamber in a pocket in the far north corner. At this end the ice is deeper and the walls have receded further, making the chamber slightly elongate in the northerly direction. The hole in the ceiling of the cavity (or floor of the ice pool) is located within the southwest quadrant of the cavity. It is an egg-shaped opening of about three by two feet, with the wider end of the oval toward the center of the chamber.

The floor of the cavity is dry breakdown, one to four feet in diameter, with no noticeable accumulation of fine sediment on or between the rock surfaces. The breakdown is littered, however, with broken flash bulbs and other trash that were apparently released from ice. Air can be felt rising up from between breakdown blocks in the center of the floor. The walls of the cavity reveal horizontally layered ice, studded with pieces of wood, paper, and flashbulbs that presumably had fallen on the ice over the years.

### Artifacts in the Ice Layers

Artifacts are embedded within the ice layers exposed in the wall of the ice cavity down to a depth of six feet, almost the entire thickness of the ice. Table I shows the artifacts recorded during our visit, which included all significant items that could be found. The artifacts appeared to be in their original locations where they had frozen into the ice. We thus presume that each must have fallen on the ice floor of the time, and must therefore be contemporaneous or older than the ice layer that covers it. All artifacts are historical (no prehistoric artifacts were found), thus we can conclude that the entire ice pool is historical in age.

If the entire ice thickness accumulated in historical times, then at some point in historical time the ice pool must have been virtually absent. When? We

can make an estimate using ice accumulation rates computed from the position of the 1956 newspaper, located at a depth of 3.6 feet. If we assume the newspaper actually fell on the floor in 1956, then in 41 years, 3.6 feet of ice accumulated on the floor of Merrill. This represents an average accumulation rate of 0.09 feet per year. The total thickness of historical ice (thickness above the lowest flashbulb) is 6.7 feet. At a rate of 0.09 feet per year, that flashbulb would have been deposited about 74 years ago, in approximately 1923. Of course, ice accumulation is rarely constant - in some years more ice accumulates, in others ice may actually be lost - so the actual date could vary by ten or more years. But it gives us some idea.

It is interesting to note that from about 1917 to 1921, Charles Henry Merrill operated a resort for tourists at Merrill Cave (Larson, 1990). Perhaps he used the cave as a source of water and mined out most of the ice. Or perhaps it had been mined out by previous visitors, and the flashbulb at 6.7 feet was dropped by one of Merrill's guests. Or maybe natural climate variations had caused most of the ice to be lost in those years.

Regardless, about 75 years ago the ice floor was 6.7 feet lower than it is today. In other words, there was almost no ice in the pool at Merrill Ice Cave. And

Table 1

Location Of Artifacts in The Ice Wall		
Wall	Depth (feet)	Description
West	1.2	Bottom of metal post (for reference)
	2.1	Flashbulb
	2.6	Charred corrugated cardboard
	3.1	Flashbulb
	3.6	1956 newspaper
	3.9	Matchbook
	4.4	Flashbulb
	5.9	Piece of lumber, 0.15 x 0.15 x 0.58 feet
	6.1	Scrap of heavy paper
	5.2	Lumber resting on boulder, 6" x 1.5" x ?
North	6.7	Flashbulb
	4.6	Flashbulb

ice has been accumulating fairly steadily since that time. Until now, of course.

### The Ice Cavity Continues

In February of 1999, we re-measured the ice cavity and found it had increased in size as expected, and the breakdown in the center of the cavity was still dry with no new ice forming. The hole in the floor measured 7.1 feet by 9.6 feet, and the inside of the bubble revealed a burned stick of lumber and a rusty can. These items sat directly on the breakdown, supporting our previous conclusion that all the ice in that pool had been historical in age.

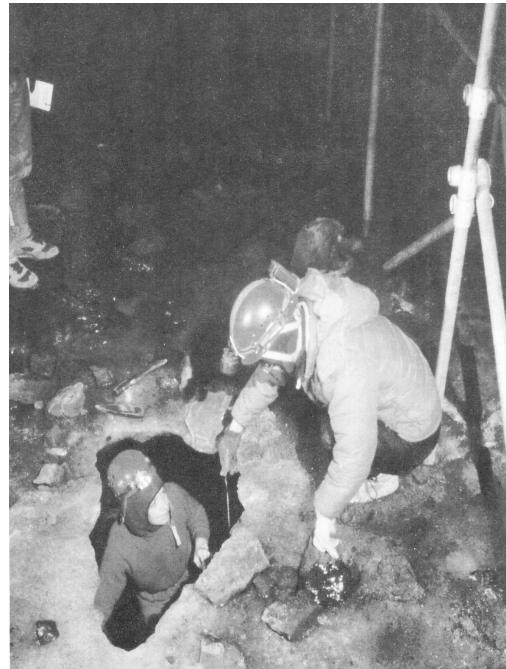
In February of 2000, the hole measured nine feet by ten feet, but the inside diameter of the bubble had not changed much. We noted an interesting phenomenon on the surface of the remaining ice floor. What once had been a smooth, planar floor, almost suitable for ice skating, was now becoming quite irregular. The floor has a scattering of cobbles, either fallen from the ceiling or tossed on to the ice by visitors. The ice surface itself is built up in places with small ice stalagmites under ceiling drips, and is eroded in other places by the dry air.

### Origin of the Ice Cavity

How do we explain this intriguing phenomenon? In order for an ice pool to accumulate in a cave:

1. The cave must be deep and have a single, relatively small entrance so that cold air can sink into the cave and maintain below-freezing temperatures
2. Rainwater must drip or flow into the cave and freeze
3. The ice must coat the floor entirely and form a seal so that additional water will pond on top and add to the ice thickness.

In the case of the Merrill Ice Chamber, apparently a change in air circulation caused the very bottom of the ice mass to begin melting or sublimating (ice evaporates.) The seal was broken. Air continued to circulate at the bottom of the ice, eating an ever larger



Janet Sowers and Ann Bosted at The Hole in the ice floor at Merrill Ice Cave

hole. Of course, the ice could continue to pond at the top of the ice mass as long as the top layers formed an effective seal for each year's new layer of ice. But eventually, in 1997, the hole broke through the surface. The pool could no longer deepen, for the layer of water that dribbles onto the ice floor in this spring will not pond but will run down the hole through the breakdown and be lost.

Some important questions remain unanswered. Why the change in air circulation? Why would a cave that has had a growing mass of ice for so long be unable now to maintain one? The air presently flows through the breakdown at the bottom of the former pool, eroding the ice. We can only speculate as to why. Perhaps a recent collapse in a lower passage has allowed air to flow upward. Could we find this lower passage? For how many years had the hole underneath the ice been growing before it broke through?

We hope that our future studies may shed light on these questions. For now the ice cavity at Merrill will remain a curiosity. We expect the cavity to continue growing, and that eventually most of the ice pond in Merrill Ice Cave will be lost. The National Park Service has now gated the Merrill Cave in the hopes that reduced visitation will allow the cave to evolve naturally.

# Lateral and Vertical Thermal Fluxes in the Hyporheic Zone of a Low-order Karst Stream

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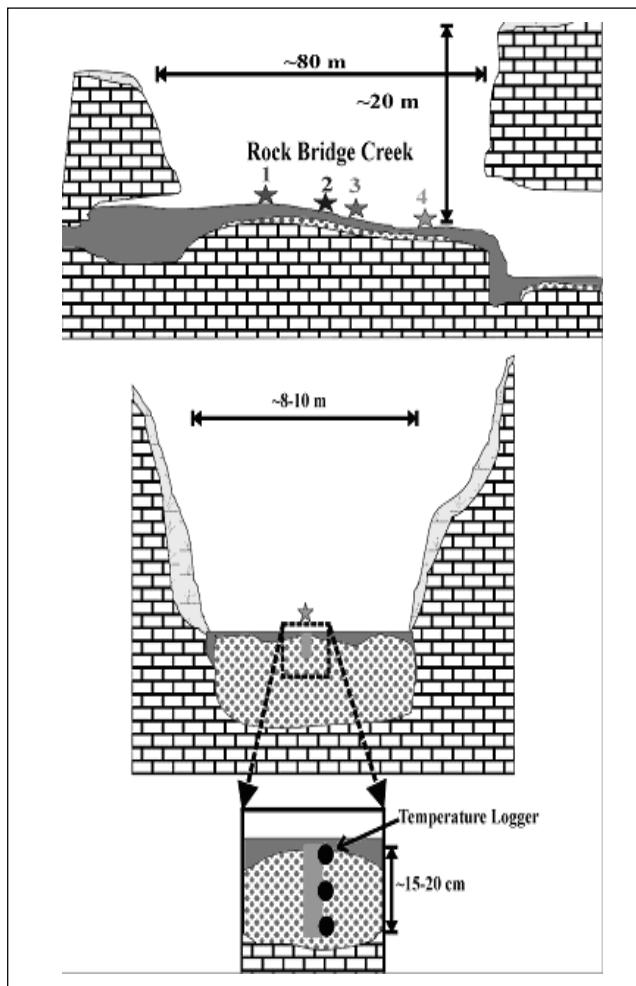


Figure 1. Schematic diagram of the Karst Window study site at the downstream end of the Devil's Icebox Karst System in Boone County, central Missouri. The upper illustration shows a longitudinal cross section of the Karst Window. Water flows out of Connor's Cave on the left, through the Karst Window, under the Rock Bridge on the left, and then eventually flows to Little Bonne Femme Creek. Four temperature

The hyporheic zone is an important habitat for aquatic vertebrate and macroinvertebrate fauna. Many of these organisms prefer to spend significant portions of their life history living below the armor layer of the stream or deeper in the stream substrate. In karst settings stygobites (obligate cave dwellers) have been observed to colonize the hyporheic habitat of surface streams adjacent to cave environments. This behavior is likely due to the similarities between deep cave and hyporheic zone environments. The advantages offered by the hyporheos to its inhabitants may include protection from predation, damped response to thermal and chemical fluctuations in the overlying surface water, and access to food. Evaluation of these potential benefits requires that the physical, chemical, and hydrodynamic characteristics of the hyporheos be understood.

As a step toward this goal, a study of the lateral (upstream and downstream) and vertical thermal variations in the substrate of a surface stream were investigated from 27 May to 9 July 2000. The study reach is fed by water exiting the downstream end of the Devil's Icebox cave system in central Missouri (Figure 1). Four stations were established in the reach with three temperature data loggers each. At each station a logger was placed at the base of the armor layer, 7-10 centimeters and 15-20 centimeters deep in the substrate.

data logging stations were established in the Karst Window (designated by the stars in the upper illustration). The lower half of the diagram shows a cross-section of a data logging station. Three data loggers (each about the size of a stack of 5 quarter coins) were buried in the stream substrate at each station between 2-20 cm.

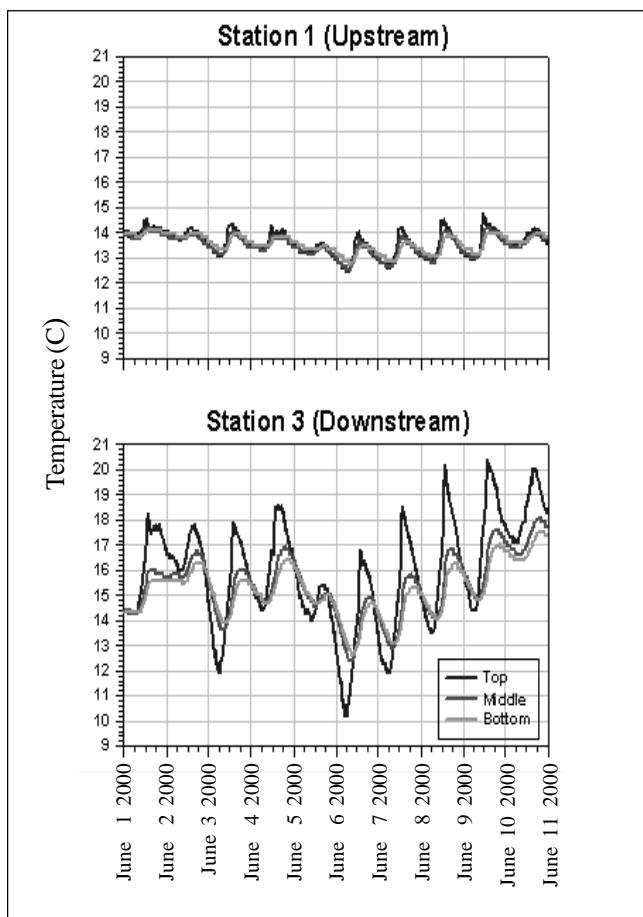


Figure 2. Baseflow substrate water temperature conditions in the Karst Window. Although data was collected over a period of months, one ten day block of time representative of baseflow conditions is presented. Station 1 is near the mouth of Connor's Cave and as such is not as affected by surface conditions such as the amount of incoming solar radiation and air temperature. Further downstream, surface water (top data logger) at Station 3 is heavily influenced by diurnal temperature fluctuations. The diurnal temperature range has also increased at all three depths at Station 3. Also, temperature has increased downstream at all levels in the stream substrate.

Additionally, surface water temperature, stream stage, and specific conductance within the substrate were measured. All data were collected at a fifteen minute interval.

The results indicate that during baseflow conditions (Figure 2) water temperature varies 2-6° C in the upper substrate and surface waters. Deeper substrate variations are damped to 1-3° C. The magnitude of

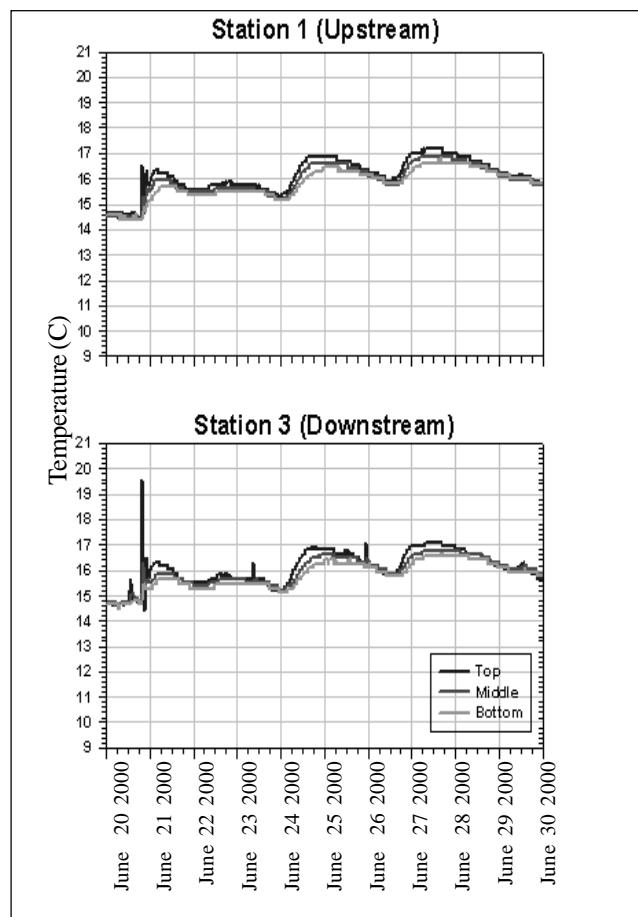


Figure 3. Storm-induced substrate water temperature conditions in the Karst Window. Although data was collected over a period of months, one ten day block of time representative of storm-induced conditions is presented. During this ten day period three storms occurred. The timing of the precipitation coincides with the beginning of three gradual temperature increase-decrease cycles. Temperature becomes rapidly homogenized vertically and laterally in the substrate (i.e., same temperature at any data logger at any station at a particular time). Typically, there is a short-lived temperature spike at the beginning of the storm-induced flow. This temperature spike is interpreted as thermally-unequilibrated runoff derived directly from adjacent hill slopes.

the diurnal variations appear to correlate with incoming solar radiation. Storm pulses through the system (Figure 3) cause an initial temperature spike (4-6° C) in the surface water and upper substrate at the beginning of the rising limb of the hydrograph. Subsequently, substrate temperatures rapidly equalize and steadily decrease (~0.25° C/day) over a period of several days until baseflow conditions reestablish and the diurnal fluctuations begin to dominate.

## Predicting heterogeneity in the Redwall paleokarst, Grand Canyon area, Arizona

*Tony Troutman,  
The University of Texas at Austin*

The Mississippian Redwall Limestone located in the Grand Canyon area of northwestern Arizona is the locale and subject of this study. The purpose of this outcrop study is to examine the distribution and evolution of the Redwall paleokarst to search for evidence that certain controlling factors might help to characterize the style and distribution of paleokarst.

The study area is an exceptionally well exposed outcrop example of a major paleokarst system. The top surface of the Mississippian Redwall Limestone represents a second-order sequence boundary, karstified during approximately ten million years of subaerial exposure (Billingsley 1999). It was buried during subsequent transgression and deposition, but has been exhumed by the formation of the Grand Canyon. The result is that this field area exhibits large numbers of paleokarst features exposed in three dimensional outcrops.

A synthesis of much of the literature, as well as my own investigations into karst systems has led me to formulate a hypothetical model for predicting the magnitude, morphology, distribution, and orientation of a paleokarst system. It is based on the most important factors that control the style of paleokarst heterogeneity. The model assumes the paleokarst was formed in a carbonate based, shallow groundwater, carbonic acid speleogenetic system. Halocinal type karst, which is formed at the interface between saline and fresh waters in the phreatic zone, is hypothetically included within the model. However, hydrothermal karst, formed by rising hydrothermal waters, and sulfur reduction karsts are not expected to fit into this model because both of these processes are dependent upon external factors with very different causative mechanisms.

The four major factors controlling this type of karst evolution, and thus the delineation of a paleokarst system, are hypothesized as follows:

Exposure time is a first-order control for a karst system. Kerans and Lucia (1999) organized a stratigraphic ranking of unconformities, grouped into super-unconformities, regional unconformities (Types 1 and 2), and cycle boundaries, to classify paleokarst reservoirs. These unconformity classes correspond to stratigraphic units of (1) supersequences, (2) composite sequences/high-frequency sequences, and (3) parasequence/ high-frequency cycles. The extent of a karst is a measure of time, ranging from smaller, less spatially dense features in an immature karst, to larger caverns and open canyons in a more mature karst.

Tectonic and eustatic sea-level changes also exert a first-order control over the development of karst. Tectonic uplift or eustatic sea level fall is necessary to expose marine limestones to subaerial erosion and dissolution by meteoric waters. The amount of uplift will determine the hydraulic gradient, providing a driving force for penetration of meteoric waters into a carbonate unit. For mixing zone type caves, the tectonic or eustatic change will strongly influence the location of the interface between marine and fresh waters where these types of caves are formed. Structurally, regional tectonic stress will result in strain that produces joints, fractures, and faults in the carbonate units, providing initial conduits for speleogenesis.

A third major, first-order control on karstification is hydrology. Features such as aquaclude (e.g., chert beds within carbonate units), perched aquifers created by lithologic or structural barriers, and fluctuations in the water table would be examples of this type of control. Water movement is required for carbonate dissolution to proceed and create karst features. Without the movement of fresh meteoric waters through a carbonate aquifer the water will quickly reach saturation with calcium carbonate and dissolution will not proceed. Permeability of surface cover of a karst will strongly affect the karstification rate. Surface drain-

age may exert a major influence on the location and flow of an aquifer or karst drainage system.

Climate is the fourth major first-order factor in the development of a karst system. Climate varies directly with latitude, and less predictably with other geographic factors. Climate is intrinsically involved in both the hydrologic system, and with exposure time, which may include long-term variation in climate. Climate factors such as temperature and rainfall directly affect dissolution rate in a karst system, which is a second order control within overall exposure time. Climate will also directly affect the amount and type of soil cover on a karst, thus influencing the rate of carbon dioxide formation in this soil cover. The combination of carbon dioxide formation in cover soil, temperature, and rainfall rate will determine the dissolution rate.

This model will provide a better understanding of paleokarst systems, and perhaps even modern karst. These major first-order factors are illustrated in Figure 1, showing the categories and processes involved, and Figure 2, showing how these first-order factors influence the development of a karst system and the resulting paleokarst.

### Results in the Redwall paleokarst

Numerous paleokarst features, primarily on the western edge of the Hualapai Plateau were examined and measured. In paleogeographic terms, the Hualapai Plateau is the westernmost outcrop of the Redwall, and thus the most seaward portion of the Redwall during the unconformity period in which the paleokarst formed.

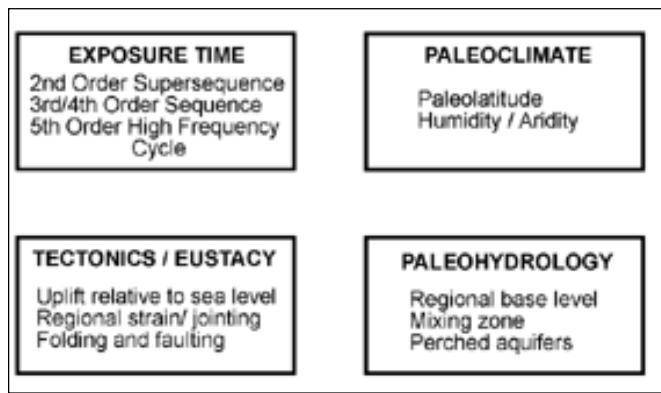


Figure 1: Major Factors Controlling Karst Evolution

Recent work by Billingsley (1999) on the Surprise Canyon Formation (first discovered by D.G. Davis in 1964) has documented the existence of a fluvial channel system on the surface of the Redwall that was filled in with sediments during the late Chesterian Series of the Mississippian. My field work verified that large concentrations of Redwall paleokarst features were found nearby and immediately adjacent to these Surprise Canyon paleovalleys. In many instances the base of the paleokarst is at the same stratigraphic level as the base of the paleovalleys, suggesting that the paleovalleys provided a local base level controlling the downward dissolution of the karst.

A significant regionally extensive layer of thin-bedded cherts, alternating with carbonates, that was first noted by McKee and Gutschick (1969), is found in the upper part of the Thunder Springs Member of the Redwall Limestone. All of the breccia pipes on the westernmost exposures of the Redwall, in Grand Wash Cliffs, have these thin-bedded cherts at their base. Breccia pipes that were found adjacent to some of the larger Surprise Canyon paleovalleys also showed this penetration depth. In the eastern part of the study area, in the Diamond Creek watershed about 100 km to the east, breccia pipes also have the distinctive Thunder Springs chert beds at the base.

Two studies of paleofractures by J. Roller (1987 and 1989) found at least eight different fracture events on the Hualapai Plateau, ranging from Paleozoic to Tertiary. Two fracture sets in the Redwall were found to predate the deposition of the overlying Supai Group. Roller was less certain that these two paleofracture sets predated the paleokarst, but did find one location where she concluded that the fractures predated the paleokarst. The Bighorn Breccia Pipe, so named due to the frequent encounters with bighorn sheep at the site, is the first evidence of a lateral connection between two breccia pipes. A long ridge extending northward from the rim of the Grand Canyon has breccia pipes exposed on the east and west sides. Between the two pipes, surface beds, and beds exposed vertically in the cliffs above the breccia pipes dip inward toward a line connecting the two breccia pipes. The orientation of this line is N55.8E. Roller's studies found that the oldest fracture set in the Redwall was oriented vertically, N57E.

The Bighorn Pipe was the site of a detailed study. Detailed measured sections were made and one inch core samples were drilled at one to two meter intervals. The core samples have been used to make thin sections and measure paleomagnetic data. At this time the paleomagnetic results are still being analyzed. The hoped-for results may help determine the timing of the collapse and formation of the paleokarst breccia. Paleomagnetic measurements of samples from a speleothem within a relict, exposed cave passage (only one wall of this cave remains) in the Bighorn Pipe have indicated its more recent origin. However, this also confirms that the Redwall paleokarst system has hosted later karsting events.

The deepest penetration of the Bighorn Breccia pipe and other breccia pipes within several kilometers of this site correlates nicely with the deepest entrenchment level of the nearby Surprise Canyon paleovalley deposits. Figure 3 shows the breccia pipe, the collapse trend, and the Surprise Canyon Formation outcrop in the background. Bat Cave Pipe in the same area, has Surprise Canyon deposits adjacent to its base, and a very large sediment-filled paleocave passage is exposed in the canyon wall across from Bat Cave Pipe at the same stratigraphic level.

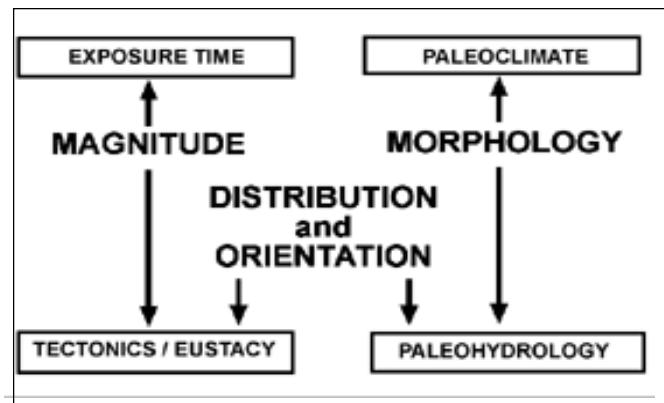


Figure 2 First-order factors influencing the development of a karst system and the resulting paleokarst.

Various levels of lateral passages were found in one paleokarst breccia pipe that had been almost totally excavated and removed by modern erosion. A paleocave located in a cliff that exposes a major bedding-sag feature, opens into the canyon 75 m (250 ft) above the breccia pipe base. The paleocave contains fine grained clastic (silt and clay) at the base of the passage which is filled completely with large calcite rhombs, as much as 25 cm (10 in) in diameter. The base of another breccia pipe is located approximately 300 m (980 ft) away, near the bottom of the canyon. This breccia pipe has been exhumed by the canyon,

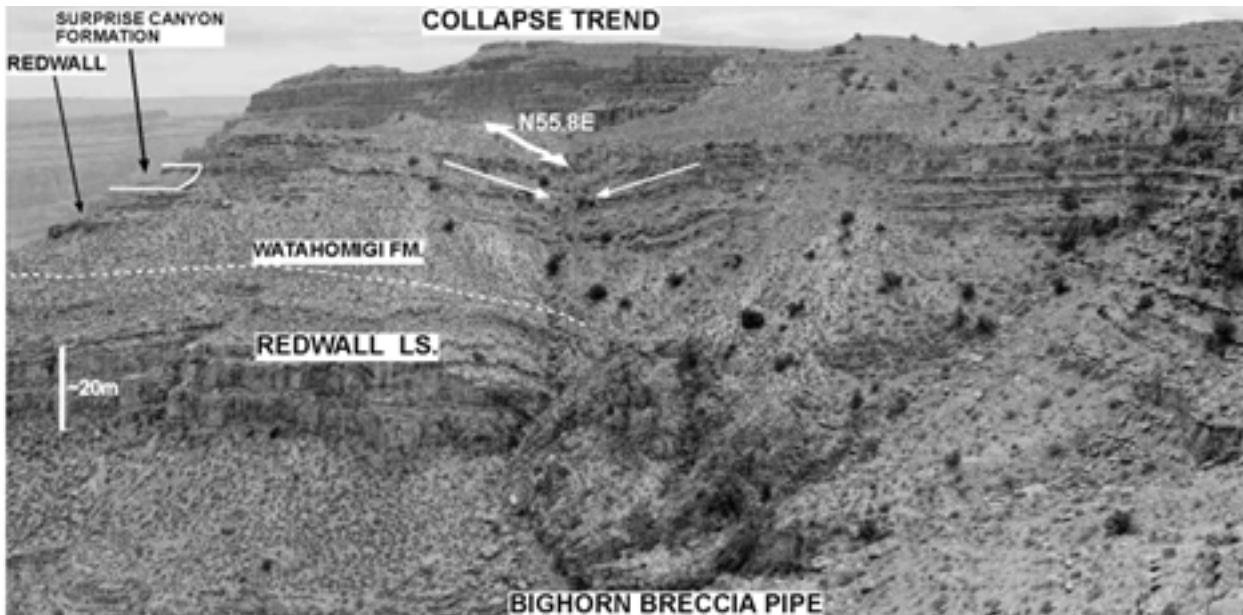


Figure 3: Breccia pipe, collapse trend, and the Surprise Canyon Formation

exposing its base, showing the breccia is in contact with the Thunder Springs chert beds in the Redwall at the base. The largest contrast between these breccia pipes, found in the Grand Wash Cliffs area, and those near the Bighorn Pipe, is that the nearest Surprise Canyon fluvio-deltaic deposits are 50 to 100 m above the elevation of the base of these pipes. This suggests that in this area the Surprise Canyon paleovalleys may not have been at the hydrologic base level, or that the caves that formed the deepest parts of these breccia pipes may have been phreatic in origin. The more seaward location of these pipes makes this significant, however reconstructing the paleoelevations is difficult due to extensive faulting in the Grand Wash Cliffs area.

## Conclusion

The majority of the breccia pipes examined on the Hualapai Plateau appear to have been vadose in origin, closely associated with the lowest portions of the Surprise Canyon paleovalley deposits. Bighorn Pipe and the adjoining breccia pipe show a definite correlation with the paleofracture sets measured by Roller. This may indicate a joint-controlled origin for this particular cave.

Uplift of the Redwall above the Redwall Sea level was at least 130 m (425 ft.), based on the deepest entrenchment of the Surprise Canyon paleovalleys found in Quartermaster Canyon. Correlation of the base of many breccia pipes with the base of the Surprise Canyon paleovalleys suggests there was a paleohydrologic correlation between the Redwall paleocave system and the paleovalleys.

Paleoclimate was a significant factor in the development of the Redwall paleokarst. Kenney (1998, 2000) estimated the long-term average temperature during the formation of the Redwall paleokarst to be 27°-28° C (80.6°-82.4° F.), using isotopic analyses of silica within chert lags found at the unconformity surface of the Redwall Limestone. Paleolatitude during Redwall paleokarst time was a few degrees south of the equator. A warm tropical location would have encouraged karstification of the exposed carbonates.

A significant number of caves must have existed near the coastline of the uplifted Redwall terrain.

These caves had a close association with paleovalleys that later filled with fluvial and deltaic deposits as rising sea level once again covered the area. The caves had about 10 million years to develop in a warm tropical environment. It is likely that both vadose and phreatic systems existed, maybe as parts of the same caves. Different levels of cave passages may be related to dropping sea levels relative to the cave system. The Redwall paleokarst has proven to be a fascinating example of a 330-340 my old cave system.

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# History

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## Mammoth Cave Gazetteer and Bibliography

*Mick Sutton and Sue Hagan*

The following is a brief summary of where the Mammoth Cave gazetteer and bibliography projects stand as of March 2002. Since the last Annual Report summary (Sutton & Hagan, 1991), both databases have expanded considerably, in both number of records and in the average amount of information per record. Both databases are in Filemaker Pro, a platform which runs equally well on Windows and Macintosh systems.

### Gazetteer

More than 2300 place names are recorded in the gazetteer of Mammoth Cave place names. The number in current use is much smaller, but still surprisingly large—the database notes almost 1000 names as being more or less current. The remainder are redundant synonyms or obscurities which have not been located. Even so, the names no longer in use are often of intrinsic interest, and are valuable for historical research.

It is not surprising that a majority of place names (64% of the total) are from historic Mammoth Cave, defined as passages and features underlying Mammoth Cave Ridge. This section has the longest history, dating from the late 1790s. The earliest names recorded are early names for the cave as a whole—Flatt's Cave and Saltpetre Cave. Flint Ridge accounts for the next largest number of names, 25% of the total. Although Flint Ridge names go back almost as far into history as Mammoth Cave (West's Cave, the earliest known name for what is now Salts Cave also dates from about 1800), by far the majority of names originate no earlier than the mid 1950s, when the modern phase of exploration began. Least complete is coverage of the Roppel section, where place names date only from 1976. Even there, more than 100 names are listed, and almost all are in current use, as opposed to historic Mammoth, where

only 36% of names are current. Flint Ridge falls in between, with 69% of the listed names in current use.

The gazetteer includes the following fields: Name; Synonyms (if any, including close variants and misspellings); Section (e.g., Mammoth Cave, Crystal Cave, Roppel Cave); Location (a brief verbal description); Maps (maps on which the name has appeared); References (publications in which the name has appeared); Earliest Date (usually the earliest date in the “Maps” and “References” fields); Current? (yes, no, or maybe, sometimes subjective); and Comments (an open-ended text field; ideally, the history of the feature or passage is summarized, and quotations from historic sources included). In a separate Location format, there are two additional fields: CRF map sheet (the current map series) and Station (CRF survey station nearest the feature, or a range of stations in the case of a passage or larger feature.)

The references in the “Maps” and “References” fields are in short-hand (e.g., Brucker & Watson, 1976), and are cross-referenced to the general Mammoth Cave bibliography. The Location format is in a rudimentary state of data entry, but will eventually allow the possibility of tying features and passages readily to a GIS type system via the survey station labels.

We have pored through most of the more readily available Mammoth Cave literature together with a smattering of obscurities, more than 2600 references in total (not all of these include place names apart from the obvious “Mammoth Cave,”) but it is safe to assume that our coverage of the extant literature will never be complete. For this reason, as well as continuing exploration and the consequent ongoing addition of new names, the gazetteer is likely to permanently remain a work in progress.

To demonstrate the type of information being recorded and its format, an example of a fairly detailed record is shown in Figure 1. *Silliman Avenue*, a major mid-level trunk in Mammoth Cave Ridge, was part of the historic “long route,” and later of the NPS all day tour.

## Bibliography

The bibliography we are constructing in collaboration with Ray Mansfield includes about 5500 records. Like the gazetteer, this is a permanent work in progress. It is probably safe to say that all of the core literature is well covered, including the contents of all earlier bibliographies, but it is also safe to say that there is a great deal of uncollected material which there is no easy or systematic way to get at. This applies especially to 19th century newspaper articles. Other categories where coverage is weak include the vast amount of unpublished material in National Park Service archives and accounts in small-circulation caver newsletters. And although major and well known foreign language sources are included, coverage of foreign language accounts (very voluminous, owing to the international fame of Mammoth Cave) is undoubtedly less complete than that of English language sources.

Fields included in the database are: Author (standardized to the fullest version of the name to allow easy sorting); Title (including the author’s name as it appears on the title page); Date (including month and day where applicable); Publisher; Place of publication; Description (ideally, more detailed than simple page numbers); Bibliography (earlier bibliographies in which the item has appeared); Topic (broadly defined, but gradually being expanded to serve as a key-word index); Catalogue number (ISBN, Library of Congress catalogue, Dewey system, etc.); Comments. In addition, there are several “working copy” fields to enable the compilers to keep notes of sources, problems to be resolved, whether a copy is available for examination, etc.

The earliest reference included in the database is Thomas Hutchins, 1778: *A topographical description of Virginia, Pennsylvania, Maryland, and North Carolina....* Although this is earlier than any record of European-American knowledge of Mammoth Cave, it

appears to be the first reference to mention the Green River country. From the bibliography entry: “Hutchins, a government surveyor, was the first European-American of record to have explored the ‘Buffaloe’ later known as the Green River, although he alludes to others who have ‘ascended this river.’ In at least one source, he (and not the later John D. Houchin) is said to be the discoverer of what later became known as Mammoth Cave (see Goode, 1986).”

The earliest plausible reference to the cave itself is Gilbert Imlay, 1792: *A topographical description of the western territory of North America...*, in which the author comments that “[Saltpeter] earth is discovered in greater plenty on the waters of the Green River.” The earliest unmistakable reference to Mammoth Cave is the Valentine Simons land patent (*Entry to 200 acres of second rate land on Green River in Warren County, Kentucky*) of 1799. At the other end of the scale, references with a 2002 date are 42 in number. The backlog of recent material waiting to be entered fluctuates greatly, but over the past decade, an average of approximately 100 records for each year are added.

One of the main difficulties, generic to any bibliography, is where to draw the boundaries. This is not trivial even in the geographical sense. References on the connected components of the system are obviously included, but there are caves such as Whigpistle, which although not generally regarded as part of Mammoth Cave, are hydrologically connected. In the end, we decided to err on the side of inclusiveness, so that the bibliography includes references to the Mammoth Cave region. However, the completeness of coverage varies greatly. Fisher Ridge is one rather obvious area cave with its own voluminous (if not very old) literature, of which we have merely scratched the surface. Coverage is better for some historically important local caves such as Short Cave, Long Cave, and White Cave. Another recurring problem is the mention in passing of Mammoth Cave or some aspect of it in an article on a broader or different topic. These require case by case judgment calls, and probably no two compilers would come up with exactly the same final list.

Name: **SILLIMAN AVENUE**

**Synonym:** El Ghor (in part); Infernal Regions (in part); Railroad Tunnel; Sillamon Ave.(Walker); Silliman's Avenue (Jones, Martin, Jillson, etc.); Sillimon's Avenue (Gwin)

**Section:** Mammoth

**Location:** Between Cascade Hall and Joe's Pit.

**CRF map sheet:** Blue Spring Branch, Main Cave

**Stations:** 2281S49-2281S26-2244S25-2244S1-2281T1-2281T4-2481T5-2481T10

**Maps:** Bishop, 1842; Anon. (Hovey), 1883; Call, 1897; Hovey, 1907; Kämper, 1908; Walker, 1936; Staples, 1938; Quinlan/Nelson, 1964

**References:** Jones, 1844:38; Merriam, 1844:321; Bullitt, 1845:88 ; Anon (Brewer's Panorama) 1850; Macalester, 1851; Martin, 1851:65; Anon. (Child), 1852; Jillson, 1854; Taylor, 1859:211-2; Anon. ("Uncle John") c. 1860; Emerson, 1860; Wright, 1860:38-41; Anon. (Rusling), 1864; Anon. (J.W.M.), 1866; Anon. (Atlantic Monthly), 1867; Binkerd, 1869:73; Knox, 1873; Gwin, 1875; King, 1875:705; Wethered, 1877; Hovey, 1880:20; Hovey, 1882:71; Johnston, 1893:42; Hovey & Call, 1897:77; McGehee, 1955; Faust, 1967:21; Toomey, 2001; Winkler, 2001

**Earliest date:** 1842

**Current?** Yes

**Comments:** This passage is a mid-level trunk canyon, "long, broad and handsome," (Jones, 1844) and "so regular that it might have been the work of engineers." (Knox, 1873) It was followed for almost its entire length by the old all day tour. Ascending from Cascade Hall through the Infernal Regions, the canyon levels off at Serpent Hall where Welcome Avenue joins it. Other major side passages are Valley Way Side Cut, Roaring River, Burley's Way, Hooflands Avenue, Rhoda's Arcade, and the Pass of El Ghor. Beyond the El Ghor junction, the passage is smaller, owing to breakdown, and soon ends in Joe's Pit. The total length from Cascade Hall to Joe's Pit is about 4,250 ft.

According to Jones (1844), and apparently Kämper (1908), *Silliman Avenue* begins at Serpent Hall, the stretch between there and Cascade Hall being the Infernal Regions. In Bullitt (1845), Wright (1860), Binkerd (1869) and on the 1842 Bishop map, the Infernal Regions are included as part of Silliman's Avenue. Jones also includes El Ghor as part of Silliman Avenue.

It was "named 'Silliman,' in honor of the distinguished Professor of Yale College." (Merriam, quoting an 1841 letter) Benjamin Silliman, Jr. was Professor of Physics and Chemistry at Yale. He visited Mammoth Cave in 1850 (Faust, 1967; but in 1852 according to Hovey (1882)). According to Forwood (1870), Silliman published four articles on Mammoth Cave in his "American Journal of Science and Arts." (The present authors know of only one such article). Jones has a more obvious explanation for the name; the passage was "so named, we infer, because it suited the fancy of the first explorer."

Figure 1: Entry from the Mammoth Cave Gazeteer

## Future directions

Both database files are in a rather nebulous state of being not quite ready for traditional publication, mainly owing to the need for extensive proofreading and the resolution of inconsistencies, but still being complete enough to be of real use. The databases have been made

available to cave managers, researchers, and anyone else with an interest who has access to the Filemaker Pro database. It seems that the fastest and easiest way of making the gazetteer and bibliography more widely available will be to publish them on the CRF web site. We are currently exploring the options for having both data sets available on-line as searchable and sortable databases.

# **China Caves Project**

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## **China Caves Project Update**

*Chris Groves and Alan Glennon*

### **Introduction**

In June 2000, Chris and Deana Groves, along with Alan Glennon, traveled to Guilin, China, as part of a cooperative research project between the Cave Research Foundation (CRF), the Hoffman Environmental Research Institute at Western Kentucky University (WKU), and the Karst Dynamics Laboratory (KDL) of the Institute of Karst Geology of the Chinese Academy of Geological Sciences. With roughly 300 karst geologists, hydrologists, and graduate students in residence, the Institute is the primary karst research center in the China. It is an agency of China's Ministry of Land and Resources (roughly equivalent to a combination of the US Geological Survey and the US Environmental Protection Agency), and as such has major responsibilities associated with karst resource management for the national government. The city of Guilin, on the Li River, has a long-standing reputation as a setting of great beauty, and has developed as a significant domestic and international tourist destination. The economic benefits of tourism have led Guilin to become one of the more prosperous regions of southern China. An important aspect of this prosperity is that it has given the region the resources to begin to concentrate on solutions to environmental problems.

The purpose of this report is to summarize CRF program activities during 2000, including a visit to China in June, and a visit by three Chinese scientists and tourism officials from Guilin to south-central Kentucky in November.

### **Project Background**

There has been a history of karst research activities between WKU and Chinese cave scientists, which has increasingly involved CRF, and in particular, the Guilin KDL. This began in 1994 when Chris and Deana Groves hosted Professor Zhang Shouyue, a leading karst scientist with the Chinese Academy of Sciences in Beijing, for a week at Mammoth Cave during a US lecture tour. Professor Zhang interacted with numerous students and scientists at WKU and Mammoth Cave National Park, and gave several lectures on research projects in China.

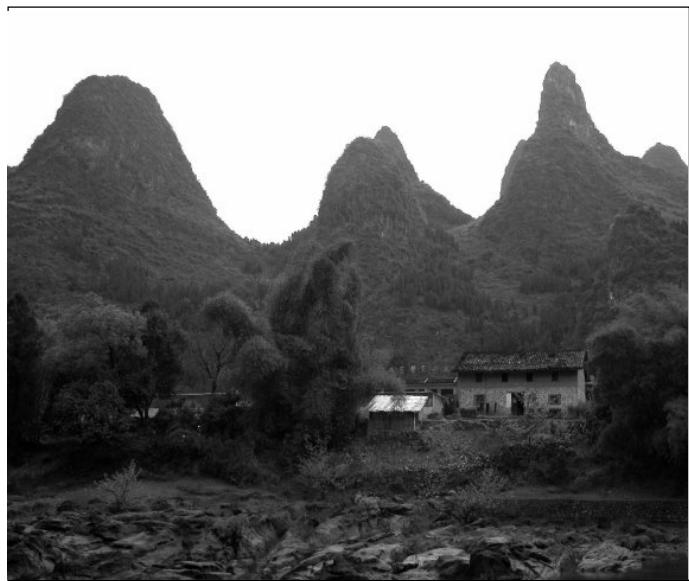
In 1995, Chris and Deana visited Guilin and the KDL for the first time, where he presented results of carbonate geochemistry research in the Mammoth Cave area. While in Guilin, he also discussed UNESCO's International Geological Correlation Program (IGCP) Project 379: Karst Processes and the Global Carbon Cycle, with the project's director and Karst Institute founder Professor Yuan Daoxian. This began a period of collaborative work in support of IGCP Project 379. During the trip, they also visited Beijing to meet with Professor Zhang at the Chinese Academy of Sciences.

In 1998, a group of organizations including CRF hosted a successful international meeting of IGCP Project 379 in Bowling Green, Kentucky. Three members from the KDL attended the Kentucky meeting along with another 110 scientists and students from a total of seventeen countries. Many of those in atten-

dance were among the top karst scientists in their respective countries, and the meeting was very successful in promoting the goals and results of the project. Nearly \$20,000 in funding was obtained from WKU, the National Park Service, American Chemical Society, CRF and the Karst Waters Institute to support travel and registration expenses of students and scientists from around the world to attend the meeting. Numerous CRF members attended the meeting and gave scientific presentations. CRF was especially active in organizing and leading several field trips on and beneath the surface of the Mammoth Cave area, which gave the participants a chance to see the great cave at whatever level of intimacy (and difficulty!) they chose and have it interpreted by those most knowledgeable about it.

### **June CRF Visit to China**

In June 2000, Chris and Deana, this time with CRF member Alan Glennon, again visited the KDL in Guilin. They presented a three-day workshop on Geographic Information Systems (GIS) tools for study of karst geomorphology, hydrogeology, and resource management, led by Alan. Chris presented results of the Mammoth Cave working group of Project 379, and the joint Chinese-US team also participated in field research into landscape evolution of the Li River Valley using newly developed methods of cave sediment dating by isotopic analysis being pioneered by Darryl Grainger.



Li River Karst, Photo by Joe Meiman

The GIS workshop was presented to a group of fifteen karst scientists and graduate students at the KDL, some of whom had traveled from as far away as Beijing for the class. Since several of the Chinese scientists in the group already had a basic understanding of GIS principles and some knowledge of ESRI ArcView software, we went through that rather quickly, and spent most of the workshop concentrating on developing tools for the three-dimensional import and analysis of cave and karst hydrogeological data. Several Chinese data sets were developed using combinations of Compass, Walls, Cave Tools, and the ArcView extensions: Spatial Analyst, 3D Analyst, and Image Analysis. The fabulous "peak cluster" tower karst areas of the KDL's experimental field site east of Guilin were especially striking when rendered with these tools. CRF funding allowed us to donate copies of the several of the most useful ArcView extensions to the KDL.

An important goal that was achieved over several lengthy evening sessions between Alan and a smaller group in addition to the workshop sessions was actually to go through the entire process of developing these data sets, and writing an instruction guide in Chinese. In this way, by the time we left China, a small group at the KDL had enough familiarity with the details of the process that they could in turn teach others, and thus, the skills were effectively transferred.

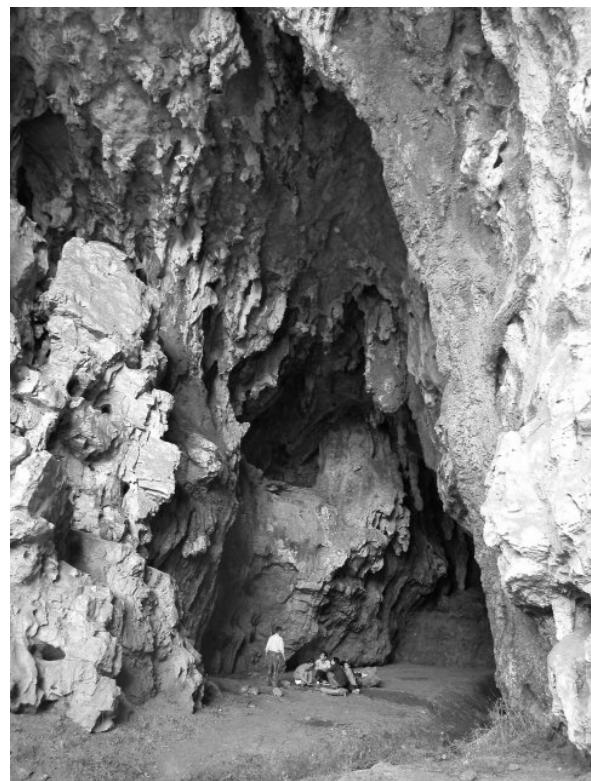
After the workshop and a day to travel through the spectacular Li River Gorge between Guilin and Yangshou, we spent three days in the field visiting caves to search for quartz sediments within abandoned stream passages in the higher elevations of the karst towers of the Li River Valley. Recently developed isotopic dating techniques developed by Darryl Granger of Purdue University measure the time when the sediments were washed into the cave, and thus when the stream passage was active. Because the caves in the towers tend to be rather horizontal and developed at the base of the towers, dating of a high, abandoned cave passage tells when the base of the tower was at that elevation, and thus can give landscape evolution rates. This is an important first step in unraveling the geomorphic history of the area, because estimating the age of the landscape can tell us what range of tectonic and climatic events have left an imprint on the landforms. In all, six caves were vis-

ited, including Tie Xing (Iron Star) Cave, Seven Star Cave, Maomaotou Cave, Panlong Cave, Shuinan Cave, and Luti (Reed Flute) Cave. Suitable gravels were located and collected from Tie Xing Cave, at an elevation of 290 m, and Shuinan Cave, at 180 m. Because the current land surface between the towers, formed by the floodplain of the Li River, is at an elevation of 150 m, these sediments should provide preliminary estimates for the time when the surface was 30 and 140 m higher than today, and thus the lowering rate of the plain over this period. The highest date obtained previously was from 30 m above the Li River plain at Through Cave by Paul Williams in the 1980s. The new samples were derived from several quartz sources, and will also allow chemical determination of the purity of the quartz to determine which are the most chemically suitable for the method. The samples were shipped from China to Dr. Granger at Purdue, and are currently under analysis.

Two other projects included a visit to the Institute's Experimental Field Site near Yaji Village, east of Guilin. The 2 km<sup>2</sup> site was established in 1986 to study various aspects of hydrogeology and karst evolution in the semitropical tower karst of south China, and recently to look at carbon cycling and the impact of karst processes on the global carbon cycle. We also traveled 10 km south to the Shanhe Town area to visit Fengyu Cave, a large tourist cave that has been developed with the assistance of the KDL, and opened to tourists in 1994. This wonderful tour is 5.3 km long, with 2 km of walking paths through several large and well decorated chambers, including one with a floor area of 25,000 meters<sup>2</sup>, and then a three kilometer boat trip from which visitors eventually emerge from a large and beautiful spring entrance at the base of several large karst towers. After the cave trip, we met with the directors of the cave, and discussed common aspects and problems of tourism development. The economic development, including hotels and other amenities, which has followed from the cave's opening, appears to have made a significant impact on the quality of life in the area, which formerly was relatively impoverished as in many rural areas of south China.

#### November visit of Chinese to Kentucky

In November, the Hoffman Institute and CRF hosted a visit by three Chinese, including Professor



Typical cave entrance in China,  
photo by Chris Groves

Jiang Zhongcheng from the KDL, and two tourism officials from the Guilin Tourism Corporation, Qi Xiang Dong and Yang Jin Hua. The group became the first foreign visitors to CRF's newly-opened Hamilton Valley Research Station, and visited south-central Kentucky for eight days. We had a great deal of help from overlapping groups including CRF (Rick Olson, Rick Toomey, and Joel Despain), Mammoth Cave (Joe Meiman, MaryAnne Davis, Vicki Carson, and Bob Ward), and other local cave experts (Gary Berdeaux, Dave Foster, and Mike May). We led them on a week of field activities and meetings to spots that included Mammoth Cave National Park, Hidden River Cave, Diamond Caverns, the Bowling Green/Warren County Tourism Commission, and the Corvette Museum and Factory. The contingent was able to meet with many of the administrators and managers at Mammoth Cave National Park to discuss differing approaches to tourism and natural resource management. The group especially enjoyed interacting with Rick Toomey to learn of his paleontology work in the cave. On one of Rick's trips into the cave, they were joined by about 110 students from Chris' intro

geography class, who enjoyed hearing stories about Rick's vampire bat fossil discoveries in the cave. Professor Jiang gave a lecture on environmental problems in south China to a group of about 60 faculty and students at WKU, attended by numerous CRF members including Chris and Alan, Rick Fowler, Nick Crawford, Joel Despain, Rick Toomey, Rick Olson, Katie Shaw Seadler, Joe Meiman and Bill Curry. A radio interview with Dr. Jiang on WKU's public radio station, along with a news article in the Bowling Green daily paper, brought community attention to the visit.

## **Future Plans**

A Memorandum of Cooperation is currently under development that has the following goals:

- to enhance communication between Chinese and North American karst scientists and students, and the mutual sharing of expertise and methods.
- to introduce American scientific techniques and experience to China's New Round of Land and Resources Survey, particularly of China's karst regions.

- to conduct research into karst resource management in both China and North America, and in particular, study the relationship between land use and hydrogeology. Primary research field sites will include the southeastern United States, and Guanxi and Guizhou provinces of China, expanding outward as appropriate.
- to continue research into karst geomorphology.
- to continue research into the relationship between karst processes and the global carbon cycle.

We are really just at the beginning of the possibilities for meaningful and productive exchange with the Guilin group. They have major responsibilities to the Chinese government for inventory and study of karst resources in the 500,000 km<sup>2</sup> south China karst region, including GIS development, which will extend at least over the next decade. It is worth noting, as well, there are very likely thousands of kilometers of unexplored cave passages yet to be mapped in Guanxi and Guizhou provinces, to which Ian Baren and the China Caves Project members can attest!

# Hawaii

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*For the past two years, CRF has been working with the Hawaii Speleological Survey (HSS) on several survey projects on the Big Island of Hawaii. For the 2000 field season, CRF cavers worked jointly with HSS projects that focused on tubes within the 1881 Flow (South Hilo District) and in Kipuka Kanohina (Ka'u District). Following is a summary of fieldwork activities.*

## Hawaii Field Season

*Patricia Kambesis*

### 1881 Flow

The 1881 Flow is a pahoehoe lava flow that originated from the Northeast rift zone of Mauna Loa. The eruption creating the flow lasted for 9 months, stopping at the outskirts of Hilo. The lava traveled a distance of over 25 miles from point of origin to just short of the ocean. Historic written accounts of the volcanic activity associated with the flow give detailed descriptions of the eruptions, the lava flows and the skylights that formed in association with the lava tubes.

In 1998, survey work began in Emesine Cave, a tube in the 1881 flow located high on the flanks of Mauna Loa. Before the 2000 field season, over six miles of tube had been mapped both mauka (up mountain) and makai (toward the ocean). However, the six miles is not all straight-line distance. There are many cut-arounds and tube mazes within the system making for complex passage configurations.

As is typical with lava tubes, Emesine has multiple entrances and the floral suites within the entrances vary with elevation. This makes for an impressive range and variety of plant associations especially since the 1881 flow originates at almost 11,000 feet and goes nearly to sea level; so far the tube only covers a third of that vertical extent.

Since the 1881 flow is on the wet side of the island, Emesine passages are very drippy. Most of the original mineral crusts and deposits that formed during or after cooling of the tube have been washed away. The Ohia trees growing over most of the lava surface send roots that reach into the passages forming veils of roots. These veils are host to delicate plant-insect ecosystems.

Emesine Cave is characterized by floors, walls, and ceilings of jet black lava. Occasionally, especially near entrances, the lava floors will be bring orange, deep red or yellow in color. The cave has very well developed gutters, levees, ledges, and catwalks throughout. Many of the ledges and catwalks are edged with a fine filigree of crenulated lava, probably a function of the viscosity of the lava and the hot air that moved over the surface of the flow.

Just prior to the 2000 field season, Kevin and Carlene Allred continued survey in Emesine Cave. Kevin, who arrived on the island first in November 1999, did a three-day solo trip to extend the mauka (up mountain) end of the tube. Carlene and their sons Soren and Flint joined the effort later in the month. Their survey work added over two miles to the known length of the system. A large maze area was complete and the main line tube extended for another quarter of a mile up a series of lava falls. Unfortunately, the tube ended there in a complete lava sump (ceiling meets floor).

The next set of trips, which occurred in December 1999, were blessed with a week of sunny weather. The second crew to work on the Emesine survey was composed of Andrew Dubois, Ali Ratliff, Peter and Ann Bosted, Ashley Chan, Bruce Brewer and Don Coons. They did a lot of clean-up survey finishing off nearly all of the leads left in the makai section of the cave. The terminal end of survey was extended by nearly half a mile past two additional entrances, through the Grim Crawl of Death (a low belly crawl on sharp lava) and into a confusing complex of large passages. The entire area was floored and "dipped" for several feet up the walls in a colorful series of lava patinas ranging from bright red, orange, mustard yellow, and even green. Some sections were

such a conglomeration of color that the explorers call them kaleidoscope lavas. Also discovered in this area were some of the longest soda straws noted to date. Several were from 1.6 to 1.9 meters long. In addition the area hosts a large number of Cockscomb (Flower Head, Puu Poo) formations. Many had developed "feathers" up to 6 cm long and "tails" more than half a meter long.

Weather-wise, January proved to be much less cooperative. Continuous rain/drizzle and blinding fog was interspersed with about two hours of quasi-sunny weather - in 15-minute increments. The team, made up of Dave and Elizabeth Bunnell, Pat Kambesis, Russell Connor, Cindy Heazlit, Mark Ohms, Rene Rogers, and Don Coons finally gave it up after three days and a thorough soaking of all gear. Additional cleanup leads and one long trip to the bottom of the cave produced half mile of survey. The lower end of the maze was delimited and the way on reconnoitered. Much remains to be done on next year's trip. Total length of survey in the cave to date is 9.07 miles.

In addition to Emesine Cave, five other caves in the 1881 flow were worked. One was a quarter mile long complex of crawls with some walking passage located about 6 miles makai of the Emesine Camp. Hopes were high that this tube would prove a route into Emesine from lower elevations and could possibly save us the long hike in from the upper entrances. Although this did not prove to be the case, there is still one lead that could yield more passage.

A series of three caves separated by short lava sumps was mapped mauka of Emesine Cave at an elevation of 7500 feet. Just over 1700 feet was surveyed in a very delicate and beautiful series of passages. Secondary mineralization of white crystals was common in many areas with frostings of gypsum and mirabilite rimming many areas of floor. A surface hike done by Ali Ratlif and Andrew Dubois also discovered another entrance near the mauka end of Emesine, just two miles below this area. A vertical drop into a "large tube" was observed just 1000 feet away from the Allred end of survey.

Kaumana Cave is located in the city of Hilo at the makai end of the 1881 Flow. The main entrance has been developed into a city park and the lava tube sees



Kaumana Cave, photo by Dave Bunnell

lots of visitation. The resurvey of Kaumana was started in 1999 and all previously mapped passages were completed this year. Total surveyed passage currently stands at 1.4 miles. However, there is still much remaining in the mauka direction. The potential exists for Kaumana Cave to be the extreme down-flow continuation of Emesine. A point of note, the town of Kaumana directs its floodwaters into one of Kaumana Cave's entrances located in town. This causes significant flooding within the tube during the wet season (from December through May).

A plot of all the known tubes in the 1881 Flow, laid out to scale, make for an impressive potential with 11.08 miles of cave documented within the flow to date. Its easy to envision all of these caves as one continuous tube within the 1881 Flow. However, gaps between the current surveys are considerably longer than the segments that have been completed. There is a lot of work to be done if we are ever to link them all into one continuous system.

### Kipuka Kanohina

Located near South Point on the dry side of the island, the lava tubes within Kipuka Kanohina are quite a contrast to the wet, drippy tubes of the 1881 Flow. Originating from the south rift zone of Mauna Loa, this lava flow is several hundred years older. Archeology abounds both on the surface and underground. The ancient Hawaiians used the caves for gathering water and as trade routes. On the surface is evidence of their agricultural practices.



Kula Kai Caverns, photo by Dave Bunnell

The tubes form a confusing knot of multi-level boreholes and sometimes three or four paralleling passages. This does not even include the braids, cutarounds, mazes and occasional cross-overs from one parallel or level to the next. The tubes of Kipuka Kanohina are very dry and many of the ceilings, walls and floors are encrusted with white mineral coatings. Because it does not rain much on this side of the island, the mineralizations do not get washed away like they do on the east side.

Ohia trees also grow on this side of the island and as in Emesine, the roots extend into the area lava tubes. However, because of an on-going multi-year drought, many of the roots are almost dried out.

So far the caves of Kipuka Kanohina consist of two systems. Kula Kai Caverns (2.48 miles) is a developed section of tube which is owned by Ric Elhard and Rose Herrera. They offer an educational, conservation-minded tour of their cave. Eli's Cave is a large parallel complex, which first came under the surveyor's chain just last year. The Maelstrom, is another tube series that was connected to Eli's at the end of the expedition bringing the total surveyed length of Eli/Maelstrom to 5.8 miles and still going. An additional last day discovery named Poha Cave added 2000 feet of survey in just one trip. No connections were made with the other caves yet, but the mauk end of this cave overlies Kula Kai and the makai end overlies Eli's/

Malestrom. Once the tubes are connected (and they certainly will be) this will make for an 8.7-mile system.

### Mauna Loa

Doug and Hazel Medville invited our contingent to join them on some of their survey projects located at some of the loftier elevations of Mauna Loa. Two large caves lie roughly parallel at comparable elevations, but in different flows, one historic and one prehistoric. Both break into multi level maze passages in their mauka ends and come together as unusually large trunk passages in their makai extensions. The shorter of the two at just under half a mile was named Booty and the Beast. The longer with nearly two miles of survey was named Big Red. This tube proved to be unusual geologically. It lies very deep within its flow; the lower half-mile of survey underlies at least two younger historic flows on the "surface" above. No indication of these overlying flows can be seen from within the cave, which finally dies in a lava sump formed of the original flow material within the cave.

Of biologic significance in Big Red, was the discovery of over 100 individual skeletons of Hawaiian Hoary Bats (*Lasiurus cinereus semotus*) located within the lower half mile of survey in the main passage. Some individuals were mummified with soft body parts complete down to fur. Because only one or two other skeletons have ever been identified in any other single Hawaiian cave this site is one of considerable biological importance. To date, no one has actually seen a live bat in a Hawaiian cave. Just why these Hoary Bats were traveling to the back of Big Red and what they were doing there in the first place are indeed questions of interest.

During one of our final days with the Medvilles, Doug suggested that Joyce Hoffmaster and I map a tube located just off of the Saddle Road (the only road that crosses the island in the middle). Joyce and I spent a pleasant afternoon mapping 800 feet of Strawberry Cave. We stopped our survey at a very low, velcroish crawlway. Though it was moving lots of air, neither of us were in the mood to shred skin and clothes.

The work accomplished during the 2000 field season puts only a small dent in what remains to be done on the Big Island of Hawaii.

# Cavebooks

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Cavebooks is the operating publications affiliate of the Cave Research Foundation. In 1983, Cave Books established a publications initiative with the goal of publishing one new cave book each year. Funding and management of this publishing effort is handled independently of other internal publication efforts. The first book in the series, "The Grand Kentucky Junction", was released in the spring of 1984. Revenue from its sales supported the cost of a second book, and so on, thereby providing a self-sustaining funding process for each following publication.

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