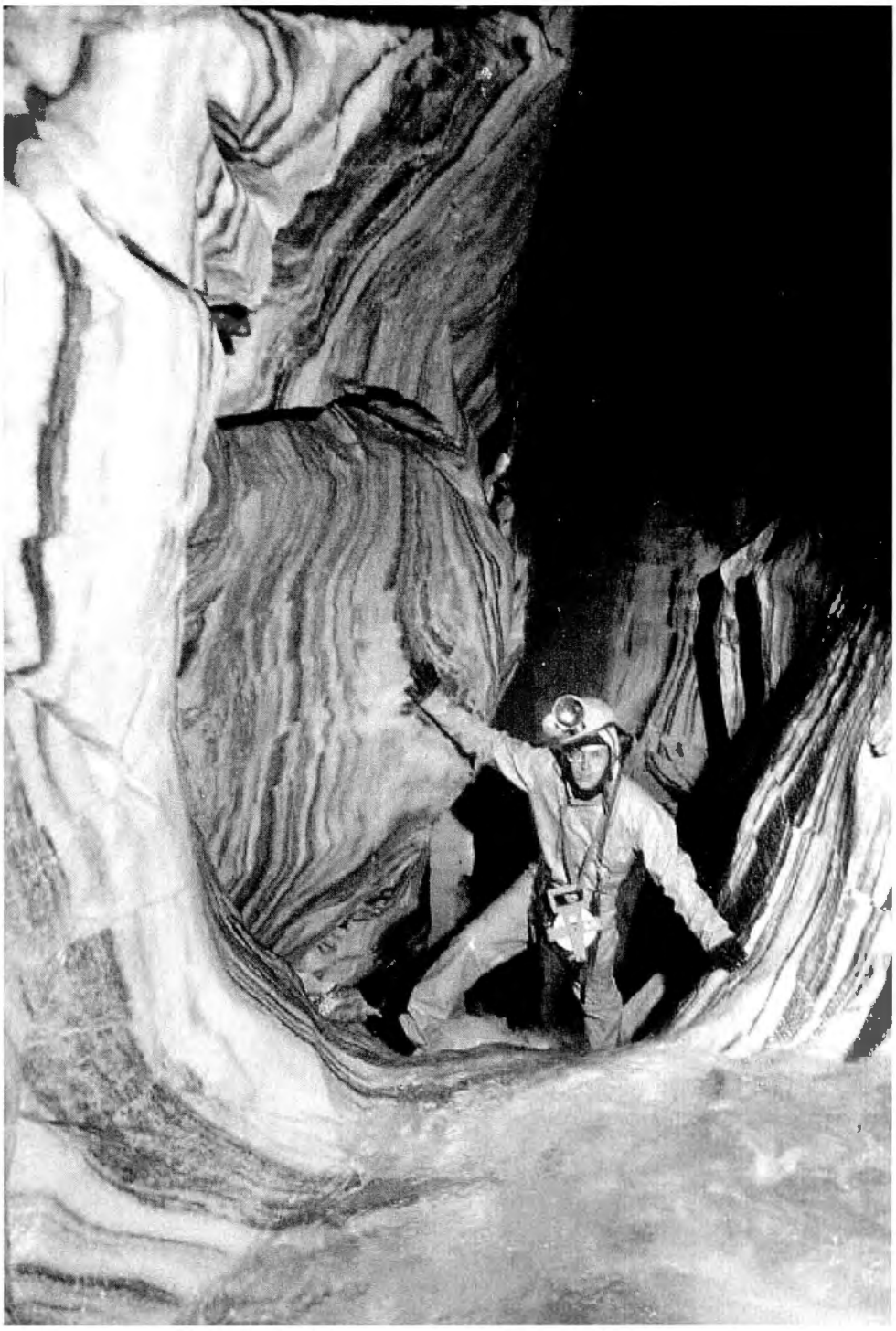

Cave Research Foundation

Annual Report
1994-1997

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:

- facilitate research, management and interpretation of caves, and karst resources
- form partnerships to study, protect and preserve cave resources and karst areas
- promote the long-term conservation of caves, and karst ecosystems

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Sequoia Kings Canyon National Park, California (Photo by Dave Bunnell)

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Cave Research Foundation

ANNUAL REPORT

1994 - 1997

Cave Research Foundation
P.O. Box 343
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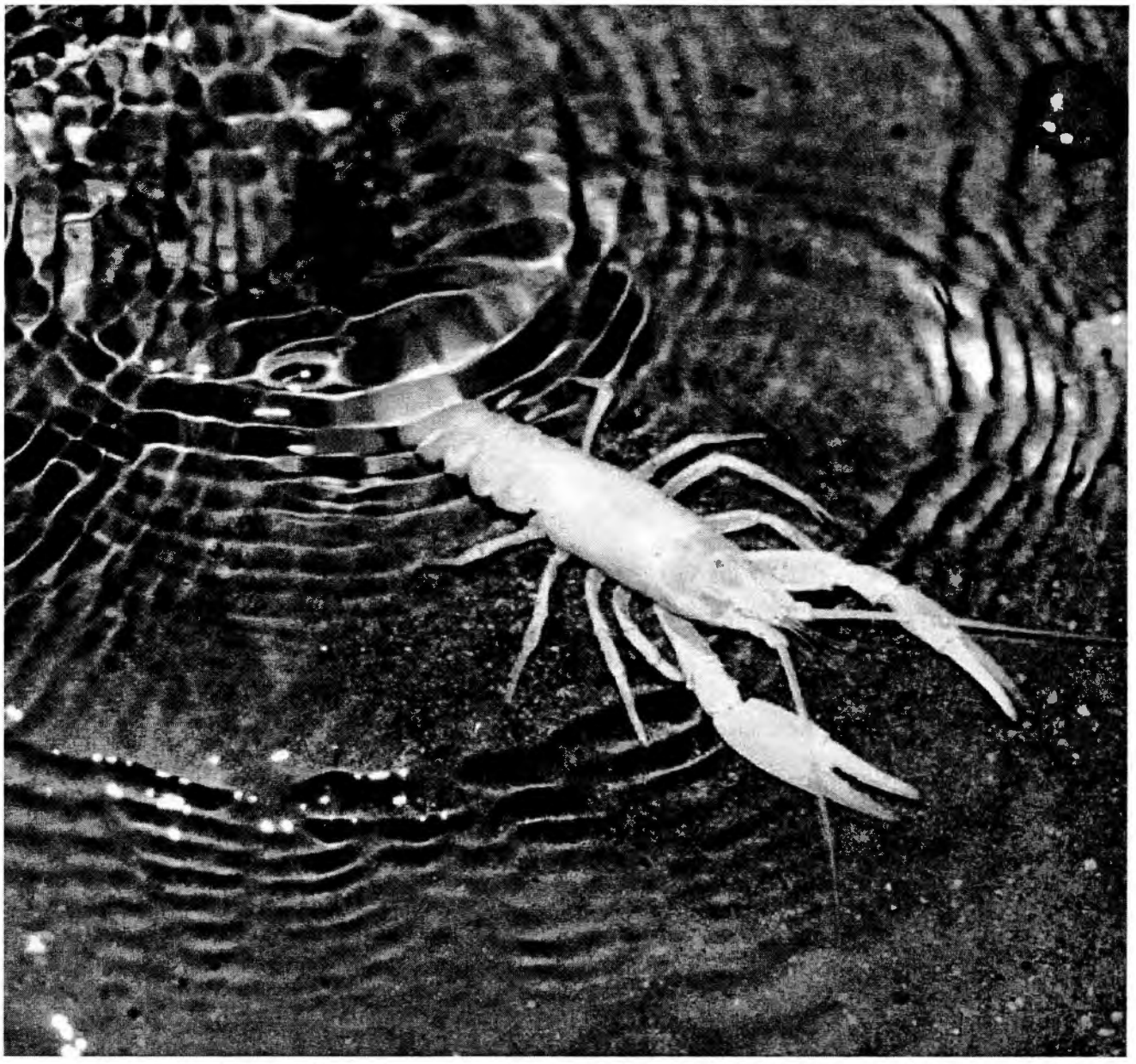


Cave Research Foundation Activities 1994

Cave Research Foundation Directors

1994

Melburn R. Park
President

Roger E. McClure
Treasurer

John C. Tinsley
Secretary

James Borden

Phil DiBlasi

Pat Helton

Scott House

Pete Lindsley

Bob Osburn

Janet Sowers

Mick Sutton

Operation Area Managers

Arkansas Operation Area: Pete Lindsley

Eastern Operation Area (KY): Jim Borden

Guadalupe Escarpment Area (NM): Tom Madison

Lave Beds Operation Area (CA): Janet Sowers

Missouri Operation Area: Scott House

Sequoia Kings Canyon/
Mineral King Operation Area (CA): John C. Tinsley

Page 6 photo credit: Troglobitic crayfish in an Alabama cave.
Photographer: Alan Cressler

1994 Highlights

Spring Board of Directors Meeting

The CRF Board met on April 23, 1994 at Horse Cave, Kentucky. Dave Foster, Executive Director of the American Cave Conservation Association (ACCA) hosted the meeting addressing the Board on the goals and purposes of his organization. With CRF establishing a land preserve and a national headquarters near the ACCA headquarters, it was stressed that the two organizations will need to cooperate in new ways.

For two years, CRF has been considering entering into a contract with the National Speleological Foundation (NSF). The NSF is an independent, nonprofit corporation established to provide sound investment management for speleological organizations. They manage, for example, several major accounts for the National Speleological Society. Treasurer Roger McClure presented the Board with a draft contract with the NSF that was approved in an amended version.

The Board approved cooperative agreements in the Missouri and Mammoth Cave areas. These contracts bring government funds to support specific research projects conducted by CRF.

Bob Osburn, Building Committee Chairperson, reported that engineering studies for the Hamilton Valley building site will be conducted this spring. Gravitometric and other studies will be done so that the engineering plans, for which we have already contracted, can be finished. The Board approved the lease and financial contracts for the caretakers on the Hamilton Valley property.

Present slate of officers were: Mel Park, President, Roger McClure, Treasurer, John Tinsley, Secretary. The Board accepted with reluctance and regrets the resignation of Mick Sutton as Director. Mel Park appointed Tom Madison as Operations Manager for the Guadalupe Escarpment area, replacing Dick Venters.

Annual Board /Members Meeting

The CRF Annual Meeting was hosted by Janet Sowers and the Tinsley's at the USGS facility in Menlo Park, California. During the closed Board meeting several changes in CRF officers and board were made: Two new board members were installed: Chuck Pease and Pat Kambesis. A reelection of the Board of Directorship was held with the reinstallation of the following directors: Phil DiBlasi, Pat Helton, Scott House, Pete Lindsley, Roger McClure, Bob Osburn, Janet Sowers and John Tinsley. Officers elected included Roger McClure (treasurer) and John Tinsley (secretary), both reelected to their respective positions. Phil DiBlasi was elected the new President. Resigning from the Board were Mel Park and Jim Borden.

The public portion of the Annual Meeting was chaired by Mel Park. Each of the operations areas gave brief presentations about their last year's efforts, new board members and officers were announced, and Roger McClure gave a presentation about Hamilton Valley and the progress made over the past few years. Presentations which focused on individual research efforts followed and included: Hydrology at Lilburn Cave (Mike Speiss); Restoration in Lilburn Cave (Bill Frantz); Cartography at Lilburn (Peter Bosted); Mineralogy of Far Western Caves (Bruce Rogers); CML Cave Mapping Language (Mel Park); The Guads Mapped in 3-D video (Pat Helton); Field Cartography in China (Pat Kambesis); Survey of Fitton Cave (Pete Lindsley); Cave Entrance Ferns at Lava Beds National Monument (Christopher Richard); Cave Inventory in Missouri and Kentucky (Scott House); Cave Inventory at Lava Beds (Janet Sowers); Dust and Sediments at Lava Beds (John Tinsley).

The Board elected six new members to the Foundation. They are: Tom Madison, Chuck Swedlund, Larry Pursell, Harry E. Grover, Richard Maxey, and Paul Cannaley.

Mammoth Cave Bibliography - Donation from Overseas

Ray Mansfield of Shepton Mallet, England, editor of Current Titles in Speleology, recently turned his entire note card collection over to the Cave Research

Foundation. This represents several decades of detailed research. It is estimated that there are about 1500 titles in the Mansfield Mammoth Cave bibliography, which ranks among the top few private bibliographic collections known.

The collection will be integrated on disk format with more modest collections underway by Sue Hagan and Mick Sutton. It is anticipated the bibliography will become publicly available within the next few years.

In turning his many years of effort over to the Cave Research Foundation, Mansfield said he looked forward to seeing his work going to a repository where it will be available for future researchers. His original note cards will eventually be housed in the future CRF Headquarters archives at Hamilton Valley.

Hamilton Valley Project

A lot of progress has been made on the Hamilton Valley property this year. Over the course of numerous work sessions, trash was removed from the site and deposited in a local landfill. Considerable work has been done on the old tenant house, both inside and house, making it a suitable place to stage Hamilton Valley work weekends. A portion of the land just off the Hamilton Valley Road has been rented to a caretaker who has installed a trailer. The presence of a caretaker will aid in controlling use of property by unauthorized individuals as well as providing security when our construction gets underway. Roger McClure worked with the Chief Forester of the Kentucky Division of Forestry to survey the property and help in the development of a forestry plan which will ultimately be incorporated into a land management plan for Hamilton Valley.

The County has improved the road to the Hamilton Valley property, adding a few new culverts, widening, straightening, and leveling the road. CRF jv's worked hard breaking up old concrete in and around the barn which will be used as fill for our road bed. Building outlines have been roughly staked out and soil depth measurements were taken on the main building site.

International Expedition Support

CRF provided financial support to Subterranean Explorers, a group organizing the first US Borneo expedition. The 60-day expedition will scour the outer and inner recesses of Gunong Buda, a limestone mountain 9 miles long and averaging 4 miles wide, with a perimeter surrounded by 400-meter vertical cliffs. The Malaysian government officials approached the expedition organizers in an effort to preserve the valuable rain forest of Gunong Buda; the area is in grave jeopardy of being logged. It is hoped that significant discoveries will be made so that this section will be annexed into the National Park System.

NPS/CRF Science Conference at Mammoth Cave

The third Mammoth Cave Science Conference (July 5-6, 1994) was sponsored by Mammoth Cave National Park and the Cave Research Foundation. Specialists in a variety of fields outlined ongoing research projects in the Mammoth Cave area. The Conference also provided a forum for the discussion of NPS management issues. The artistic and historic value of a name painstakingly carved into a wall was debated against the need to preserve the natural resource. Bob Ward (NPS) argued that from a historical perspective all that is required is good documentation. Photographer Chuck Swedlund made a counter-argument that the signatures have intrinsic value as works of art. Swedlund and Larry Pursell gave presentations showing their different approaches to recording signatures. How best to market the park provoked remarks about the need for a park museum. The importance of long-term data collection was underscored by a number of presenters.

The Conference was the first open forum for presenting CRF's proposed three-year small cave inventory. The presentation by Scott House centered on the scope and expected outcomes of obtaining and organizing baseline information on a large number of caves within the park. Among the many other presentations involving CRF joint venturers's were Paul Rubin's detailed reconstruction of the sedimentary history of Kaemper Avenue, and a discussion by Richard Zopf on the conservation aspect of management actions.

CRF Fellowships and Grants

In 1994, CRF received 10 proposals. Of these, six were awarded grants. A total of $5,500 was distributed among the following proposals:

1. *Structural and Lithological Controls on Karstification in the Great Valley of Pennsylvania*, Mr. Rolf V. Ackermann, Department of Geological Sciences, Rutgers, University, Busch Campus, Piscataway, NM ($1,000)

This research includes a comprehensive regional study to better understand the relative importance of geological controls on karst development within the Great Valley of Pennsylvania. Of special interest is a study to determine if a correlation of purity of limestone and degree of karstification found in a preliminary study of Cumberland County holds true for the remainder of the Great Valley.

2. *Evidence for Pleistocene Climatic Change in the Barrack Zourie Cave System, Schoharie County, New York*, Mr. Kevin A. Dumont, Department of Geosciences, Mississippi State University, Mississippi State, MS ($1,000)

Mr. Dumont's research focuses on a cave system in east-central New York, where the effects of Pleistocene glaciation are recorded in the sediments, the depositional history of the speleothems, and the genesis and development of the passages. The study includes survey, dye-tracing, sedimentology, paleomagnetic signature of cave sediments and U-series dating of speleothems.

3. *Paleontology and Age of Cave Sediments, Isla de Mona, Puerto Rico*, Mr. Edward Forrest Frank, Department of Geology and Geophysics, University of Minnesota, Minneapolis, MN ($1,000)

This study will focus on the sequencing and timing of principal periods of speleogenesis on Isla de Mona, including their relation to periods of tectonic uplift and sea-level fluctuations. The setting offers attractive opportunities to conduct sampling for vertebrate remains among datable phosphate and speleothem deposits.

4. *The Evolution of Cuticular Waterproofing Mechanisms During Adaptive Shifts of Endemic Hawaiian Crickets (Caconemobius) into Physically Extreme Habitats.* Mr. Eamonn P. O'Toole, Department of Zoology, University of Hawaii at Manoa, Honolulu, Hawaii ($1,000)

In Hawaii, drastically different environments occur in close proximity. Environments inhabited by the *Caconemobius* cricket genus range from wet to dry. Rates of water loss and lipid composition of the crickets' epicuticle are key parameters to be studied. Strong correlation between epicuticular compositions, environmental conditions and water loss rates will be considered evidence of natural selection by parallel adaptation for maintenance of cuticular permeability at specific levels. General but weak correlations among these factors will be interpreted as evidence supporting regressive evolution owing to reduced selection for metabolic requirements. Weak correlations among water loss, lipid composition and habitat, coupled with a strong correlation between lipid composition and time since cave inhabitation, will be interpreted as evidence of neutral regressive evolution.

5. *Analysis of the Ecology of a Potentially Chemoautotrophic Anchialine Cave*, Mr. John W. Pohlman, Depart. of Oceanography, Texas, A&M University at Galveston, TX ($1,000).

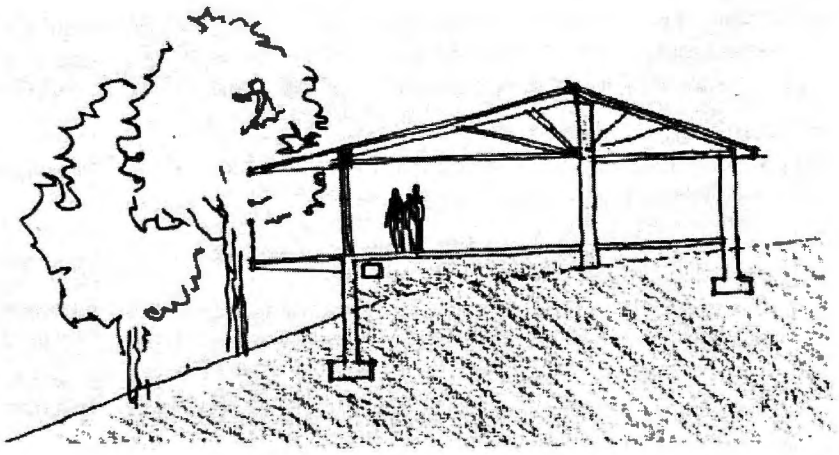
This research tests the hypothesis that the biota of the Maya Blue Cenote, an anchialine cave near the Caribbean coast of the Yucatan Peninsula produce organic matter using chemoautotrophic processes. It should be possible, using C^{13} and N^{15} stable isotopic analysis, in conjunction with the chemistry of the water, sediments and biota, to identify the source of the organic material and trace its transfer through the food web.

6. *Paleoenvironments of the Extinct Megalonyx Jeffersonii, Northwest Alabama*, Ms. Marla Jo Spry, quaternary Studies Program, Northern Arizona University, Flagstaff, AZ ($500).

This research builds on a preliminary site study and chronology developed by others. Ms. Spry will intensively examine a middle Pleistocene fauna from northwestern Alabama, in order to characterize the local environment in which the ground sloth lived 172,000 years ago, describe the associated microvertibrate communities, conduct a pollen analysis of associated clay layers and try to establish an upper limit for the age of the deposits.

Hamilton Valley Project Overview

Roger McClure
Mel Park
Red Watson



In 1957, CRF operated out of a small hut inside Mammoth Cave National Park (MCNP) on the Crystal Cave property managed by Bill and Jacque Austin. After the National Park Service bought the property in 1960, CRF-East continued to operate from this Flint Ridge base until 1991 when CRF operations were moved to Maple Springs, still inside MCNP.

The probability that CRF-East (Eastern Operations) would have to, some day, move out of MCNP to its own facilities was in the minds of CRF Board members since the inception of the organization. There was a chance to make this move as early as 1965, when two farms just outside MCNP came up for sale. To buy one of them, CRF would have had to borrow $15,000—a lot of money then, and nobody had the courage to saddle CRF with such a debt.

After the move to Maple Springs in 1991, CRF lost an independent operations center. The Maple Springs facilities are now shared with other groups, so CRF- East cannot design an independent calendar of support for scientists who want to work in the Central Kentucky karst. With the thought that CRF-East should move outside MCNP and with the intention that there should be a national headquarters, the CRF Board initiated a building fund and the Hamilton Valley Project in 1989. The objectives of the project are to accomplish the following goals:

1) Establish a national headquarters for CRF
2) Provide a base for CRF-Eastern Operations.
3) Build a field research station for cave science.

In 1991, Roger McClure looked into the possibility of purchasing of piece of land in Hamilton Valley which is located adjacent to property owned by Stan and Kay Sides. The CRF Board determined that this could serve as a national headquarters as well as CRF's Eastern operations center and approved the purchase. Thus began the Hamilton Valley Project.

At the end of 1992, the Foundation was able to acquire 196 acres of Hamilton Valley. The land is located just east of the Salts Cave Entrance. The valley overlies part of Salts Cave and is an important part of the Pike Spring drainage. On the southwestern border of the property is a projection of sandstone-capped highland. This knoll provides an extraordinary building site with one of the finest views of karst landscapes in the world. The land itself will be managed as a preserve in a way that is its due by virtue of being part of the watershed of the world's longest cave.

Architect Rod Hemni has designed a main building that contains toilets and showers, a kitchen, a dining hall that can also be used as a conference hall, two laboratory rooms, and a wraparound porch (large enough for summer dining) looking out over a beautiful karst valley. Two 20-person dormitories are planned, with

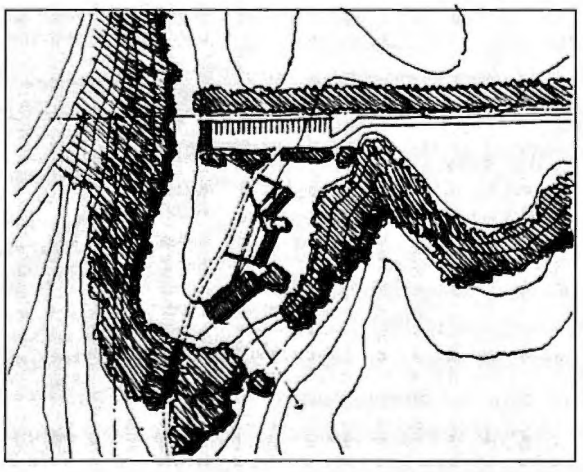
room for a third. These are excellent facilities for CRF members working on cartography programs and assisting cave scientists, fulfilling the basic premise of CRF that scientists need the assistance of explorer-surveyors to provide maps basic to all cave science, and of caver assistants to help them get about and do their work in caves.

The plan is conceived in two phases. The first phase is already completed in part. CRF owns the property and is the custodian of a watershed overlying major passages of the world's longest cave. A deep well has been drilled, a road has been built, the buildings are designed, and electricity is available. CRF is now soliciting contributions in order to construct the main building and dorms. Once enough money is raised, the construction project will begin. The main building will be constructed first, providing temporary housing for Joint venturers's on expeditions, work and study areas for scientists, and the establishment of the national headquarters. The dorms will follow. The cost estimate for completing Phase I of the project is $500,000 and CRF is currently conducting a fund raising drive to raise the money. Once the Hamilton Valley Center is finished, it should be occupied at least every weekend of the year—as an operations base for expeditions and field scientists, by discussion groups, by CRF members and scientists needing a retreat to draw maps or to think or to write a paper, and by CRF members maintaining the property. Once the dormitories are completed, CRF could rent the facilities to Western Kentucky University for its summer karst program, to the American Cave Conservation Association for its projected karst camps for students, and to organizations such as the Karst Waters Institute and the National Speleological Society for conferences and meetings.

Phase two is the construction of laboratories and housing for a full-time research director and for visiting scientists. Phase two will cost at least a million dollars, This money will come in part from major foundations. CRF can go to these foundations only after we have demonstrated our commitment and seriousness by completing phase one of the project ourselves. CRF also must be able to apply for grants from major foundations if we are to support basic research as government funding of basic research is diminishing.

The Hamilton Valley Project represents a major, long-term commitment to the study of karst regions in the Mammoth Cave area and all over the world. Our national headquarters will make CRF an important member of a major cave community that includes the American Cave Conservation Association, Karst Waters Institute, Kentucky Down Under, MCNP, Central Kentucky Karst Coalition, and Western Kentucky University.

With the support of a dedicated group of members who love cave science, CRF has a bright future on the forefront of speleology. The Hamilton Valley Project is more than land and buildings. It is a plan in which CRF can cooperate with the larger scientific community to further CRF's founding goal - to be at the leading edge of the world of speleology.



Plan view of Hamilton Valley Facility

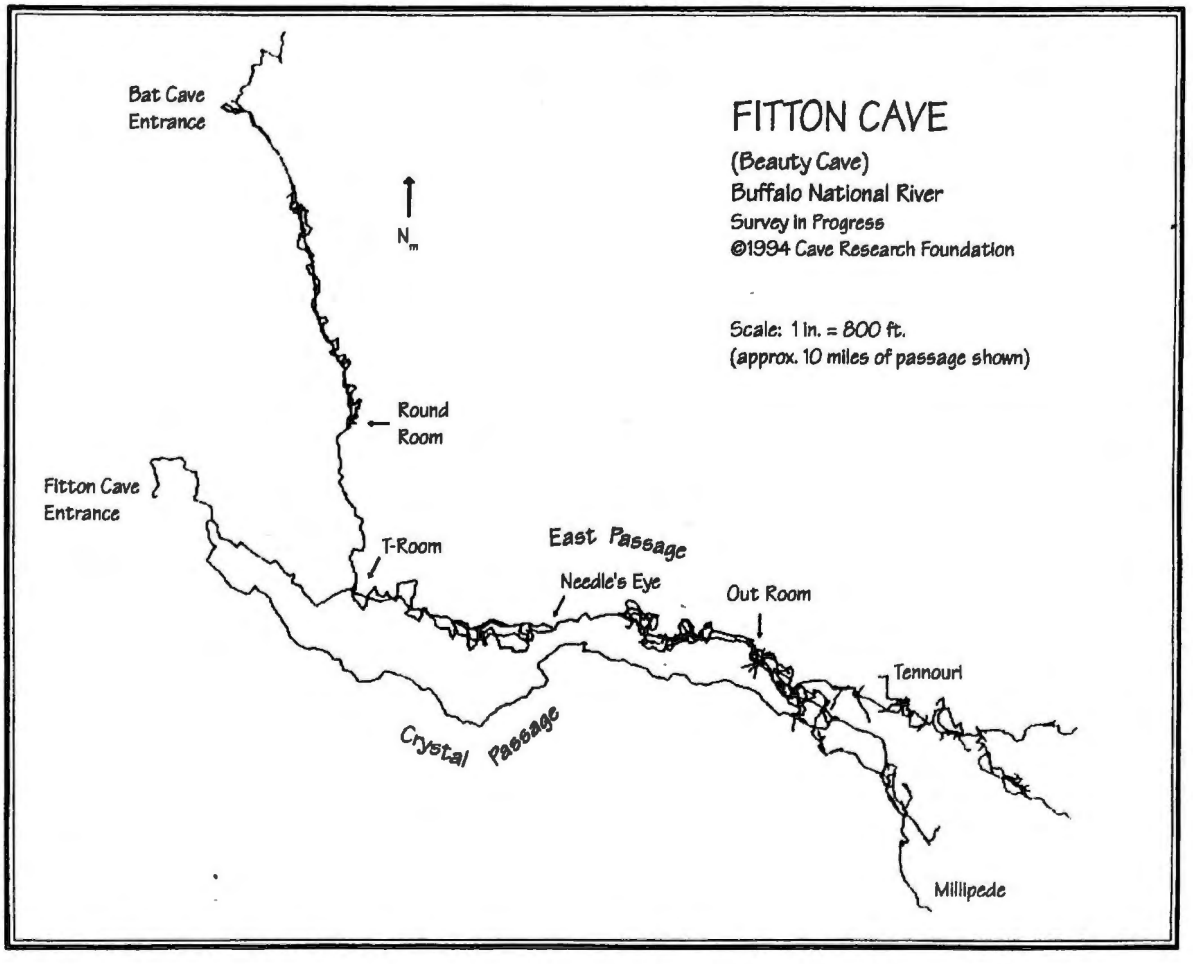
Operation Area Reports - 1994

Arkansas Operation Area
Fitton Cave Survey Project Report

Pete Lindsley

The Fitton Cave Survey Project in Arkansas fielded six enjoyable expeditions during 1994. A total of 53 cavers attended the expeditions and spent a total of 725 people-hours underground. Five of the expeditions were 1-day trips and one was a 3-day trip. A total of 18 survey parties worked in the cave during 1994.

During 1994, emphasis continued on the lower level portion of cave from the Round Room downstream to the Out Room. This section of the cave, known as Lower East, is quite complex with up to four levels below the major East Passage trunk. Some of our surveys in these more complex areas used pairs of teams that surveyed simultaneously along adjacent levels in order to tie the surveys together for closure control. Also during 1994, work started in generating multilevel cross sections in some of the more complex areas of the cave to enhance the present East Passage quads.



During the 3-day August expedition we completed the survey of the Double Drop Pit passage, a small connecting passage between the two parallel trunk passages. Only a few cavers have traversed this obscure connection between Crystal and East Passages and the path has always been one-way from Crystal to Lower East, due to some tricky climb-downs. The connection to the Lower East Passage survey was through an obscure lead that had been missed by numerous survey parties during the past year.

Also during August a surface traverse was completed between Fitton Cave, Ice Box Cave and Mud Cave entrances. Mud Cave, a segment of large trunk passage, lies on the other side of Cecil Creek from Fitton entrance and was found to be about 100 feet from the breakdown room "end" of Ice Box Cave and just above it in elevation. There is now little doubt that Mud Cave is the source of the airflow seen in Ice Box Cave. The small stream in Ice Box lies about 24 feet below the floor of Cecil Creek, which was quite dry except for a few pools during August.

Additional areas surveyed during 1994 in Fitton included portions of the Tennouri and Helictite passages. The majority of the Tennouri work was resurvey and wall detailing which will allow us to start working on the complex closure problems expected with the New Maze area between Tennouri and Jurgen's Leap passages A map showing about 10 miles of Fitton Cave surveys was prepared for a paper about the history of the cave and illustrates some of the survey in progress in the cave.

A surface stream enters the cave just uphill from the Bat Cave entrance and reappears in the cave as a small waterfall. This stream has downcut the floor of the Bat Cave passage and is seen to meander under the older, upper levels of the passage. This stream continues south past the Round Room to the T-Room where the Bat Passage connects with the East Passage. At this point the stream turns to the east and continues it's meandering about 50 feet under the larger trunk of the East Passage. The stream is joined by other, smaller, sources of water at the T-Room and midway towards the Out Room. Additional amounts of water join the main stream from the New Maze and the stream disappears after reaching the Grand Central area just before the Millipede Passage. The stream reappears in Fitton Spring Cave approximately 2000 feet upstream from the shelter-like entrance just above Cecil Creek, which acts as the base level for many of the caves in this area.

Eastern Operation Field Work

Compiled by Pat Kambesis

Field work at Eastern Operations was productive and varied during 1994. A total of 10 expeditions were fielded from the Maple Springs Research station at Mammoth Cave National Park. Following is a summary of the many activities and projects supported at Eastern Operations during the year.

Archeology

An archeological trip was fielded to Lee Cave to search for paleofeces in support of Patty Jo Watson's dating project. Several previously known specimens were successfully located as was also one apparently unrecorded deposit. This party also noted that Lee Cave is a probable gray bat site: there was a fresh guano pile at one point, and in the entrance area, bats hibernating singly and in loose clusters were observed.

Phil DiBlasi led a surface archeology trip to Bells Tavern in Park City. The site consists of a large ruin, a ruined icehouse, a scatter of historic material, a quarry, a cemetery and a cave. Phil discussed the significance of the site with the town mayor (the tavern was a key staging post for trips to Mammoth Cave) and was invited to address the city council on desirability of maintaining the site as an interpretive park.

In Main Cave, a reconnaissance group checked to evaluate the extent and quality of prehistoric archeological materials in that section. The fine sediments here are predominately yellow/orange sands and silts of fluvial origin that appear to be extensively dug. The walls at least as far as Symmes Pit show extensive prehistoric gypsum mining. An odd feature was noticed in the fine sediment along the trail, where there are round puffy masses of loose sediment 10-15 cm in diameter. Large numbers of selenite needles occur in these masses. They apparently form rapidly, since one circle disrupted a very recent boot print.

Armed with a federal antiquities permit, George Crothers went to Lee Cave's Marshall Avenue to collect cane for radiometric dating and paleofecal material for analysis. The human paleofeces deposit turned out, on closer examination to be portions of a mat of bat guano. Another paleontology crew went to look at the potential of Rafinesque Hall and Audubon Avenue. The soil borrow pits between Bunker Hill and the Mushroom Beds expose more than four meters of sediments which were examined for bones, etc. The sediments can be divided into two units. The lower four meters consist of laminated silts that appear to be relatively old waterlain sediments. One bat bone was observed near the top of this unit. The upper unit is 10-20 cm thick and consists of a mix of silts, cobbles, and charcoal; it seems to have been extensively modified by human activity. Two possible textile fragments were seen in the cultural horizon.

Biology

Larry Mallory returned with colleague James Bigelow to Larry's microbiological study sites in Olivia's Dome and Katherine's Dome. They inoculated sterile agar plates with water from small drip pits in the domes, and placed glass and limestone slides in water-saturated sediment at both sites. Larry is interested in finding additional damp sites with minimal traffic.

Mammoth Cave Cartography Program

Throughout the year, survey teams continued to work at improving and refining survey data, sketches and information for cave passages in the Mammoth Cave System including areas in Mammoth Cave Ridge, Flint Ridge (Salts, Pohl Avenue, Unknown, Cocklebur), Proctor Cave and the Logsdon River. Other caves within the Park that saw activity were Ganter, Buffalo Creek and a number of smaller caves. CRF also provided field support for Hidden River Cave, Vinegar Ridge and Roppel Cave.

Ecomonitoring

A team was fielded to support the Poulson/NPS long-term entrance-monitoring program. A detailed survey was done of the first 200 feet of the Frozen Niagara Entrance as far as the Rainbow Dome.

A team also worked on making a detailed sketch of the entrance area of Great Onyx Cave for the NPS biomonitoring project. The party concluded that the sink normally pointed out as the collapsed original entrance does not correspond to any cave feature, and that the real historic entrance is a much less obvious small hole. This will have practical implications, since NPS plans to open the old entrance sufficiently for invertebrate access before placing a hermetically sealed gate on the present entrance.

Geology

A geology crew went to the area near P. Strange Falls in Logsdon River to do an initial reconnaissance for a study of large burrow chert structures which is being planned by Tammy Eifert and Michelle Warren, two Southern Missouri State University geology students. CRF assigned escorts with vertical experience to assist Eifert and Warren. The objective of that trip was to test the possibility of mapping the main area of chert by using photomosaic techniques. Test shots were successful and photodocumentation by overlapping one square foot areas was commenced. In addition to photomosaic work, a stratigraphic section of the research area was done to assess the depositional environment of the burrows. Samples were collected for thin sections.

Paul Rubin conducted a reconnaissance for sediments around the Forks of the Cave at the west end of Kentucky Avenue. He believes that flowstone deposits here may be of a similar age and formed under the same conditions as deposits in Kaemper Avenue. Rubin continued collecting data for stratigraphic studies in the area.

A crew was fielded near Gothic Avenue in the Historic Section of Mammoth to see if index fossils can be found and used to delineate the bedrock stratigraphy. They were able to find the lower Girken index fossils: *Talarocrinus* (crinoid) and *Campophylum gasperense* (coral) very close to the trail in several areas, but had difficulty finding any of the Ste. Genevieve index fossils except for a few fragmentary remains. This is unusual since Ste. Genevieve fossils are noted in abundance in other parts of the system. The lack of fossils is possibly due to the abnormal thinness of the Ste. Genevieve in this area, as noted by Palmer in 1981.

Signature Documentation

A historic signature crew worked for two days in Great Relief Hall. Some of the unusual graffiti included the Luther Ewing String Band, and some Chinese writing. Historic signatures were recorded during two trips to the Great Relief/River Hall area. Notable signature clusters included the 85th Regiment Band, College of the Ozarks, and ROTC Co. F, Camp Knox, KY (1921). The River Hall area is now complete and the survey will move into Sparks Avenue.

Signature documentation crews also worked in El Ghor. These were the first trips into this area, which has a generally lower signature density than those along the Historic tour routes. Several "old friends" from Pensacola Avenue were located among the El Ghor clusters. Overlaps such as this will enable Larry Pursell to develop a better picture of the routes and timescale of trips during the earliest days of visitation to the far side of Echo River. A quick reconnaissance also turned up a "Jessie James 1870" inscription, which will require further scrutiny. A trip to Sparks Avenue found a few historic signatures but most were of mid-seventies self-guided tour vintage.

Teams went to Silliman Avenue and to Morrison Avenue. Signature collection in the Echo River area was complicated by the presence of mud. An interesting find was "0. Strona 1835" near the river. Larry Purcell notes that "the date in the cave does not support the commonly accepted time line for discovery and development within Mammoth Cave."

Historic signatures were collected from the bottom of Mammoth Dome to the Audubon Avenue end of Little Bat Avenue, an area heavily impacted by graffiti of the 1960's and 1970's. This trip also included a feasibility study for a possible project to record historic artifacts along the Historic area tour routes.

Small Caves Inventory work at Deer Lick Cave, Mammoth Cave National Park. Photo by Rick Toomey

A Historic photography crew took two trips to Gratz Avenue to photograph names, drawings and other artifacts. Items recorded included a couple of cartoons (from the 1920-30's), a digging stick, and paleofeces. It was noted that the signature "General Jackson" was observed and photographed numerous times, but while looking closely, they found some tiny drawings, (a cartoon and an abstract). Another photography trip went to Upper Salts near Mummy Valley to photograph an elegant drawing of a schooner and the prehistoric drawings.

Data collection at Silliman's Avenue between the high water mark and Echo River was hampered by a light coating of mud on signatures which lie below the high water level. The area is not especially rich in data, but by observing where the signatures are clustered it is possible to estimate where the trips used to stop in the late 1800's and early 1900's. One find was a cluster of signatures from a large party from Covington, Kentucky dated 1865.

Paleontology

A preliminary reconnaissance was conducted for paleontological bat guano between Waldach Dome and Chief City. In 1959, Davis had identified Mexican freetail bat remains in guano deposits in Chief City. Paleontological bat guano deposits were exposed adjacent to and above the tourist trail in several areas. In fact, guano is eroding out onto the edge of the trail and were more extensive than originally described. They are generally limited to protected areas, such as under large rock fall blocks and are not very extensive. Bat bone was exposed in the guano in several places. This material is quite susceptible to impact by tour activities, but on the positive side, it could be used in tour interpretation.

Two more significant bat bone containing deposits were found at Lookout Mountain. Much of the material appeared to represent pipistrelle remains. Along the wall there is an extensive, thick (15-cm) guano deposit. The ceiling above is stained from bat use. One skull in the guano was identified as possibly *Myotis sodalis* (Indiana bat)—this would correlate century accounts which often mention the huge numbers of clustered bats (presumably *M. sodalis*) to be found in the winter in Audubon Avenue, earlier known as Big Bat Avenue. A mummified bat in Gothic Avenue was identified as a red bat (*Lasiunts borealis*). This is not a cave dwelling species. Backslider Alley was examined and two bone deposits were found.

Guadalupe Escarpment Operation Area Report

Pat Helton

Carlsbad Caverns

The Carlsbad Cavern survey is unofficially at 30.8 miles which is amazing when compared to the 19.6 mile total we had in September 1991. A new, detailed set of survey standards was put into effect in 1994. These new standards increase the responsibilities for all members of the survey party and increase the required skill levels of CRF joint venturers's for participation. The results to date are encouraging with sketches and survey data more descriptive and accurate. Loop closure error has already been reduced over 50%. Cavers, scientists, and resource managers now request cave maps with much more information and detail. Efforts are now beginning to redraft the Cavern maps to fulfill those needs. This will be a massive but not impossible undertaking. The results should be exciting, Ron Lipinski has developed a 3-D rotation map of Carlsbad Cavern that has already proven useful in highlighting new discovery potential. We are now in the process of developing solid 3 - D modeling of the Cavern and other backcountry caves. These efforts are bringing CRF survey and mapping up to a new level of expertise and professionalism.

Spider Cave

Spider Cave is located to the west of Carlsbad Cavern and south of Lechuguilla Cave. Until recently, cavers assumed that Spider was pushed to its survey limits at approximately 8300 feet. CRF JV Richard Knapp has been managing further exploration and survey in this cave and is nearing the 20,000-foot mark with much more to be done. This cave often exhibits tremendous airflow indicating far more passage exists than known at this time. In addition to the exploration and survey, geological inventories are revealing new mineralogy discoveries that may have an impact on current theories of speleogenesis in this area.

Dry Cave Project

CRF recently reopened the exploration and survey in Dry Cave. The Carlsbad District of the Bureau of Land Management manages Dry Cave. Work in Dry Cave in the 1960's and 1970's pushed and surveyed approximately 50,000 feet of passages in this complex maze cave. In the first few trips into Dry, approximately 4,000 feet of new, unsurveyed passage near the entrance area was pushed and mapped. This is a long-term project that should culminate in over 100,000 feet

of cave when completed. Dry Cave was closed for many years so that significant paleontological discoveries could be excavated and studied. The cave remains closed to the general caving public. Because of this long-term closure, a baseline biological inventory was conducted under the direction of JV, Saul Cross prior to cavers reentering the cave.

Fort Stanton Cave

Fort Stanton Cave is located in the Roswell, New Mexico district of the Bureau of Land Management. Under the direction of CRF's John and Gavin Corcoran, CRF is involved in a precision survey of this historically significant cave. The current survey is nearing the nine-mile mark. In addition to the exploration and survey, CRF is cooperating with BLM and other groups in restoration work in this cave. CRF JV, Randy Cabeen is working with BLM in setting up a security system to help protect this often-vandalized cave.

Lincoln National Forest Project

Under the direction of CRF Member, Dick Venters, CRF is conducting exploration, ridgewalking, and survey in this new-to-caving area west of Roswell, New Mexico. The area is at high elevation and is marked with big, unexplored limestone sinks and blowholes. Significant new caves have been discovered and mapped. Much more work remains to be done, and many more years of good, virgin caving remain on this project. CRF conducts a week long camp in October on this project.

Carlsbad Caverns Restoration Field Camp

CRF holds a week long restoration camp at the Cavern. Under the direction of Dave and Sue Ecklund, thousands of volunteer hours have been donated and hundreds of tons of rock and rubbish have been removed from some of the more historic areas of Carlsbad Cavern. For the last few years, work has concentrated on the old lunchroom area that was leveled with dirt and rock fill years ago. Restoration has revealed many rimstones, popcorn and other beautiful formations. Along with the noticeable restoration, the restoration crews have uncovered several historically significant artifacts.

Lava Beds Operation Area

Janet Sowers

There are currently over 300 known lava tubes at Lava Beds National Monument. Towards the effort of gaining baseline data for the Monument's lava tube resources, Lava Beds National Monument and CRF have entered into a Challenge Cost-Share partnership.

This work at Lava Beds is coordinated by Janet Sowers and Bill Devereaux and projects are aimed at developing a cave management database for the Monument. Activities include: preliminary reconnaissance and survey of newly discovered tubes; resource inventory and detailed survey of known tubes; obtaining high-precision GPS location of entrances; cleanup and restoration of "commercial" tubes; measurement of ice levels inside tubes; bat counts

In 1994, thanks to special funding, the Monument was able to hire a seasonal to begin reconnaissance and geo-referencing of caves. Through those efforts and the continuing work by CRF, over 20 new caves were discovered and an additional 3-4 miles of passage was added to the Monument's inventory.

Missouri Operation Area Report

Scott House

CRF continues to do field work on lands of several different agencies. The greatest proportion of this work was done on the Mark Twain National Forest but a fair amount of field work was done elsewhere as well.

Missouri Department of Conservation

Missouri Department of Conservation (MDC) lands in Missouri consist of state forests, conservation areas, river accesses, wildlife refuges, and natural areas. Many of these have caves and other karst features within them. CRF work in 1994, funded by a MDC grant, concentrated on two continuing projects:

1. the continuing survey of Powder Mill Creek Cave,
2. the survey and inventory of caves on new lands acquired by the Department in the southeast Missouri Ozarks.

Survey trips in Powder Mill Cave concentrated on the Hell Hole Series, the major side passage of the cave. Several trips surveyed over 1000 feet in the area; one other trip surveyed leads off of Windy Crawl, another sizable side passage area.

Fieldwork in the Pioneer Forest. Photo by Scott House

The new lands acquired by the Department consists, in part, of approximately 80,000 acres near the Current River. CRF continues to inventory and map caves on this tract. One trip to the Pipestem Hollow area finished the survey of Woodrat Cave; this was the last cave to be surveyed in this beautiful drainage off of the Jacks Fork River. Two other caves were surveyed near Allens Branch Cave, also off of the Jacks Fork. Although not a Department cave, one trip was taken to Allens Branch to remove some exploration debris left by earlier explorers.

Two other trips were taken to the Meramec River basin. The purpose of one was to assess the effects of visitation on a (previously) pristine cave while the other trip collected springtails from a known site in order to clear up an undescribed species question.

Ozark National Scenic Riverways

The Ozark National Scenic Riverways consists of about 70,000 acres along the Current and Jacks Fork Rivers. Approximately 290 caves and many springs lie within the park boundaries. One float trip this year netted several new caves (which were mapped) along the stretch from Owls Bend to Van Buren. One of these, Beal Arch Cave, was described in a book some years ago but had never been located. It consisted of two entrances leading into a large room with short side passages off of the room.

At the end of the year CRF and the Riverways were putting together a proposal to update and organize the park's cave files; an organized file system is necessary to fully implement the 1988 Cave Management Plan.

Mark Twain National Forest

Most of CRF's activities on the Mark Twain have been on the Eleven Point District

where we have been engaged in bioinventory and surveying projects for several years. This large district lies along the Eleven Point National Scenic River and includes the Irish Wilderness, an area of 17,000 acres. Two trips were taken to Blue Hole Cave where over 1000 feet has been mapped in this gray bat cave. One cave received a follow-up inventory trip to see if it harbored endangered bats (it didn't). However, another cave along the river was inventoried and was established to be a gray bat colony cave; unfortunately this cave will have to have a new map - the old one (non-CRF) is not of sufficient quality to be useful. A two-day float trip down the Eleven Point saw several caves mapped and/or inventoried.

A trip into the Irish Wilderness inventoried several small caves that had already been mapped. Another trip to map and inventory a sinkhole cave failed because the cave was essentially full of water; however, a nearby (and similar) cave was enterable and was inventoried.

Elsewhere on the Forest, two trips were taken to Davy Crockett Cave in the Willow Springs District. The cave continues with a length, at present, of 1600 ft.

Pioneer Forest

Pioneer Forest is a privately-owned forest which consists of about 180,000 acres, virtually all of which is in the "scenic rivers" region of southeast Missouri. Pioneer Forest only has a few full-time employees and CRF is helping out with the survey and inventory of caves on Pioneer Lands. The area worked on at present is along Leatherwood Creek, a canyonesque area off of the Jacks Fork River. A survey and inventory of Big Cave was begun and was just as quickly stopped when it was discovered that the cave is not only a gray bat summer colony but also a small hibernaculum for grays. A smaller cave nearby was surveyed completely. Another trip along the creek with three crews resulted in six mapped and eight inventoried caves. Although none of these caves are particularly lengthy, they are very interesting and frequently have very large and beautiful entrances. The biota is also quite diverse in these caves. Finally, the area may prove to be of archaeological interest as well.

Sequoia and Kings Canyon/Mineral King Operation Area

John C. Tinsley

The year 1994 was the first full year of dividing our efforts among three projects areas: Redwood Canyon, White Chief Basin (Mineral King), and Panorama Basin (Mineral King). Productive activities in Redwood Canyon and in the Mineral King area are coordinated by John Tinsley and Glen Malliet respectively. We consider ourselves fortunate to enjoying every way supportive and positive working relationships with the NPS at SEKI. The King's River District Ranger, Randy Coffman, was away much of the summer on a Himalayan climbing expedition. Since his return, he has been helping us resolve a recurring problem with disturbances of our field station and is taking an active interest in helping us to improve our wilderness-friendly use of the Redwood Canyon area. Joel Despain has made it through all NPS filters and as of October is a permanent hire as SEKI's cave management specialist. We look forward to a continuing our productive working relationship with Randy, Joel, and the rest of the SEKI management and staff as we seek to expand our involvement into other cave areas of the Parks in the years ahead.

This year featured 6 expeditions to Redwood Canyon, the first and last expeditions (May and November) are dedicated to hydrological studies and maintenance of the logging equipment. In late summer, when the water is low and the mountain air is warm, an early August expedition, the Labor Day expedition, and a late September expedition were dedicated to mapping and inventorying caves in two areas of Mineral King Valley.

Redwood Canyon Karst Area

Active research projects include Cartography (Peter Bosted), Hydrology (Jack Hess and Mike Spiess), Sedimentology (John Tinsley), Communications (Mike Bettencourt), and anemometer development (Richard Fellows). These are summarized below.

Cartography

Peter Bosted reports that survey parties in Redwood Canyon gained 1840 feet, 120 of it in Mays Cave in 20 stations and the balance in Lilburn Cave. More than 1100 feet was surveyed in a new area, the Penthouse (so named because it is above the Attic and the Attic Attic). The surveyed length of Lilburn Cave now stands at 14.4 miles.

Hydrology

It was a dry winter again, and the hydrological studies continued. Jack Hess's student, Linda Urzendowski, completed her MS study of Big Spring last year.

Sedimentology

The low runoff year meant that sedimentological studies basically got to take the year off, in terms of charting any significant changes in the distribution of sediment along the active streams of lower Lilburn Cave. Static sediment samplers were relocated from the Z-Room area to the Lake Room and White Rapids areas late in 1993, but did not even get their feet wet in 1993-4's dry winter. Three new sinkholes were discovered and were mapped and added to the inventory of surface karst features in Redwood Canyon.

Communications

The old telephone line has deteriorated over the past 23 years to the point that it is no longer reliable and often shorts out spontaneously. Mike Bettencourt has undertaken the stringing of a new data and communications line, which now reaches from Meyer Entrance to Crevice Way above South Seas Junction. Expeditions in May and July 4 and October succeeded in stringing 3000 feet of line and connecting up the 3 segments into a continuous system. We should complete the job next year, which will usher in a new era in continuous monitoring of karst processes in Lilburn Cave.

Anemometer

Richard Fellows has built a prototype anemometer and it has been tested and pronounced more or less cave-proof. Now that the hardware exists, we look forward to collecting some useful data to characterize the various winds that blow through the labyrinths of Lilburn Cave.

Cave Restoration

Bill Frantz has spearheaded efforts to erase the adverse impact of cavers past and present on the well-decorated areas of Lilburn Cave. This year, the Glacier, the Jefferson Memorial, and the Great White Pillar received cleaning and refurbishing. These turn out to be quite popular trips. One gets to go to pretty areas and make them yet prettier. The trips into the cave are rather arduous, owing to substantial loads of water which are packed using surplus 5-liter aluminized mylar wine bags. The wine bags generally stop for awhile at the Field Station until they are relieved of their initial cargo.

In 1993, CRF expanded its Sequoia-Kings Canyon operations beyond Redwood Canyon. One new project will inventory and map the caves of Mineral King. There are more than 20 caves in the Mineral King area at elevations ranging from 8,500-11,000 feet. Not all of the caves are fully explored. Mineral King, once coveted by Walt Disney for a ski resort, was transferred to Sequoia-Kings Canyon National Park from the Sierra National Forest in the Omnibus Wilderness bill under the Carter Administration.

Mineral King Valley Area

The 1994 CRF Mineral King field season involved 19 participants on four expeditions held August through October. These included trips to the Panorama basin/ Franklin Lakes drainage, White Chief Canyon, and the sinkholes below Eagle Lake. While progress was made on inventory and hydrology, the main focus was cartography. Developing accurate maps for use as base references for further studies is a priority. Over one-

half mile of cave passage was mapped and over 4,300 feet of surface survey was completed.

Cartography: Four trips continued the remapping of the Cirque/House Cave "System". The existing (Hedlund) map of the caves was proven, as expected to lack both geometric accuracy and significant detail. Field checks verified the south (upstream) portion of the cave turns sharply east, as plotted on the 1993 preliminary map and contrary to the linear trend shown on the Hedlund map. Over 650 feet of passage was mapped in Cirque Cave during 1994, including completion of the overlying House Cave portion of the system.

The traverse of the main Cirque Cave passage was continued from the Green Pool Room to the Sink Entrance, and beyond to a narrow crawlway and pit leading to the Lake Room. Survey then continued into an unmapped room southwest of the Lake Room. This room, located past an upclimb through breakdown, contains anastomoses, rillen, and organic-rich sediment. Additionally, a survey was made into the Terrace Room (below the Sand Room) to a pool with a passage trending toward the Lake Room. Finally, side passages in the upstream portion of the cave were mapped including the Pika Passage, an interesting joint-controlled tube trending southeast from the primary passage. Many leads remain to be checked and surveyed, including the two large rooms in the cave, the Lake Room and Mud Room. The Mud Room is large, with curiously little mud. In the Panorama area, a trip into Bathing Cave completed that survey. Four trips into what were separate caves, Panorama and Sink, resulted in the mapping of an estimated 2,000 feet of passage, and the finding of an impressive new connection between the caves.

A late September, unscheduled expedition of four people began mapping an area of rooms and large walking-high passage found during the previous expedition. After 12 stations they pushed a lead into walking passage trending toward Panorama Cave for an additional 25 stations before stopping for the night. The following day the team surveyed into Sink Cave from a new entrance and continued the down-karst survey to a decorated side passage and waterfall, recognized as the back of Panorama Cave. The survey then continued to previously mapped portions of Panorama Cave.

During the three-day period four cavers set 110 stations surveying more than 1,600 feet of passage. The Panorama/Sink system currently totals 3,000 feet with many leads remaining. A surface traverse of 4,300 feet connected the entrance of Panorama Cave to Alto Cave, passing over several sinkholes including the insurgences to Sink Cave. It is hoped that this traverse will eventually be tied into the White Chief Canyon traverse to provide an accurate baseline delineating the two areas.

Karst Inventory: The geologic inventory of Panorama Cave was completed and additional inventory was made in Sink and Panorama Caves. An informal inventory was made during the mapping of Cirque Cave. The diverse conditions in the cave deserve a thorough inventory of geologic and biological features, as abundant insect life is present.

Hydrology: Quantitative observations were made at several sites including Eagle Lake sinks, the insurgences from Eagle Lake drainage which apparently resurges nearly one-half mile away at Tufa Spring. Pool levels were measured in Cirque Cave to evaluate the hydraulic gradient between the Green Pool and the Lake Room pool. Electrical conductivity and pH measurements were made in the White Chief drainage between the inflow to Cirque Cave and the stream adjacent to camp, about 800 feet lower in elevation. Measurements indicate that active corrosion is occurring in Cirque Cave.

Archeology

CRF Archeological Project, 1994

Patty Jo Watson

CRF Archeological Project personnel were involved in three research endeavors over the past year.

(1) Paleofecal Research Project—Paleoethnobotanists Kristen Gremillion (Ohio State University) and Kristin Sobolik (University of Maine) completed their analyses of macro- and microbotanical remains in the human paleofecal specimens (all approximately 2500 years old) collected from Salts Cave Mammoth Cave in 1992 (see CRF Archeological Project summaries in the 1992 and 1993 Annual Reports). They will present their results in a jointly authored paper at the SAA annual meeting in Minneapolis, MN, on May 5, 1995.

Patricia Whitten (Emory University) has also completed her assays of the hormonal biochemistry remaining in these paleofecal specimens: all but one were apparently deposited by adult males; the exception may have left by a woman (or, perhaps, by a prepubertal adolescent). Whitten will describe and discuss her results in a paper to be presented at the spring 1995 annual meeting of the American Association for Physical Anthropology.

(2) Hourglass Cave Project—Subsequent to the initial discovery in 1988 of human skeletal remains approximately 8,000 years old in a high-altitude cave located in the southern Rockies, a research project was initiated in collaboration with the USDA Forest service. The osteological materials were photographed, X-rayed, and cast; and various analyses were taken including DNA sequencing. The Hourglass man was between 40 and 45 when he died in the cave, and was a strong robust individual. He was probably familiar with the locale and the cave entrance and may also have been inside the cave previously. Hourglass Cave has now been gated, and the ancient caver's remains have been repatriated in accord with the Native American Graves Protection and Repatriation Act of 1990. Kenny Frost, a member of the Southern Ute tribe and Native American liaison to the Forest Service, supervised the repatriation procedures. Frost and Cyndi Mosch presented a paper on the Hourglass Cave study at the American Anthropological Association meetings in Atlanta, Georgia, on December 1, 1995- Several analyses — including that of the well-preserved DNA — are continuing.

(3) Shell Mound Archaeological Project—This long-term investigation in the Big Bend region of the middle Green River some 40 miles west of Mammoth Cave National Park is an outgrowth of 1960s-1970s research in Salts Cave. Summaries may be found in CRF Annual Reports of the information about the Shell Mound Project, which is co-directed by William Marquardt (Florida Natural History Museum) and Patty Jo Watson (Washington University). In May 1994, Christine Hensley completed her dissertation (Department of Anthropology, Washington University) on non-shell midden sites in the Big Bend area (Archaic Settlement Systems in the Middle Green River Region, (Kentucky). In June and July 1994, George Crothers (Ph.D., candidate in Anthropology at Washington University) — as part of his dissertation research — carried out several weeks of excavation at a large shell mound in the Big Bend of Green River: 15Bt6, the DeWeese site. Crothers was also supervising the Earthwatch Project in Mammoth Cave.

CRF Archeological Project II

George Crothers

In addition to the CRF Archaeological Project directed by Patty Jo Watson, CRF personnel were involved in three other research projects over the past year.

(1) National Park Service/Earthwatch Cultural Resource Survey of Mammoth Cave — JV-Archeologist, George Crothers and Mammoth Cave National Park, Cultural Resource Specialist, Robert Ward, completed the second year of a three year pilot project to inventory and map cultural resources along the tour route in "Main Cave". This project was begun under the direction of Mary Kennedy, Patty Jo Watson, and Bob Ward in 1993 (see Kennedy 1993), and has now been passed down to George Crothers. Charles Swedlund is the project photographer. Other assistants participating in the project include archaeologists, Christine Hensley and Chet Cain, and computer specialist, Daran Neff.

The goals of the project are to locate, describe, and map all historic and prehistoric artifacts, features, and structures remaining within Main Cave, excluding the ubiquitous prehistoric torch debris (cane, weed stalks, and sticks) and the numerous historic cloth torch "twists" (those flaming, coal oil-soaked, rag torches that are now banned from the cave tours). The prehistoric and historic torch material will be quantified by systematic sampling to indicate its distribution through the passage. This exhaustive and labor intensive inventory has three purposes. First, it will provide the Park Service with a provenienced inventory of all cultural materials that they may use to monitor impact to the resource from tours, after hours trips, and cartography and scientific expeditions. Second, the inventory may be used as a database for designing future research projects or to serve other researchers in their endeavors. Third, the distribution of material will be analyzed to reveal patterns of cave use and associations among certain artifact classes that are not apparent (or at least not empirically verified) from previous, less intensive surveys.

The project has been a successful marriage between management concerns and research objectives. The Park will have a better archaeological inventory for monitoring and designing cave use policies, and archaeologists will have a set of data that is the most comprehensive and detailed record ever attempted on this scale for a deep cave site. After two years the result are encouraging; over 3000 linear feet of cave passage have been surveyed, and over 1800 artifact and feature locations mapped and recorded. The success of the project is due to the highly motivated Earthwatch volunteers who sign onto the expedition, and the hard work of the Science and Resources Management Division of the NPS who provide facilities and logistical support and give freely of their time to provide talks or evening cave trips for the Earthwatch volunteers.

Four expeditions were mounted in 1994, two in July and two in October; teams consisted of six to ten-members. Each expedition ran for ten days. Participants have included school teachers, high school students, retirees, business and corporate types, and engineers and professionals. A few have been cavers or have archaeological experience, but most did not. Four volunteers have come from overseas (Australia and England). The project was initially approved for three years, but we hope to extend the project for an additional two years (1996-97) in order to complete the survey from entrance to entrance.

(2) Lee Cave Paleofecal Quest and Redating Project — As an adjunct to the Paleofecal Research Project (see Watson this report) an attempt was made to locate possible paleofeces in Lee Cave, Joppa Ridge. The initial archaeological survey of Lee Cave by Patty Jo Watson (Freeman et al. 1973) identified some organic material that was thought to be feces, but no conclusion was made whether it was of human origin. Because Lee Cave has provided the earliest radiocarbon dated evidence of prehistoric exploration in the Mammoth Cave area (4100 + 65 years B.P.; Freeman et al. 1973:125) it was considered to be the best candidate for contain-

ing isolated Archaic Period (ca. 5000-3000 B.P.) fecal material, important to the study of dietary change in the Eastern Woodlands at this time period immediately preceding the extensive gypsum mining in Mammoth and Salts caves.

Richard Zopf, George Crothers, and Naoko Yokoyama-Crothers made a successful initial visit to Lee Cave during the Winter Expedition (March 19) to relocate the potential fecal specimens, and returned during the Thanksgiving Expedition, armed with a Federal Antiquities permit and a 30x portable microscope, to examine these deposits in greater detail and obtain additional torch material for radiocarbon dating. As we suspected, the organic material appeared to be clumps of degraded bat guano, that had fortuitously broken into human-sized and shaped fecal deposits. Identification of the degraded bat guano was later confirmed by Rick Toomey, paleontologist at the Illinois State Museum.

Two radiocarbon samples were collected from Marshall Ave. to compliment the single date obtained in the early 1970s. Sample 1 was collected near K28, consisting of two fragments of cane (*Arundinaria* sp.), and Sample 2 was collected near K60, also consisting of two cane fragments. These samples have been submitted to Beta Analytic, Inc., Miami, Florida, for radiocarbon dating.

(3) Shell Mound Archaeological Project excavations at the DeWeese Site, Butler County, Kentucky — Closely related to the CRF Archaeological Project has been the investigation of Archaic Period shell middens to the west of Mammoth Cave. The DeWeese site (15BT6) is one of three large shell mounds in the Big Bend of the Green River (previously the Carlston Annis site (15BT5) had been the focus of most of the SMAP work). A small excavation project was carried out by George Crothers and assisted by Naoko Yokoyama-Crothers and other students from Washington University, to obtain subsistence remains that will be comparable to the more extensive excavations at Carlston Annis.

This work was conducted in June and early July, excavating a 1 by 2 meter unit from the surface to the base of the midden at 2.1 meters below the surface. All excavated soil was waterscreened in the field through a graded series of screens to recover artifacts and subsistence remains. A flotation sample was collected for each 10 cm level and will be processed shortly. Analysis of this material, excavations at a third shell midden site (15Bt11) in the spring of 1995, and additional analysis of Carlston Annis site material will comprise the core data for Crothers' dissertation project.

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Biological Sciences

Figure 1. Victor and James Lewis in the entrance to Wool's Whim (Circle) Cave, Crosley State Fish & Wildlife Area. Besides its significance as a bat hibernaculum and a diverse terrestrial community, the cave entrance looks out on a high quality old growth deciduous forest community growing adjacent to the Muscatatuck River.

Inventory of the Cave Animals of the Crosley State Fish & Wildlife Area

Julian J. Lewis, Ph.D.

As part of an ongoing survey of the animals inhabiting Indiana's caves (Lewis 1983, 1993, 1994, 1995), an inventory of the cavernicoles of the Crosley State Fish and Wildlife Area, Jennings County, Indiana was conducted in 1994. The Crosley Wildlife Area is found about three miles south of the town of North Vernon. The property is managed primarily for the production and harvest of game species by hunters and fishermen. To this end ponds, access roads, trails, parking lots, and a shooting range have been established on the wildlife area.

The Crosley Wildlife Area occurs in the physiographic landform called the Muscatatuck Regional Slope. Rocks of Ordovician, Devonian or Silurian age comprise the bedrock of the region. In much of the Muscatatuck Regional Slope slightly dipping strata of limestone and dolomite are exposed at the surface. To the west lie the Scottsburg Lowland, the Norman Upland and the Mississippian rocks of Indiana's other karst region, the Mitchell Plain and Crawford Upland (Powell, 1961).

Streams flowing across the Muscatatuck Regional Slope characteristically cut deep narrow channels on their routes to the Ohio River or East Fork White River. At Crosley the Muscatatuck River flows at an elevation of about 580-600 feet with the adjacent hills rising to around 730 feet in elevation. The flat, glaciated plains of Jennings County have been dissected by the river to create scenic wooded valleys, shallow canyons, and gently rolling hills in the adjacent uplands. Not surprisingly caves, springs, sinkholes, and other karst features are common in the limestone terrain at Crosley (Figure 1). Nearly every valley in the wildlife area contains one or more caves. Compared to the caves of the Mitchell Plain, caves of the southeastern Indiana karst are usually shorter and have simpler plans. The cave entrances are typically associated with streams (many are spring entrances) and multiple entrances are common due to the relatively shallow relief. The majority of Crosley caves are short, although four have been listed on Indiana's list of long caves as having over 1,000 feet of passages (Fee, 1994). These are Biehle, Crosley I, Wool's Whim, and Brown's Farm caves. The longest cave in Jennings County is Meek Cave, at 2,067 feet ranking 127th among Indiana's caves in length. The passages of Crosley caves range from the walking height canyons of Biehle Cave to the miserable stream crawlways of Crosley I or Brown's Farm caves.

During the 1994 field work, 21 caves at the Crosley State Fish and Wildlife Area, in Jennings County Indiana, were entered. Three other Jennings County caves were also visited and sampled for fauna. A total of 126 species, including 105 invertebrates and 21 vertebrates, were found during the field work, in the literature, or in the unpublished records of other zoologists. Fourteen species were found that were felt to be troglobitic, including two amphipods (*Crangonyx packardi*, *Crangonyx* sp.), two aquatic isopods (*Caecidotea rotunda*, *Caecidotea stygia*), two spiders (*Phanetta subterranea*, *Porhomma cavernicola*) one millipede (*Trichopetalum uncum*), five collembolans (*Pseudosinella* sp., *Sinella alata*, *Sinella cavernarum*, *Sinella* sp., *Onychiurus* sp.) one beetle (*Pseudanophthalmus chthonius*), and one fly (*Spelobia tenebrarum*). Four undescribed species (new to science) of troglobites were found at Crosley: the *Crangonyx* amphipod and *Pseudosinella*, *Sinella* and *Onychiurus collembola*.

Two new state records (species not previously found in Indiana) were found: the pseudoscorpion *Chthonius virginicus* and the millepede *Pseudopolydesmus collinus*. Three species known from the southcentral Indiana karst, but not previously known from caves in the southeastern karst, were found: the terrestrial *Carychium exile*, and the millipedes *Trichopetalum uncum* and *Conotyla bollmani*. New localities were found for two species of Indiana endemic troglobites that were formerly known from less than five sites: the isopod *Caecidotea rotunda* and the springtail insect *Sinella alata*. A rare, but widespread troglobitic spider, *Porhomma cavernicola, that* had been found in only two other Indiana cave systems was found at Muscatatuck Caverns. One record of a federally endangered species, the Gray Bat *Myotis grisescens*, was included in bat census records provided by Dr. Ralph Kirkpatrick.

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Escape Responses of *Hadenoecus subterraneus* Before and After Feeding

Kurt Lewis Helf

As a preliminary experiment to a larger study of the foraging behavior of the obligate trogloxenic cave 'cricket', *Hadenoecus subterraneus* (*Hs*), the escape responses of adult individuals were tested.

One adaptation to living in the nearly constant high relative humidity (97-99%) range of the hypogean environment is that trogloxenic arthropods display a high integumental permeability (Howarth, 1983). A consequence of this vulnerability to water loss is that *Hs* must forage in the highly variable epigean environment only at night; and only when conditions most closely approximate those of the nearly constant hypogean environment (Studier et al., 1986).

During these nightly forays some *Hs* may be consumed by a suite of nocturnal predators. The primary predator avoidance strategy available to *Hs* lies in using its highly elongated hind appendages to leap away from potential predators. This avoidance strategy consists of several long hops that usually has *Hs* changing the direction of each leap, ostensibly to ensure its escape.

An easy way to distinguish whether *Hs* has been foraging is to examine its abdomen for distention. Their thin, lightly pigmented integument allows the researcher to sometimes distinguish what *Hs* has been feeding on simply by its color (pink coral berries provide a striking example). *Hs* possess an extremely large crop and elastic abdominal integument which enables it to consume as much as 200% of their body weight (Poulson et al., unpublished data). I set out to determine if this sort of 'tanking up' would hamper the leaping abilities of *Hs* when faced with a potential predator.

Twenty adult individual *Hs* were picked from Great Onyx Cave, with individuals being selected according to sex and 'fullness'. Fullness was indicated as the amount of distention present in the abdomen at the time of capture. The category 'full' denotes some amount of distention visible (though nowhere near capacity). The category 'empty' denotes no visible distention, indicating that the individual *Hs* has not foraged in at least 10 days. The experiment began with ten individuals of each sex and five of each fullness class. All assays were performed inside Great Onyx Cave in a passage with a flat wide floor.

A large plastic ring with a fine screen stretched over one side acted as a holding pen. The ring was large enough to accommodate the long antennae of *Hs* so that they might feel relatively "comfortable" in the holding pen. Each *Hs* was allowed a five minute rest period after being transferred from a communal wooden cage to the holding pen to avoid exhaustion of the animal and to allow it to 'calm down' from the stress of being handled.

Following the rest period the holding pen was lifted away and the animal was allowed to freely move about. Its movements were tracked in fifteen second increments for two minutes. At the end of each fifteen second interval the animal's last location was noted and a marker was thrown down at this spot for later measurement. Any hops the animal made were recorded. Both treatments (non-fed and fed) also involved 'goosing' the animals at the start of the second one minute interval. The goose consisted of a rough shove from behind the cricket using a pencil. This goose was designed to simulate a sneak attack by a predator upon the individual *Hs* in order to demonstrate the effects of foraging upon escape response and ability. At the end of the two minute interval the *Hs* was then collected and put back beneath the holding pen. The distances between the markers were then measured. Compass directions of the animals movement were also noted in order to contrast the animals patterns of movement while calm and stressed.

The second assay involved almost the same procedure as above. The animals were allowed to feed (on a mixture of moistened cat food and cereal) for fifteen minutes before the assay began. The individual's fullness after the feeding interval depended upon their fullness category in the first assay and on how long the individual fed. Those *Hs* that were empty before the

Number	Cricket	Non-Fed	Fed
1	Me	1082	648
2	Me	179	376
3	Me	672	362
4	Fe	856	0
5	Fe	487	140
6	Me	517	321
7	Ff	268	218
8	Fe	704	23
9	Mf	539	492
10	Fe	838	130
11	Mf	396	256
12	Mf	798	126
13	Ff	664	254
14	Mf	81	0
15	Ff	0	438
16	Ff	171	482

Table 1. Total distances (cm) traveled by Non-Fed and Fed individual Hs. M-Male, F-Female; f-full, e-empty. Letters indicate pre-fed condition.

feeding period were usually full after the feeding period; those *Hs* that were full before the feeding period were usually designated 'replete' (at or near 200% capacity) afterward.

Total distances traveled before and after feeding were determined and divided into two columns (non-fed and fed) per individual cricket (see Table 1.). Four assays were discarded due to procedural irregularities. Using the statistical package SYSTAT, a t-test for paired comparisons was then performed in order to determine whether the mean of sample differences between the pairs of readings in the two columns was significantly different. The t-test would indicate whether a significant difference existed between the distances traveled by non-fed and fed individuals. As shown by the data given in Table 1, 13 of the assays indicated that the total distances traveled by fed *Hs* was less than that of the cricket when unfed. Three of these assays indicate that individuals 2, 15, and 16 traveled greater distances after they were fed than before.

Despite the small sample size, a paired sample t-test indicated a significant difference between the two columns ($p=.018$), thus disproving the null hypothesis (no difference between the distances traveled by non-fed and fed individuals).

The results of these analyses would seem to indicate that escape responses by *Hs* are hampered by much food intake . Additionally, *Hs* has never been observed in a 'replete' state as a result of natural foraging habits. The animals have been observed at .5 capacity (or 100% body weight), however no experiments have been performed to see whether this state of fullness would affect escape ability (though presumably it would).

A more quantitative approach to the fullness category may be needed, which could be corrected through weighing in future assays. In addition, constant 'goosing' after the 1 min. mark would eliminate any 'safeness' the *Hs* may have felt inside the cave (where the assays took place), obviating the 'within cave' effect on the treatments.

I am indebted to many people: Tom Poulson, Kathy Lavoie and her students, the staff of Mammoth Cave National Park, and the Cave Research Foundation.

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The Evolution of Cuticular Waterproofing Mechanisms During Adaptive Shifts of Endemic Hawaiian Crickets *(Caconemobius)* into Physically Extreme Habitats

Eamonn P. O'Toole

Endemic Hawaiian Crickets of the genus *Caconemobius* have undergone adaptive radiation into habitats differing greatly in water availability, including lava tubes, lava flows, and the rocky intertidal zone. This species group provides a fascinating model for the study of the evolution of water balance maintenance in arthropods, particularly regarding the chemical composition of the epicuticular lipid layer and its effect on cuticular permeability. I have been awarded a 1994 Karst Research Fellowship for research directed toward investigating the microclimate of *Caconemobius* habitats as well as for comparative studies of their water loss rates and epicuticular lipid composition. Analyses of variability and correlation between these characteristics at the individual, population, and species levels will allow for inferences to be made concerning their physiological evolution, particularly in regards to current hypotheses of regressive evolution and speciation.

The initial step of this research is the delineation of differences in cuticular lipid composition between species in different environments. To this end, troglobitic *C. varius* and *C. uuku* were collected from Kazamura lava tube in Mountain View, Hawaii Island. Several lava flow crickets (*C. fori*) were collected within Hawaii Volcanoes National Park (Volcano, Hawaii) using baited traps. Additionally, a few C. *varius* were collected near traps placed inside a small surface cave within the park.

A Legacy funded biological cave survey of the U.S. Army's Pohakaloa Training Area, led by Drs. Francis G. Howarth and Fred D. Stone and administered through the Nature Conservancy of Hawaii, allowed for the collection of troglobitic *Caconemobius* species from a previously unknown cave system which is some distance from known *Caconemobius* habitats, subterranean or epigean. Troglobitic *Caconemobius* species are present but are surprisingly not as common at Pohakaloa as they are in caves at lower elevations.

Continuation of field research and the initiation of laboratory studies will lead to the elucidation of mechanisms of physiological evolution of *Caconemobius* in particular and arthropods in general. Collections at Pohakaloa Training Area and other locations this spring and summer will augment the number of specimens available for subsequent physiological and biochemical analyses.

Baseline Biological Inventory of Caves in Southern Missouri

Mick Sutton

We have completed the fourth year of this extensive cave mapping and bioinventory program, which began as a project to map and inventory caves surrounding a mineral lease area in the Mark Twain National Forest (MTNF) between the Eleven Point and Current Rivers in Oregon and Shannon Counties. Following completion of that first study (Sutton, 1992), the project expanded to cover other caves within the MTNF Eleven Point District. Background on the project is given in the CRF Annual Reports for 1990-1993.

Work also continued on two other mapping and inventory projects in the same general area: on Missouri Department of Conservation (MDC) land, and on the Pioneer Forest, the largest privately owned forest in Missouri. Both of these areas are in Shannon County, within the watershed of the Current River. This attempt to look comprehensively at all known (and some previously unknown) caves in a relatively large area is helping to build a broad overview of the regional cave fauna.

Mark Twain National Forest

Eleven field trips were taken, scattered widely throughout the Eleven Point District. Maps were completed on ten small to medium sized caves, two of them previously unrecorded. Biological inventories were completed for 21 caves and partly completed tot two others. Although many of these caves are small enough to lack a dark zone, some are fairly long. We mapped more than 1000 ft. in Bluehole Cave, with passage continuing into an unexplored area. Mapping in the Bliss Camp System extended its length to 2600+ ft. Although we have probably found the limit of this cave in an extensive breakdown zone, large passage remains to be mapped here. The cave is biologically rich and has showed some interesting variations in the two years we have visited it. In 1993, the river-level passages near the entrance had a large population of spot-handed crayfish, a common surface species. In 1994, following severe winter flooding, the crayfish seem to have disappeared, to be replaced by a population of southern cave fish which had not shown themselves last year. Another aftermath of the winter floods was apparent—several dozen pipistrelles had drowned in the long, wet crouchway near the Outflow Cave entrance. These results are giving a hint of the dynamic aspects of the region's cave ecology. This is likely to prove quite important, especially in areas such as this river-level cave which are subjected to widely varying flow regimes. Another example is furnished in nearby Sand Cave, where a State-sponsored inventory by Gene Gardner in 1986, when the cave was dry, showed little of interest. When reexamined by a CRF crew the cave was in flood, revealing an unsuspected population of cave crayfish.

There was a supplementary winter visit to a cave which had a cold-trap entrance, and hence was a potential Indiana bat site; however, the bats apparently think otherwise. Elsewhere, in two known gray bat summer caves, we ran into small numbers (up to 200) gray bats out of season. This is a phenomenon we've encountered a lot recently. It somewhat throws a wrench into trip scheduling, since with more or less year round occupancy, we are largely limited to September for field work.

An attempt to map a newly reported cave was stymied by the inconvenient fact that the entrance had become a completely flooded spring. We still managed some bioinventory, as a large water snake *(Nerodia sipedon)* objected to our presence and came shooting up out of the flooded entrance fissure in an apparent attempt to drive us off. Panther Cave was another unusual situation, as the entrance is a large sink-in the Ozarks most caves are entered through a resurgence or paleo-resurgence. As a result, the cave is nutrient-enriched with washed-in leaf litter to an extent we rarely see, and is biologically diverse. It also shows another example of population shifts—Gardner (unpublished MTNF report, 1978) had observed Salem cave crayfish in the cave's terminal pool, but no fish. On the CRF visit, this situation was reversed. The cave's fauna also included a genus of gnat (*Cecidomyiidae: Lestremia* sp.) rarely reported from caves. Elsewhere, we have picked up another unusual gnat from a different family (*Mycetophelidae*, but not the common webworm), and a species of "humpbacked fly" (*Phoridae*) apparently known only from Missouri, and not previously reported from caves.

A trip to finish the map of Woodrat Cave completed fieldwork in Pipestem Hollow, which has a dense concentration of mostly small caves. A report on the caves and cave biology of this area is in preparation by Scott House. In addition to our formal MDC bio-inventory, there was a trip to MDC-owned Wet Hollow Cave (Washington County) at the request of collembolan taxonomist Ken Christiansen, to attempt to collect additional specimens of an undescribed springtail. Samples of three species were collected, one of which may be the creature in question.

Pioneer Forest

The remote and beautiful Leatherwood Creek has another unusual concentration of caves, at least one of which (Big Cave) may be fairly long—we failed to find out because, once again, we ran into an off-season concentration of gray bats. This was not a known bat cave, but appears to have a significant summer colony, judging by the quantities of guano. A total of nine caves were mapped and inventoried along Leatherwood Creek.

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Cartography/Resource Inventory

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

Scott House

Within Mammoth Cave National park, there are over 300 small caves, most of which lie south of the Green River; however a large, and 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 vast majority of these caves. A cooperative project between the Cave Research Foundation and the National Park Service seeks to establish an inventory system that will produce usable data on these caves on an ongoing basis. An initial study area, selected by the park, consists of several drainage basins on the north side of the Green River. Included within this area are at least 5 caves longer than 1000 feet and approximately 40 other locations of smaller caves. Previous work in the study area includes 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 areas scheduled for a three year project. The project has two main 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 and/or analyzed 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 is to be evaluated and tested. The methodology is to be refined over the course of the first year. One larger and approximately 12 smaller caves were selected for developing the system the first year.

Because of an immediate park need for management information, the process got off to rather a quick start by inventorying Running Branch Cave, a mile-long cave. This was accomplished by sending experienced specialists to the cave on six trips. The immediate result was a narrative inventory report delivered to the park. This is a different product from what will be done for the rest of the project. All other inventory information will be put into database format with relatively few written reports. Additionally, surveys of these caves will be emphasized as a part of the already-existing cartography project. Much of the work, however, will be done simultaneously with crews performing surveys and inventories at the same time.

A good amount of work was done in the few months of 1994 that the project was actually underway. (It began at the end of September.) Several survey trips were taken to two large caves, Buffalo Creek Cave and Ganter Cave, to continue ongoing surveys there. Big Spring, or Minton Cave was surveyed and inventoried as were: Fishtrap Hollow Pits 1 and 2, Beech Tree Sink, Deer Lick Cave, Salamander Cave, Squeeze Cave, Two Entrance Cave, and Feather Cave. Inventories were also done on these previously-surveyed caves: Bent Tree Sink, Cade Cave, Jawbone Cave, Stillhouse Sink and Cave, and Johnson Spring Cave. Reconnaissance of several areas were undertaken and another three locations were verified. Numerous other locations failed to have any cave associated with them.

Hidden River Cave
Hart County, Kentucky

Mike Yocum and Dr. Chris Groves

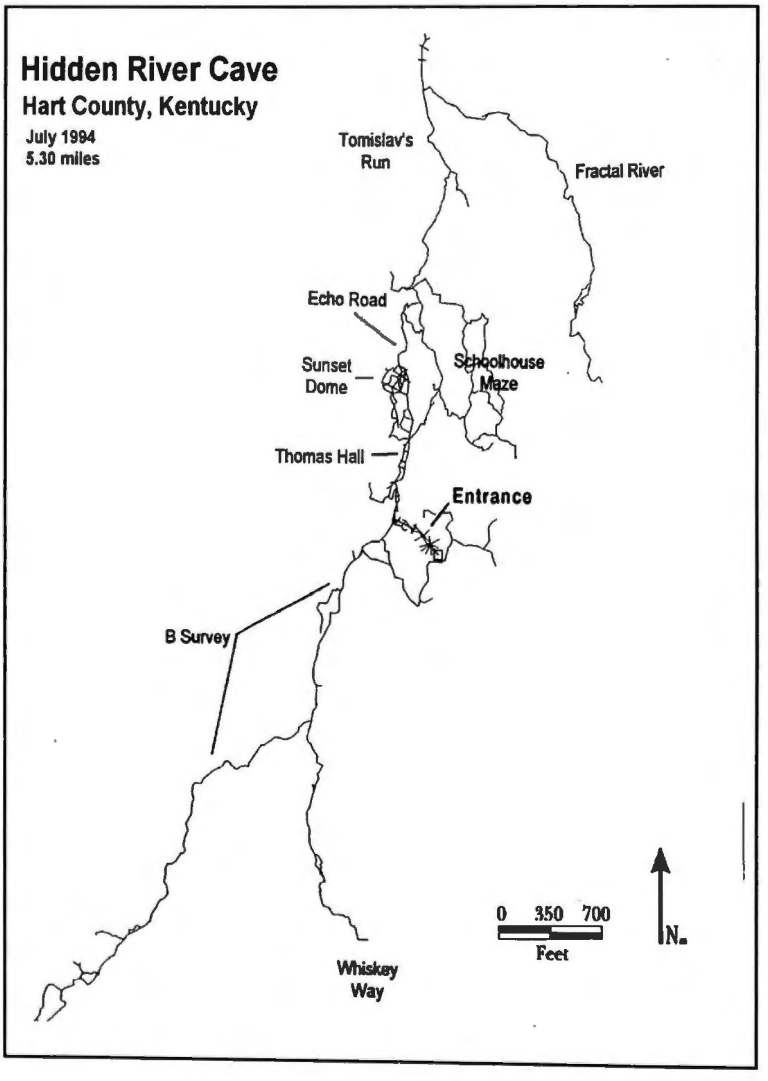
Hidden River Cave has been known for approximately two centuries. The cave's impressive entrance, refreshing natural breeze, and underground river made it a popular spot among local residents and visitors in the 1800's and early 1900's. Commercial tours of the cave were offered from 1900 until 1942, when pollution of the underground river made tours of the cave impossible.

For half a century the cave was unenterable due to pollution. Pollution making its way into the underground river from nearby sinkholes included whey from a dairy, spilled petroleum products, raw sewage, and heavy metals from the discharge of an inadequate wastewater treatment plant. The once thriving ecosystem of the cave was destroyed. A strong odor from the entrance pervaded downtown Horse Cave on summer days.

Waste management in the area was significantly improved in the late 1980's and early 1990's. A new wastewater treatment plant was constructed. Discharges of pollutants to sinkholes in the catchment area of the cave were reduced. In 1991, it was found that the cave could once again be entered and explored.

Sketchy accounts of exploration during the 1930's suggested that approximately three miles of cave passage had been seen at that time. Mapping in easily accessible passages in 1991 easily reached one and a half miles. Then in 1992 high water levels slowed exploration to a small number of trips. Very low water levels in the summer and fall of 1993, plus an exploration breakthrough into an extensive network of unexplored passages, have led to a surge in mapping trips.

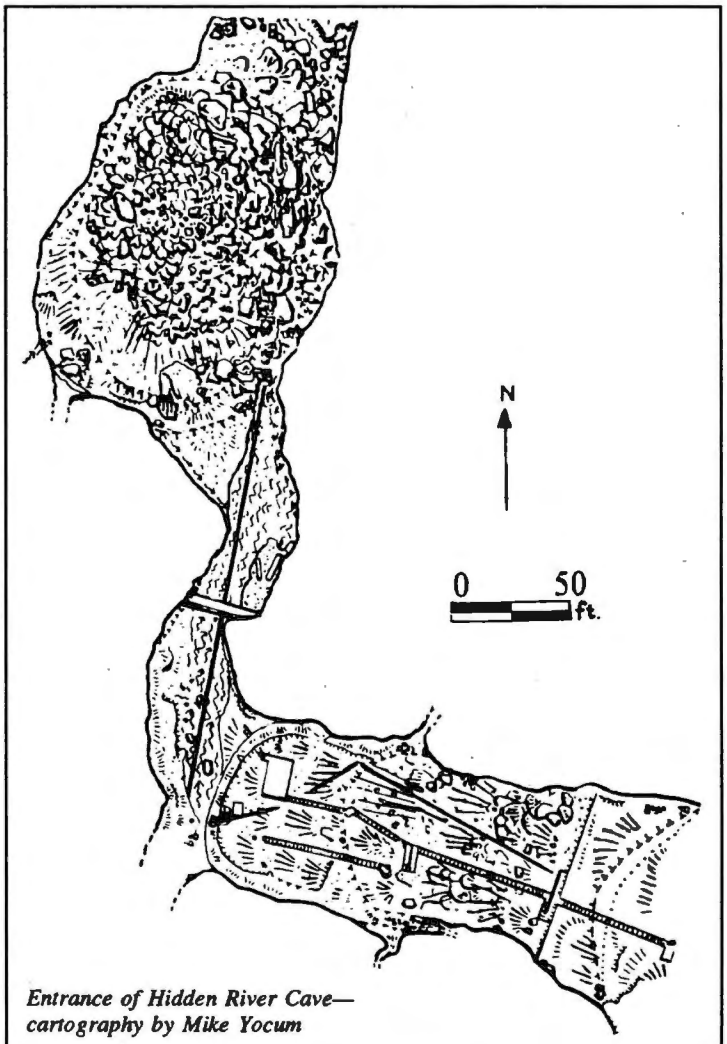
During the summer of 1994, CRF began assisting the ACCA (American Cave Conservation Association) with the survey of Hidden River Cave in Horse Cave, Kentucky. The July expedition saw four CRF crews add a half-mile of new survey and several hundred feet of detailed resurvey. One party completed mapping the new Echo Road route from the north side of Sunset Dome to the Schoolhouse Maze. This shortcut provides a welcome bypass to Bluegrass Hall, the 400 feet of mostly mud crawling that was the only way to reach the down stream section of the cave until the recent discovery. Another party surveyed a walking tube that connects Schoolhouse Maze to Echo Road.



In support of the ACCA's effort to obtain a very accurate map of the historic section of the cave, a derailed resurvey was run for 1750 ft. from the first viewing platform at the entrance to a station in Thomas Hall. With this survey completed, only a couple of hundred feet remained to be done before reaching Sunset Dome (the largest room in the cave, an impressive 200 ft. in diameter) which has already been resurveyed and resketched in detail.

Another crew returned to the D Survey, an upstream walking passage with abundant leads that many cavers have ignored. They picked up a 5 feet high, 10 feet wide lead and surveyed over 700 feet. Their find of a whiskey bottle, presumably the debris of backflooding, led to the christening of the D Survey as Whiskey Way. Cave fish and crayfish were abundant in this passage.

On the final day of the expedition a party began checking leads in the B Survey. Many were eliminated from the lead list, a couple were mapped for a (very) few stations, a couple of new ones were added, and before the crew could really get to work they were routed by the loud sounds of a thunderstorm accompanied by sudden inputs of rushing water. They exited quickly, but without problems.



Entrance of Hidden River Cave—cartography by Mike Yocum

During the Labor Day expedition more detailed resurvey was completed as a crew slimed through Bluegrass Hall in an attempt to correct some of the closure errors associated with that part of the cave. In other areas, radio location stations were tied in to the existing survey in Sunset Dome and the B Survey; the last couple of hundred ft. of Thomas Hall were resketched; and, during an attempt to locate an old station at the junction of Bluegrass Hall with Schoolhouse Maze, yet another passage was discovered that connects the maze with either Sunset Dome or Thomas Hall. Downstream of the Schoolhouse Maze, the passage ended in a sump.

Between expeditions, Tomislav Grancanin (a longtime CRF member), discovered a blowing bypass to the sump. The passage is an overflow channel which leads a large chamber (named Horse Hall), nearly 300 feet long, 40 feet wide and 50 feet tall. The downstream continuation led to low airspace over deep water with no airflow. An infeeder just before the downstream terminus opened into a large stream gallery that has been surveyed for over a mile. The stream intersects another complex section called the Mandelbrot Maze.

Hidden River Cave has been connected via dye-trace to the Hidden River Complex, an extensive (14+ miles), mazey baselevel cave system that resurges on the Green River. A bypass to the Horse Hall Sump could very well lead to a connection between the two caves. More exploration and survey work is necessary in order to realize that potential.

Redwood Canyon Survey & Cartography

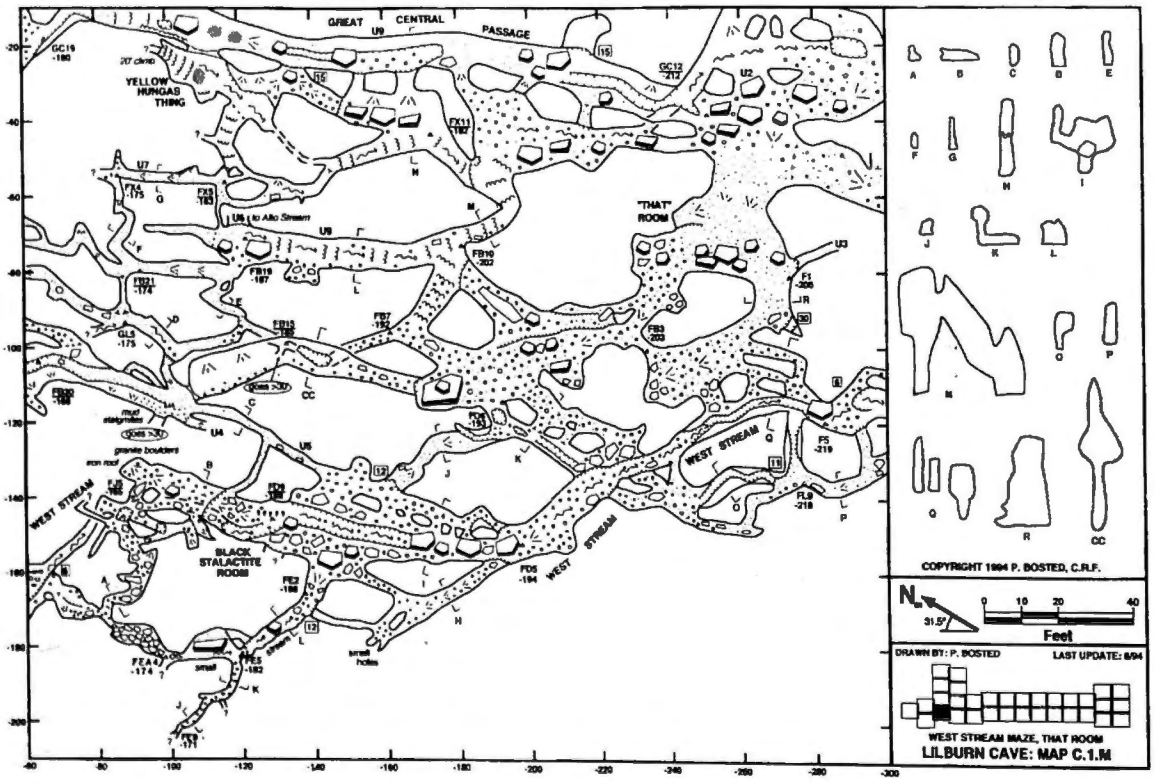
Peter Bosted

There were three 1994 expeditions involving cartography to Redwood Canyon in Kings Canyon National Park, California Of the ten survey trips into Lilburn Cave, two surveyed small side leads off Curl Passage for 145 feet, three surveyed leads off the West Stream for 400 feet, one surveyed a tight 80-foot crawl from the beginning of the Incredicrawl to the Attic, one surveyed 135 feet off the Pandora Complex, and the last three were to a newly discovered area dubbed the Penthouse, where 1140 feet, were mapped. The Penthouse is above the Attic, and was reached by two difficult climbs pioneered by Bill Farr and others.

An extensive horizontal maze was found at the top of the second climb, with no connection back to known cave. A total of 2000 feet of new passage was surveyed bringing the length to 23.2 kilometers (14.4 miles), while the vertical extent remains unchanged at 155 meters (509 feet). Many small leads remain throughout the cave. One survey trip was made in May's Cave, mapping 140 feet to bring the length to about 715 feet The remaining leads are extremely tight, but air and water flow indicates a likely connection with the Attic-Attic in Lilburn, 200 feet lower and 200 feet away horizontally.

Good progress was made on producing maps. A map of Cedar Cave showing both plan and two profile views was published in the *California Caver* (No. 200). All the Lilburn data has been divided up according to levels, and line plots are ready for each of the approximately seventy-five 11- by 17- inch quadrangles. Eighteen in the north end of the cave, one in the middle, and about fourteen in the south end of the cave have been drawn up, and include all surveys to date in these areas.

Drawing is done on Macintosh computers, using Canvas or Illustrator drawing programs. This makes it easy to update the maps as new passages are surveyed and allows several versions of the map to be printed out, since various features are on different levels. Overlay maps are also being produced showing how levels in a given area relate to each other. Five people are now working on producing quadrangles, with one new cartographer, Brad Hacker, making exceptionally valuable contributions this year.



Geosciences

Cave Phosphates, Isla de Mona, Puerto Rico

by Edward Forrest Frank

Abstract

Isla de Mona is a small, raised tabletop, carbonate island located 68 kilometers west of Puerto Rico, approximately half way between Puerto Rico and the Dominican Republic in the Mona Passage. Hundreds of caves are found around the perimeter of the island.

During the late 1800's and early 1900's extensive commercial mining of guano-derived phosphates from these caves took place with an estimated 200,000 tons removed (Wadsworth, 1973). This ongoing investigation is examining the mineralogy and origin of the phosphate deposits, the associated fossil materials, and their relationship to the geologic history of the caves in which they are found. This research represents one aspect of a broader investigation of the geology and hydrology of the island being spearheaded by the U.S. Geological Survey.

Geologic Setting

This island forms a flat-topped, raised platform 50 to 90 meters above sea level bounded by steep to vertical cliffs extending from the platform edge to a depth of up to 30 meters below sea level. The island is 12 kilometers long and 5 kilometers wide, kidney shaped, with 5,510 hectares (ha) of area (Peck and others, 1981). A small sister island, Monito, is located 5 kilometers northwest. It is similar in description but is only 17 ha in area (Peck and others, 1981). Isla de Mona consists entirely of carbonate rocks. The two primary units consist of the Miocene- age Mona Dolomite, which makes up the bulk of the island, and an upper capping unit, the Mio-Pliocene-age Lirio Limestone. Caves literally ring the perimeter of Isla de Mona. The caves are preferentially developed, but not restricted to, the Lirio Limestone/ Isla de Mona Dolomite contact. The caves found around the rim of the island are flank margin caves (Frank, 1993) similar to those described from The Bahamas Islands. The flank margin model of cave development (Mylroie, 1988) was developed based upon work on caves in the Bahamas (Mylroie and Carew, 1990) and describes the formation of caves along the perimeter of the carbonate islands at the edge of the freshwater lens. Briggs and Seiders (1972) depict the entrances of 25 of the larger caves and outline maps of their extent on their geologic map of the island. Near Punta Este there is a continuous string of caves for over two kilometers along the coast. Surveys conducted of the floor areas of twelve caves found their combined floor areas to be 444,000 meters^2.

The island is in a tectonically active setting near the northern boundary of the Caribbean Plate and has undergone sequences of uplift and renewed sea level cavern development since the late Miocene. Superimposed on these uplift sequences have been Pleistocene glacioeustatic sea level fluctuations.

Phosphate Minerals of Isla de Mona

The earliest descriptions of the mineralogy of Isla de Mona were by Sheppard in 1882. He described the minerals monetite, monite, and pyroclasite from the island. These were the first descriptions of the minerals monetite, $CaHPO_4$, and monite. Monite has been interpreted as hydroxylapatite based upon analysis of samples of similar description (Altschuler 1959). Pyroclasite had previously been described from Islas Los Monges, off Venezuela by Sheppard in 1856.

Altschuler (1959) provided a much more detailed examination of phosphate minerals collected from the Island in the 1950's by C. Kaye. The predominant mineral identified in the samples was hydroxylapatite. Other

minerals described included apatite $Ca_5(PO4)_3(F,Cl,OH)$, martinite (hydrous and carbonate variation of whitlockite), whitlockite $Ca_3(PO_4)$, brushite $CaHPO_4.2H_2O$, and crandallite $CaAl_3(PO_4)2(OH)_5.H_2O$.

These deposits formed through a combination of alteration and leaching of a parent, bat-derived guano deposit. Phosphate minerals in general are fairly insoluble under surface conditions. They may become solubilized in guano deposits with the combination of organic substances from within the guano, water, and carbon dioxide. Calcium phosphate, soluble in water which contains carbon dioxide, will precipitate in the presence of excess calcium. A suite of different phosphate minerals may form through this process, each dependent on the presence or absence of other elements, amount of water present, amount of carbon dioxide, and other environmental factors. The relationship between these minerals is poorly understood and provides the focus of this investigation.

Continuing Investigations

In June 1994 a series of samples were collected from caves on Isla de Mona. These samples included loose, non-indurated phosphate material that had been commercially mined, reaction rims formed at the contact between the loose phosphate material and limestone bedrock and breakdown blocks, and of fossils contained within the phosphate material. These samples are currently being analyzed. Mineralogical analysis methods include: laboratory chemical analysis, x-ray diffraction, thin section optical mineralogy, scanning electron microscope imaging, cathode ray fluorescence, and electron microprobe mapping. Initial analysis have found similar mineralogies to those previously reported. More detailed analysis are expected to better define the relationships between these mineral phases and to possibly identify additional mineral phases within the reaction bands. Some samples have been radiometrically dated using radiocarbon dating, and uranium alpha- counting. At this stage the results of the dating tests are still awaiting confirmation. Fossil identification is continuing and being conducted in conjunction with Dr. Donald McFarlane.

Acknowledgments

Appreciation is expressed to Joseph Troester, Calvin Alexander, Don McFarlane, and Bruce Panuska for their help in these investigations. Financial and equipment support was provided by the Cave Research Foundation, The University of Minnesota, and the U.S. Geological Survey.

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A Preliminary Report on Structural and Litholotic Controls on Karstification in the Great Valley of Pennsylvania

Rolf V. Ackerman, Allan Lemon, and Roy W. Schlische

This article serves as a preliminary report on work in progress conducted with a Cave Research Foundation grant entitled Structural and Lithological Controls on Karstification in the Great Valley of Pennsylvania, received in August 1994, and contains as of yet unpublished data. This study began in 1992, and seeks to evaluate the effects of geologic structure on the surface expression of karst (e.g. sinkholes, closed depressions, springs, etc.) within the Great Valley of Pennsylvania. As of yet, a comprehensive regional study of the effects of geologic structure on karstification remains to be done. We hope to fill this gap in the literature. This preliminary report focuses on work done in Cumberland County, Pennsylvania. The availability of extensive bedrock fracture data in the Great Valley of New Jersey from the New Jersey Geological Survey has led us to extend our overall study area northward into New Jersey. Thus, we have included some preliminary New Jersey data as well.

The Great Valley (within the Appalachian Mountains) of Pennsylvania (Figure 1) provides and excellent opportunity to study the effects of geologic structure on karst development. Underlain by a series of Cambro-Ordovician carbonate rocks, the region is dominated by closed depressions, sinkholes, rolling hills/hummocky topography, springs, and caves. The valley is bounded to the north by Blue Mountain (also known as North Mountain), which is made up of Ordovician and Silurian sandstones. It is bounded to the south by South Mountain, which is comprised of Cambrian quartzites. The northern third of the valley is underlain by Ordovician shales. Within the Great Valley of Pennsylvania, bedding strikes primarily to the northeast, while dips are variable, but mostly to the southeast (Becher and Root, 1981). Cleavage is axial planer, strikes NE and dips SE, while fanning the folds (Becher and Root, 1981). There are multiple major anticline-syncline com-

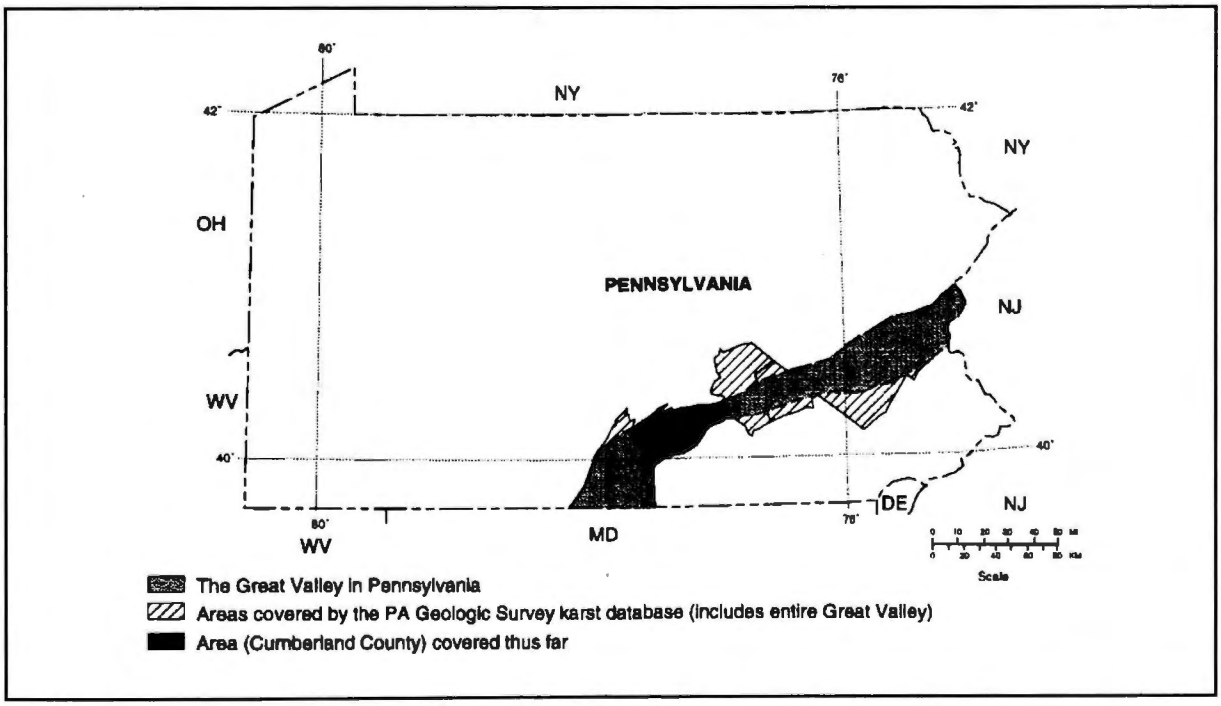

Figure 1: Areas of Pennsylvania discussed in this report

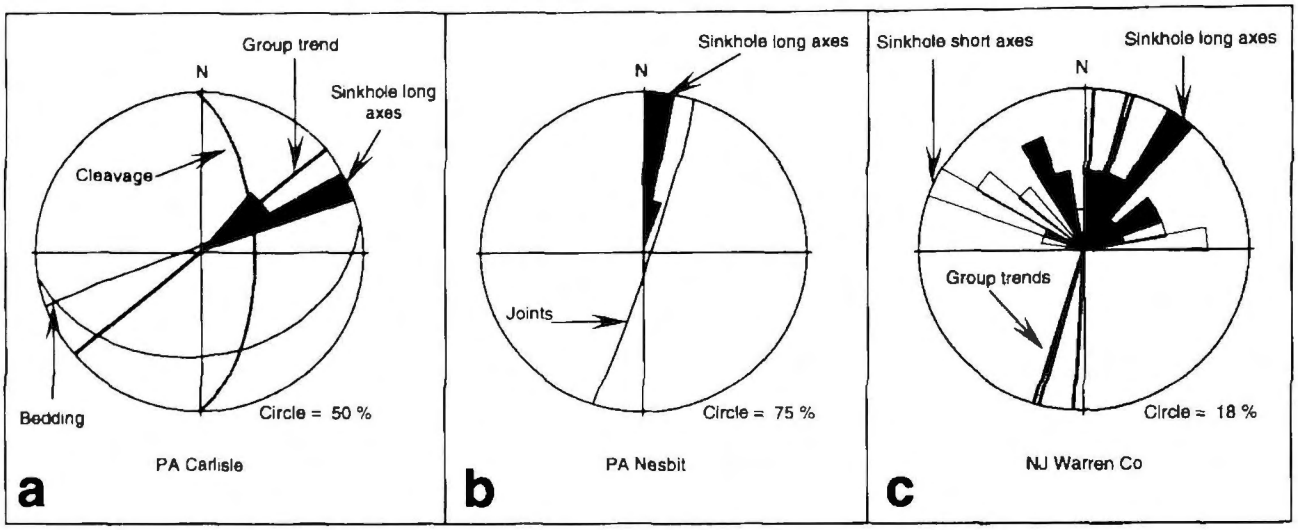

Figure 2: Alignment diagrams for three selected areas

plexes in the Great Valley, with some folds having one limb overturned, usually to the SE with axial surfaces dipping SE. Fold axes bear NE-SW, and plunge in both directions. 'Mere are multiple Paleozoic thrust faults in the Great Valley, all of which strike generally NE and dip SE (Becher and Root, 1981). Fracture traces and joints trend NE and NNW.

A large database (in the form of maps) of karst features has been compiled by the Pennsylvania Geologic Survey (Kochanov, 1987a,b; 1988a,b; 1989a,b,c; 1990) (Figure 1). Thus far, we have used only a small portion (Cumberland County) of this database, as well other existing data concerning the geographic locations of karst features, the hydrogeologic characteristics of Cumberland County, and the chemistry of the carbonate formations within the initial study area. Thus far, we have compiled data concerning 366 mapped sinkholes and over 9000 closed depressions and their relations to the structural, lithological and spatial characteristics of the initial study area.

The data from this preliminary study suggest that structure dominates lithology in the development of karst features within the study area. For example, within the initial study area it was found that there is a greater amount of karstification along fold hinges. This is because the rock cleavage is axial planer, with the intersection of cleavage planes being greatest near the axial plane of a fold. This in turn increases secondary porosity, leading to greater karst development. Karstification along the limbs of a fold is less likely because the deformation along a fold's limbs is generally less intense than in the hinge region. Karstification along joint sets follows along the same premise of increased secondary porosity. Joints are commonly well-developed along the outer arcs of folds.

Individual sinkhole long axes, as well as sinkhole group trends have thus far shown general alignment with joint sets and bedding strike. Figure 2 presents limited data from three different small areas, and illustrates these relationships. It is interesting to note the wide range of group trends in the New Jersey data (Figure 2c), though the dominant trends of individual sinkholes and group trends are parallel. Another example of structural control on karstification is a major diabase dike (Jurassic in age) that cuts N-S through the study area, normal to groundwater flow (Becher and Root, 198 1; Ackermann, 1993). The dike is a hydrologic barrier, causing the groundwater table to be significantly higher on the upgradient side of the dike. Ackermann (1993) observed that there is more intense karst development on the upgradient side of the dike, perhaps the result of the mounding of the water table.

The data thus far also indicate that there are a greater number of karst features per unit area in areas of purer limestones (units with a lower percentage of acid insoluble residue). White (1988) observed that a

minimum of 90% $CaCO_3$ is required for full karst development. We propose that lithological variations impact karst development only when structural features are present to provide secondary porosity that enhances chemical weathering (Ackermann, 1993). This is necessary in order for groundwater to chemically attack, and eventually compromise, the carbonate bedrock. Other factors such as the volume and pH of the water percolating through the rock will exacerbate or limit this process, e.g. natural waters with a higher pH will chemically weather carbonate more quickly (Ackermann, 1993). Neighboring non-carbonate bedrock lithologies affect karst development in several ways. Within the initial study area, there is higher karst development in areas where runoff is chemically more aggressive, where colluvium is thicker and coarser grained (Ackermann, 1993) (Figure 3).

The role of faulting in influencing karstification in the initial study area has thus far proved inconclusive. This is surprising in that fracturing (and associated porosity) would be expected to increase along a fault zone. The lack of decisive data on faults and karstification in the initial study area may be due to the relatively small number of faults that were present. Another anomaly in the structural data is that the karst features do not follow fold hinges as closely as one would intuitively think. It remains to be seen if this incongruity persists over larger areas than covered thus far.

In order to more effectively cover the expanded study area, we are digitizing Kochanov's (1987a,b; 1988a,b; 1989a,b,c; 1990) maps and using a computer gridding and contouring program to produce maps illustrating the levels of karstification in the Great Valley of Pennsylvania, based on an inverse-distance to the nearest-neighbor feature gridding algorithm. This has proven to be much more problematic and time-consuming than originally anticipated, and has stunted our progress. When areas of high and low karst intensity have been quantitatively delineated, data on joint densities within the areas of low and high intensities will be collected in the field in

Pennsylvania. The availability of bedrock fracture data in New Jersey will expedite our study. Because of the large areal extent of the Great Valley, we expect the Pennsylvania field work to require consider-

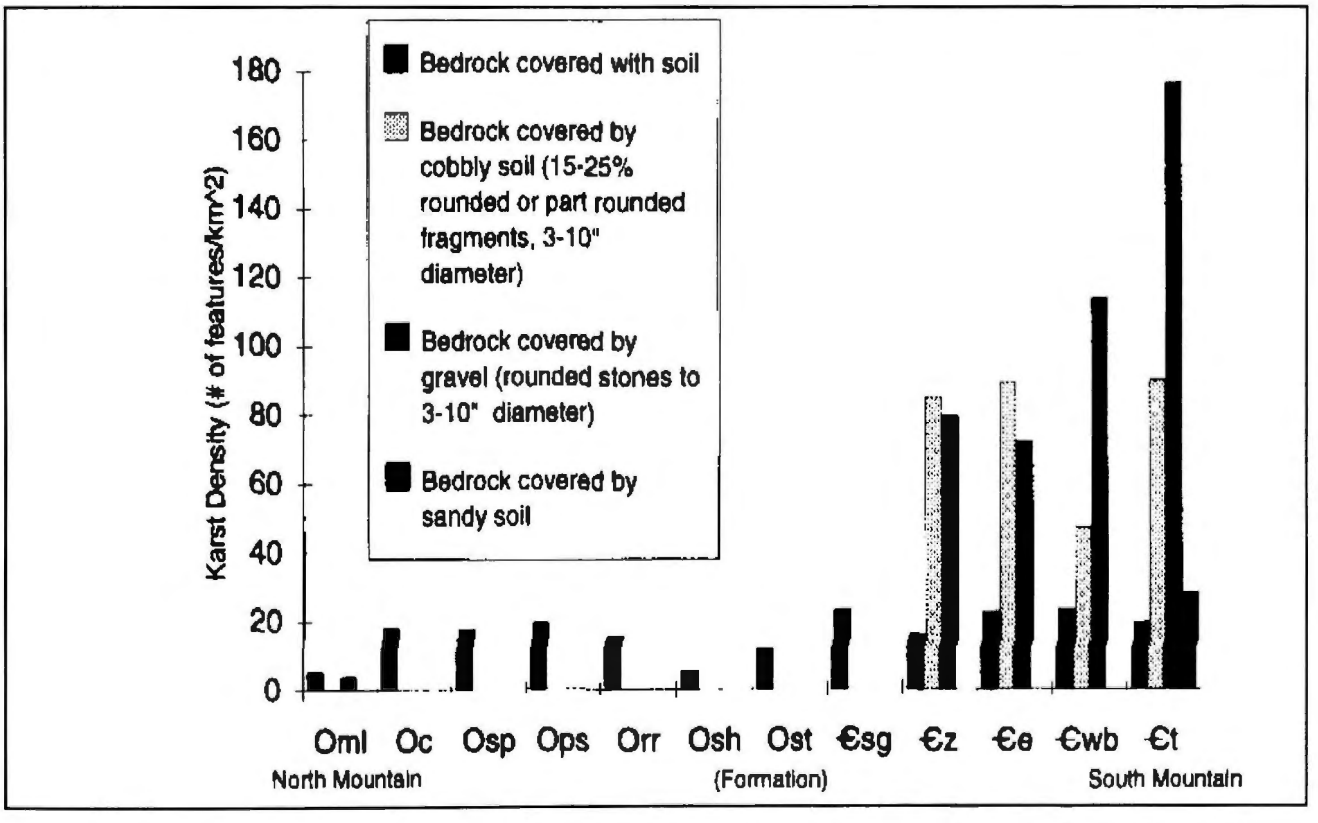

Figure 3: Higher karst development in areas where runoff is chemically more aggressive and where colluvium is thicker and coarser grained

able time. Variations in joint densities, if any, between areas of high and low karst intensity will then be compared.

The areal extent (square kilometers) of each of the carbonate lithologies included in the database (Kochanov, 1987a,b; 1988a,b; 1989a,b,c; 1990) is being determined during the digitizing process, along with the number of karst features underlain by each formation, and values for the number of karst features per square kilometer by formation. This is a simple and efficient means by which to determine lithological controls on karstification within the study area. The formation data will then be compared to published chemical data on acid insoluble residue, iron, magnesium, etc., where available (e.g. Epstein et al., 1974; Maclachlin, 1983; Root, 1971, 1968), so as to establish the presence or absence of any correlations.

Two broad questions remain to be answered: What are the structural controls on karstification within the Great Valley in Pennsylvania?; and Does the correlation of purity of limestone and karstification found in Cumberland County hold true for the rest of the Great Valley in Pennsylvania? When finished, we hope the results of this study will be a valuable resource for land-use planners, state and local governments, consulting firms, and scientists when resolving issues such as conservation, zoning, building requirements, and site remediation within the Great Valley of Pennsylvania. The use of geologic structure as an initial predictive tool for karst would be far more efficient and cost effective than haphazard guessing using the subsurface methods currently employed.

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Cave Research Foundation Activities 1995

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Page 41 photo credit: Scott House in Round Spring Cave, Ozark National Scenic Riverways
Photo by: Scott House and Richard Young

1995 Highlights

Annual Meeting

CRF's Annual Meeting was held on November 4, 1995 at Mammoth Cave National Park's Learning Center. Several changes within the Board of Directors occurred and a new editor for the Foundation's Newsletter was named. Janet Sowers, resigned from the Board due to growing family responsibilities. She will continue to serve as the Operations Manager for Lava Beds. Roger McClure resigned as treasurer after 18 years of service. Paul Cannaley was elected to the Board and replaced McClure as treasurer. Mick Sutton and Sue Hagan resigned after 8 years as editors for the CRF Newsletter. Buz Grover was appointed to take on the editorship.

Two JV's, Joyce Hoffmaster and Mike Yocum, were elected to membership. Joyce was nominated because of her consistently excellent work as an expedition leader, trip leader, member of the publications committee and for her work on the tenant house rehabilitation. Mike Yocum, who serves as the Eastern Operations Manager, was nominated for his excellent job representing CRF with the Science and Resources Management Division at Mammoth Cave National Park, for reorganizing expedition procedures and for his development of training programs at Eastern Operations.

The Board accepted Don Coon's donation of portions of 100 acres of his Kentucky property which will take place over a period of years. When the transfer is complete, the Foundation will manage the land, which falls within the Biosphere Reserve, as a nature preserve in an effort to protect karst resources. Combined with the nearby Hamilton Valley property, CRF will manage a growing portion of the karst watershed east of Mammoth Cave National Park.

Hamilton Valley

Work weekends continue on a regular basis on the Hamilton Valley land to improve existing structures and maintain the property. Repair work was done on the valley barn to repair doors, siding, roofing and to paint the structure. Road gates and a road sign was installed on the property. The tenant house (now dubbed the Hoffmaster House for the project guru Joyce Hoffmaster) has been refurbished. Eastern Operations fielded its first expedition from the Hamilton Valley property in April.

Geological Seminar at Carlsbad Caverns/ Guadalupe Mountains

A geology seminar, led by Harvey DuChene and Cyndi Mosch, was featured at the Memorial Day Expedition at Carlsbad Caverns National Park. Mike Goar and John McClean also assisted with the seminar. The purpose of the seminar was to train CRF members in geological and mineralogic inventory, with hands-on experience in the identification of rocks and fossils typical of the Capitan Reef complex and Guadalupe cave mineralogy.

On Saturday, following DuChene's short orientation talk, the fourteen participants traveled to Guadalupe Mountain National Park to hike the geology trail at the mouth of McKittrick Canyon. The relationship between the Delaware Basin, the Capitan Reef, the reef slope and shelf deposits were discussed with emphasis on the fossil and rock types characteristic of each environment. Later, back at the Park, ``````` DuChene showed slides of minerals, speleothems and rock types typically seen in Guadalupe caves. Mosch set up her collection of rocks, minerals and fossils for everyone's examination. On Sunday, Mosch and DuChene gave hands-on instruction on fossil and rock identification and geology/mineral inventory procedures.

Ozark Scenic Riverways Cave Management Team

A cave management team was formed by the Ozark National Scenic Riverways to help update and implement a long-standing NPS cave management plan. Charles Putnam (NPS) leads a team which includes two CRF people (Scott House and Mick Sutton) in addition to NPS historian and archivist Jeff Kroke, NPS archeologist Caven Clark and Rick Thom, cave specialist with the Missouri Department of Conservation.

The team met in March of 1995 and discussed the establishment of individual management prescriptions for Park Service caves, and the development of fundable cave and karst research proposals. A lot of time was spent on Scott House's proposal to develop a flexible interagency cave database. By having all users agree to a specific order of fields, the database would be easily importable between software platforms, and additional fields could be added on by individual user's to meet their specific needs.

There was also discussion of a CRF cost-share proposal which the NPS recently approved. House will collate and rationalize all the accessible information from a wide variety of sources regarding the Riverways' 300 known caves. This information will be included in a version of the database discussed above, and a proposed management prescription will be included for each cave. This project will mesh with the ongoing establishment of a centralized archive for the ONSR.

"Don't Mess with Mammoth" Day Cleanup

CRF and the American Cave Conservation Association co-organized a day of karstland stewardship on September 16, 1995. A cleanup was orchestrated at CRF's Hamilton Valley property in order to remove rubbish from sinkholes and to take care of some sheet and gully erosion in a former tobacco field. The cleanup served to help remove sediments and possible toxic substances that degrade the water quality of the karst aquifer and harm the aquatic biological communities in area caves and baselevel streams.

CRF Fellowship & Research Grants

In 1995, the Cave Research Foundation received six proposals. Three proposals were awarded funding; one Fellowship and two Grants. A total of $4000.00 in awards was distributed.

1. *Early Holocene Hunter-Gatherers in Central Brazil Karst.* Mr. Renato Kipnis, Museum of Anthropology, University of Michigan, Ann Arbor, Michigan Research Fellowship in the amount of $2,500.00.

Mr. Kipnis' research is part of a long-term archaeological project that will systematically evaluate the dynamics of cultural change in Central Brazil. The research will investigate the kinds of responses that were employed by hunter-gatherer groups in eastern central Brazil during the early Holocene by evaluating the idea that subsistence diversification and intensification were the two main responses to climatic instability in the area. An alternative hypothesis to be evaluated is that buffering dispersal and mutualistic relations among groups of people were the main strategies employed by prehistoric societies in central Brazil as responses to food stress.

2. *Investigations on the Paleontology and Archaic Archaeology of Grand Canyon National Park, Arizona.* Mr. Larry L. Coats, Quaternary Studies Program, Department of Geology, Northern Arizona University, Flagstaff, AZ 86011, CRF Research Grant in the amount of $1,000.00

Mr. Coat's research is directed at the paleoecology and Archaic archaeology in Grand Canyon National Park. He will be completing a systematic excavation of Rebound Cave to recover new fossil material for paleoenvironmental data concerning the Archaic culture within the region and its association with extinct faunal species. The area includes vertebrate fossil assemblages (California condor, among other taxa) that should add significantly to the Pleistocene and Holocene paleoecology of the park. The research also includes an effort to use the new data in concert with prior studies to interpret the cultural affiliation of split-twig figurines and other artifacts.

3. *Morphological Change in Late Pleistocene Rodents from Hilltop Cave, Trigg County, Kentucky, and its Relationship to Climatic Conditions.* Ms. Cindy Gordon, Department of Biology Murray State University, Murray, KY 42071. CRF Research Grant in the amount of $1,000.00

Ms. Gordon's research seeks to determine if morphological change in the dentition of rodents is related to changes in climate in late Pleistocene rodents, specifically the pine vole (*Microtus pinetoru*) from cave sediments in Kentucky. The cave preserves diverse and abundant vertebrate remains dating from 250,000 years ago; the upper parts of the section are amenable to radiocarbon dating. Preliminary excavations indicate that sufficient microfaunal remains are preserved to allow meaningful statistical analyses on the remains of the rodent population.

Operation Area Reports

Arkansas Operation Area
Fitton Cave Project Report

Pete Lindsley

The Fitton Cave Survey Project in Arkansas fielded five expeditions during 1995. A total of 49 cavers attended the expeditions and spent a total of 560.5 people-hours underground. Three of the expeditions were 1-day trips, one was a 2-day trip and one was a 3-day trip. A total of 16 survey parties worked in the cave during 1995. An additional 11 people-hours were spent topside working with GPS survey locations, and 107.5 people-hours were expended in a renovation project of the Chestnut Cabin kitchen in conjunction with 35 hours by NPS personnel.

The April 22 trip emphasized leads at the end of the Helictite Passage and in the Lost Passage. The high leads at the end of the Lost Passage and a tie point to the Lost Passage survey was performed on the May 27th trip. In addition, a major profile survey with several cross sections was done in Crystal Passage. Work was continued in the Bat Passage stream on May 28th. (Also, several expedition members participated in a survey trip to Temple Cave on the 28th. Although not an official CRF trip, CRF JV's have been supporting Wayne Pierce on his survey of this NPS cave.)

The June 17 trip concentrated on several loose ends in the New Maze and Tennouri areas. In addition, cross sections were made at several brass caps in the Crystal and East Passages. The August expedition took advantage of low water with leads being checked at the back of Fitton Spring and in Bat Cave. Photographs were also made at the 41-foot waterfall in Bat Passage. The September 30 trip fielded a team that checked the Lower East Passage area between the T-Room and the Needle's Eye and another team that checked a small lead heading off from the Double Drop Pit Passage. Two more teams performed an East Passage resurvey and tie to new surveys along the route between the Needle's Eye and the Out Room. Breakdown rooms between 100 and 200 feet long were noted and are placed on our survey list for 1996.

During the September expedition we had an opportunity to try out the new Park Service GPS equipment. The Trimble field unit was extremely easy to use and the unit recorded information that could be post-processed with differential correction data available over the internet or via modem through a BBS. The Trimble "roving mode" collected data over a period of time when the signal level was acceptable. Up to 400 points were averaged for our brass cap located near the Chestnut cabin, and multiple readings were made at some points to determine the repeatability and accuracy of the measurements. Data was recorded at the Bat Cave and Fitton Cave entrances as well at the Fitton Spring resurgence. Future GPS work is planned at other locations and measurements this winter will determine the effect of the forest without the leaves on the trees.

Eastern Operations Activities

Compiled by Pat Kambesis

Eastern Operations ran 11 expeditions during 1995. With the exception of the April trip, all other weekends were fielded from the Maple Spring Research station. The April expedition was held at CRF's Hamilton Valley property. Though camping and facilities were a bit more primitive than accommodations at Maple Spring, the expedition proved to be well organized and very productive. Expedition fieldwork supported archaeological/paleontologic reconnaissance, geologic fieldwork, survey/cartographic objectives, His-

toric Signatures documentation and photomonitoring. In addition, several training sessions and an Operations meeting also took place this year.

Archaeological/Paleontologic Reconnaissance

Paleontologist Rick Toomey was taken on a quick tour of potential sites for paleontological remains. Stan Sides conducted visits to Jim, Proctor, Adwell, Dogwood, and Owl Caves. A party went to Rodger's Avenue to look for Mississippian shark remains on the wall. The remains consist of at least four teeth in different orientations. Nearby are two vertebrate tooth fragments in the ceiling. All of this material is in a shell hash layer at least 50 cm thick, consisting mainly of brachiopod shells, crinoid stems, and horn corals.

Over the Memorial Day expedition, a research party examined Little Bat Avenue for bat remains. Bone found seem to belong to Little Brown or Indiana bats. An area of ceiling staining probably represents the main bat roost. Further bat remains were documented in Backsliders' Alley. A crew was fielded to Long Cave during the July expedition for the purpose of looking at bat bones, sediments and for resketching areas around the entrance. The reconnaissance noted that Long Cave has extensive bat guano and bones deposits. An archeological team went to Main Cave in order to photograph glyphs in preparation for the upcoming Southern Archeological Conference. A trip was also made to Salts Cave to examine guano deposits for paleontologic potential.

Survey/Cartography

The Lesser Caves Inventory Project was in full swing this year. Parties were fielded to Lesser Cave objectives during each expedition. In November, a weekend was dedicated to Lesser Cave project work. Fieldwork to enhance data, improve sketches, fix closure errors and to finish up remaining leads continued during all expeditions held during 1995. Teams were sent to Historic, Proctor, Salts, Unknown and Logsdon River. In addition, survey work was supported in Roppel, Sides and Hidden River Caves.

Geology

At the Memorial Day expedition, A geologic reconnaissance crew went to Blue Spring Branch and Blackall Avenues in search of well-exposed sediment banks. The only good exposure in either passage was a 2-meter deep excavated trench in Blackall Avenue. A stratigraphic column was recorded here. Evidence of a large earthquake is suggested by infilled fractures in the sediments.

During the July expedition, a party was fielded to work on the geology of the downstream section of the Hawkins River. The team measured a stratigraphic column from the confluence of the Forks upwards to the Corydon Chert in a big breakdown zone. The beds here are about 30 feet lower than the corresponding beds at the Amos Hawkins Formation.

Photodocumentation of the burrow chert above P. Strange Falls continued during the October expedition. The team was unable to complete all of their objectives due to high water flow in the River.

Historic Signature Documentation/photography

During the February expedition, Chuck Swedlund took two trips to Main Cave to test procedures in preparation for his Summer in the Park photography course. Chief City was chosen as a suitably vast venue for testing lighting techniques. Signature documentation continued in Silliman Avenue. High water in Echo River curtailed the effort after 250 feet of passage had been completed. The biggest cluster of names was across the passage from Bleeding Heart Spring. Another signature party continued along Broadway towards Giant's Coffin, under cold and drafty conditions.

Chuck returned in March to continue testing techniques in preparation for his photography course. Some beautiful historic signatures were also located near Violet City. A signature party went to Little Bat Avenue to look at the "Alfred Croghan 1820" signature for handwriting comparison with the similar looking "Alfred Alexander 1854" in El Ghor. They then resumed data collection in Broadway, working from the ox stalls to the artifact cases. The area is damaged by modem graffiti, but they crew managed to find some pre-1820 clusters.

At the Memorial Day Expedition, the Names-Without-Faces photographic survey moved out of Gothic and Gratz Avenues and into Main Cave. Signatures were documented from the Rotunda, past Gothic to Giant's

Coffin. The high density of the summertime tours reduced the speed of progress. A reconnaissance to Blacksnake Avenue showed that despite disturbance by recent visitors, there are numerous unspoiled older names in the area.

In July, three trips took place in support of the historic signature documentation project. With the collection of signatures around Giants Coffin, work on the Historic tour route was completed and the crew planned their next inventory section along Main Cave.

Photomonitoring for Resource Management

In April, Chuck Swedlund assisted by Dave Taylor-Warren (NPS), shot color photos of the recently cleaned gypsum snowballs in the Snowball Dining room. These were taken from recoverable points and will provide a benchmark against which any future deterioration can be judged.

Training/Meetings

The primary focus of the February expedition was an Eastern Operations Meeting. Among the topics discussed were: Eastern Operations funding procedures, updating the expedition leaders' manual and the CRF personnel manual, improved training procedures, Hamilton Valley work weekends, etc.

A Leadership Training expedition was held on April 22-23. Twenty-one CRF members attended, 15 whom participate in training. On Saturday morning, Bob Osburn and Pat Kambesis held a classroom session on sketching and in general how to produce clean accurate and usable survey notes. In addition to the sketching training, instructional discussion was held on trip leader responsibilities. In the afternoon, participants went to Proctor Cave and split into two parties; one group practiced setting point and reading instruments while everyone else used the data generated by group I to practice sketching. Later in the afternoon, the teams returned to Maple Spring and worked on producing maps from their sketches. On Sunday morning, another survey session was conducted in Marion Avenue where everyone got to try out his or her sketching/survey skills.

Biology and Geology training sessions were conducted during the July expedition. Dr. Tom Poulson and Mick Sutton led a classroom discussion followed by a field trip to Running Branch Cave, for the biology segment. Art Palmer gave a geology training session at the Historic Entrance and provided an instructional look at the rock units and passage type.

Miscellaneous.: JV's assisted and modeled for a TV film crew. The film will air on cable TV as a segment on Mammoth Cave and CRF in a series called "America's Crown Jewels: The National Parks".

Report on Guadalupe Escarpment Area

Carlsbad Caverns National Park

Pat Helton

The Carlsbad Cavern operations are primarily concerned with a comprehensive correction of the existing survey by implementing a resurvey of the majority of the Cavern. This resurvey will utilize an existing 300 point precision loop in the main Cavern passages. New confirmation surveys will be tied to these precision points to verify accuracy and to identify closure problems. This will eliminate the error that has crept into the survey over the forty or so years of survey activity. Current surveys, since September 1994, are now reporting an error factor of less than 0.5% using hand held instruments.

To eliminate wear and tear on the cave passage due to teams continually going back in to correct errors and to pick up additional survey from unpushed leads, current policy is for the team to push all available leads before moving on. This has resulted in a significant amount of new passage survey along with the resurvey footage. It has also cut down on about 70% of the re-

turn trips into selected areas and has been instrumental in our "minimum impact" policy in the cave.

Current survey stands at 31.16 miles through Labor Day 1995. Labor Day 1991, the survey was at 19.6 miles. During the Memorial Day Expedition 1995, we held another geology training school. This was under the direction of Harvey DuChene and Cindy Mosch. We now have a good group of people skilled in inventorying geologic features. Now, a trained inventory person is a part of each survey team. Our GIS inventory system is up and running which will give a type illustration by features on the cave map or a listing of geologic features by survey station or a combination of the two. This is running on Fox Pro in conjunction with a hybrid Compass/CSS survey program under Windows 3.1.

Lincoln National Forest—Capitan Peak Study Area

Dick Venters

The CRF Lincoln Forest—Capitan Peak Study Area Project (LNF-CPSA) began as a field mapping expedition for locating all karst features within the Lincoln National Forest (LNF), Capitan Peak Area, NM.

From its inception in 1991 to the present, karst data collected within the 15-square. mile study area has yielded a multitude of diverse types of geologic, structural and bio-environmental dissimilarities. LNF-CPSA is now moving into its second phase: an in depth study of the structural geology, lithology and paleo-karst formation within the study area. Studies will also include: how the association and diversification of paleo-environments formed many (diverse) bio-environments within the known caves of the study area. No extensive structural geologic work is known to have been completed for this area, only surfacial geologic mapping on a large scale. We hope to improve on the structural significance of cave formation and paleokarst features as related to the more recently formed cave systems for the area. This data will help us locate, with more accuracy, features and structures needed for a structural geologic work and karst-feature(s) locations.

Early in the week, we were visited by four Lincoln National Forest personnel (John W. Brown, David Johnson, Larry O. Cordova and Ransom Turner) for the purpose of obtaining (permission for) a dig permit for Dick's Blowfly Cave (DBF). A walk thru and familiarization of the area's karst features followed a trek to DBF cave. The LNF personnel seemed very interested and pleased with our project and what CRF is trying to accomplish.

By the end of the week we revisited some previously ridgewalked areas near the Camp Area and Serpentine Root Cave--unbelievably, we located four new caves and one large sink! This brings our total to nineteen caves and seventy-four sinks!

Once again, many thanks to everyone who has graciously donated time, energy, and enthusiasm to the LNF-CPSA Project (1991-1995). It looks like there might be a light at the end of the "cave" after all.

Many thanks to the LNF personnel and all the caver-volunteers (10) who helped with the April field work. Expedition participants were as follows:

Jon Conrad (CO), Dorothy Corcoran (NM), John Corcoran III (NM), Fritzi Hardy (NM), Jim Hardy (NM), Brian Holcomb (NM) Bob Pape (AZ), David Sherrow (CO), Dick Venters (NM), Bill Ziegler (NM)

Lava Beds Operation Area Update

Janet Sowers

The Cave Research Foundation has conducted cave surveys and cave resources inventories since we first began working at Lava Beds National Monument in 1988. Partly as a result of CRF's efforts, over 300 caves are now known on the Monument. And there are more found every year. CRF is continuing to help document these caves.

The documentation of any cave at Lava Beds involves several steps of which only the first two are required for every cave (see sidebar). Further documentation, steps 3 through 6, is done on only the more significant caves.

We are presently assisting Lava Beds with steps 2, 3, and 4: mapping, marking, and inventorying. Of course, if we just happen to a find a new cave, we will do step 1 also. We are following with some step 5 and 6 studies begun earlier.

Mike Sims is heading up the mapping effort. Janet Sowers is in charge of the inventory effort and Bill Deveraux deals with putting in the brass markers.

Another project Bill Deveraux is working on is to precisely located as many caves as possible with the Monument's GPS system. The system can determine latitude and longitude of any point very precisely, taking about 10 minutes worth of satellite readings from both a remote station and a base station simultaneously. As many of us find out the hard way, a compass in lava can be unreliable. We hope that the GPS will finally give us a good way to navigate and pinpoint cave locations in this kind of terrain.

Mike Sims is also continuing the monitoring of ice levels at six ice caves, a "Step 6" program begun in 1989. This is done twice a year, in the spring and fall, to try and get the maximum and minimum ice levels each year.

Documentation Steps at Lava Beds

All	1. A reconnaissance Cave Inventory card must be filled out. This 4"x6" card contains basic information on the location and features of the cave.
All	2. The cave is assigned a cave number, and the number and name of the cave are stamped on a brass monument that is set into the rock above the cave entrance.
Many	3. A compass-and-tape survey of the cave is made and a map of the cave drawn, if the cave is sufficiently significant.
Few	4. A detailed cave resources inventory is conducted of mapped caves that are known to contain important natural or cultural resources or could be valuable recreational or educational caves.
Very Few	5. Further documentation is done of any resources considered to be especially significant. This documentation may consist, for example, of photographs, detailed inventory of a specific resource, or special scientific studies.
Very Few	6. A monitoring program is set up to document the condition of resources.

Missouri Operation Area Update

Mick Sutton

The 1995 field season included work on lands managed by the Missouri Department of Conservation, Mark Twain National Forest, the Ozark National Scenic Riverways, and the privately owned Pioneer Forest.

Missouri Department of Conservation (MDC)

A mapping and inventory crew visited the remote and beautiful Sunklands area in Shannon County, a region of remarkable surface karst, featuring very large sinks. This is part of an extensive tract recently acquired by the Missouri Conservation Department. A collection of small caves and a natural arch along Boyds Creek was mapped and inventoried. Two of the caves were "new". A day was spent doing reconnaissance near the valley bottom, which contained a small aquatic habitat, complete with troglobitic amphipods. Partly as a result of this trip, the MDC is considering an expansion of nearby Burr Oak Sink Natural Area (a protected designation) to encompass the cavernous section of Boyds Creek.

A special-purpose bioinventory trip went to Jagged Canyon Cave in search of additional specimens of an undescribed springtail. After spending much time searching this fairly long cave, we concluded that the only visible springtail habitat was a beaver den within the twilight zone. This did yield a few specimens but probably not the species in question.

Powder Mill Creek: Three crews continued mapping the Hell Hole series of Powder Mill Creek Cave. In the Grand Gallery Trunk a party surveyed 850 feet of walking high passage to a definite end. Later, the same crew mapped 420 feet in the Dismal Hollow area. A third trip led to 300 feet of mop-up survey around the Grand Gallery. Hell Hole is now close to completion. The final Powder Mill party of the season went far upstream, and mapped 685 feet in the Third Watercrawl (the upstream main passage). The crawl ended in walking-high passage that led up a nice series of flowstone cascades, and continues.

Mark Twain National Forest

Work on the US Forest Service mapping and inventory project continued with a trip to the privately owned Eleven Point Ranch (along a scenic easement within the Eleven Point National Scenic River), where detailed maps of neighboring Cricket and Onyx Caves were completed (to replace earlier preliminary maps by others) and a surface survey was run between them. One objective was to collect pseudoscorpions to try to confirm a possible new variant or species collected on an earlier trip. One was found in the very limited patch of habitat, but it proved to be a typical example of *Hesperochemes occidentatis*, so the earlier specimen was probably an anomaly.

There were two trips to Panther Hollow on the USFS Eleven Point District. A wetsuit party headed up-valley in heavy, continuous rain to look at a low stream crawl. Not the ideal conditions, one might think, but fortunately the little spring cave closed down after only 30 feet and the survey and inventory was completed despite the high outflow. Work was initiated in Root Cellar Cave, which consists of a complex of maze passages.

A party mapped and inventoried Dewey Minnick Cave. This is a dry canyon, featuring a large entrance shelter that is a likely archeological site (much looted, unfortunately). The cave is 450 feet long, more than double the estimates of an earlier report.

Survey and inventory was conducted in Crewse Cave, Ripley County. This is a short (110 feet) but interesting example of the inside of what is normally a flooded spring channel. The cave can only be entered via a normally flooded pit, during the seasonal groundwater low of late summer.

There were two trips to Bliss Camp Cave. The first, intended to complete the survey, mapped a section of austere, breakdown-floored trunk and brought the

length of the cave to 3,000 feet But instead of ending in breakdown as expected the passage continued into a large, well-decorated area featuring some nice dripstone. The passage has seen little traffic. The second party mapped another 630 feet along this trunk. A final trip to Bliss Camp Cave extended its length to over 4000 feet. Bliss Camp, most of which has been very lightly visited; features exceptionally fine calcite decoration, with some areas very delicate. A biological inventory still needs to be completed; towards this end, a bait station for terrestrial invertebrates was set up.

Nearby Sand Cave was also completed at about 200 feet, and a surface survey between it and Bliss Camp was carried out. It is speculated that Sand Cave was a disjointed section of a Bliss Camp passage, but the surface survey showed this not to be the case.

Boze Mill Cave on the Eleven Point River was mapped to replace an earlier preliminary survey. The cave is a summer gray bat site; although it is ungated and the entrance is heavily visited by canoeists, the colony is somewhat protected by a series of squeezes in the crawl leading to the bat roost. A supplemental inventory was done, mainly to gauge the status of the bats, but the inventory also turned up an unexpected southern cavefish in the small sump pool. This suggests more extensive hydrological connections than meet the eye. The pool is at river level, and the flooded passage between it and the river would be rather short.

There was an overnight backpack trip into the Irish Wilderness to work on a collection of mostly small caves along Whites Creek. One crew mapped and inventoried Saddle Cave. There was no previous information on this site, but it turned out to be a surprisingly large canyon with 300 feet of passage.

Meanwhile, another crew found a state of utter confusion farther down Whites Creek. Earlier efforts here have produced two sets of vague and mutually contradictory locations and descriptions, Assigning names and numbers to the caves will be an interesting job. The party mapped two caves, one of that is perhaps Beaver Pond Cave, the other probably new. The next day, a crew returned to inventory those sites and to map a third small cave near Beaver Pond. This may be Den Cave, although the match with published descriptions is oblique, to put it mildly. Another loose end was tied up at Root Cellar Cave in Panther Spring Hollow. The survey here had been suspended in the summer to avoid annoying a vulture chick. A crew mapped 240 feet to complete the survey of this unusual spongework-type maze cave, which has a final length of about 1,100 feet (again, significantly longer than the 200 feet of an earlier report). This was followed by a visit to the nearby Panther Caves to do a supplemental bioinventory.

Elsewhere on the Mark Twain National Forest, there were several trips to Davey Crockett Cave in Howell County that extended the surveyed length to over 2300 feet. One crew added 350 feet to the downstream portion of the cave while another added 250 feet to a dry upper level lead off the main line. On the second trip, a party added 600 feet of survey to the downstream area. One low, wet crawl ended after 12 feet but the main downstream passage continues. This appears to be virgin passage—either that or a tremendous amount of water has erased all signs of previous visitors. Unfortunately, that is not true of the rest of the cave, which is experiencing increased traffic. Soda bottles and beer can were removed during the survey, and many directional rows were encountered as well as fresh names and initials scratched in the limestone.

Other Eleven Point caves turned out to be longer than anticipated from earlier reports—not an unusual situation on this project! During a float trip on the Eleven Point River, a party intended to knock off Thundering Rapids Cave, a short, wet cave at river level. The crew ran out of time after the entrance crawl unexpectedly broke out into a nicely decorated walking high canyon, which continues. Likewise, a party intending to finish the last lead in Bluehole Cave found instead large-scale continuing passage. The cave is a known Gray Bat site, but the extension considerably expands the known size of the colony—the floor of a large dome was deeply covered with guano. The 600 feet mapped on this trip extends the cave's length to 1,800 feet

Pioneer Forest

An exceptionally scenic comer of Shannon County is Leatherwood Creek on the privately owned Pioneer Forest. There was a visit to continue mapping and inventorying the mostly small caves clustered along the creek. An erstwhile shelter proved to have a stream passage 100 feet long, while two low neighboring caves

were found to be one and the same cave, after moving loose sediments a little to open a tight spot.

Ozark National Scenic Riverways

There was a short trip in the Ozark National Scenic Riverways (NPS), an area somewhat neglected of late owing to other priorities. A crew mapped and inventoried Granite Quarry Annex Cave, which turned out to be longer than expected—about 200 feet of muddy but mostly walking high passage.

Sequoia Kings Canyon/Mineral King Area Activity Report

John C. Tinsley

The year 1995 was the second full year of dividing our efforts among projects in Redwood Canyon and White Chief Basin sector of Mineral King Valley. John Tinsley and Glen Malliet coordinate activities in Redwood Canyon and in the Mineral King area respectively. We consider ourselves fortunate to enjoy in every way supportive and positive working relationships with the National Park Service. The King's River District Ranger, Randy Coffiman, and his number two man, Eric Morey, visited Redwood Canyon and spent a day underground with Tinsley in Lilburn Cave. Joel Despain completed his first full year as SEKI's Cave Management Specialist. We look forward to a continuing our productive working relationship with Randy, Eric, Joel, and the rest of the SEKI management and staff as we seek to expand our involvement into other cave areas of the Parks in the years ahead.

This year featured 8 expeditions to Redwood Canyon, the first and last expeditions (March and November) were dedicated to hydrological studies and maintenance of the electronic data logging equipment. As this was an unusually heavy snow year (snow depths exceeded 30 feet in parts of Mineral King Valley) two expeditions to Redwood Canyon were canceled owing to inclement weather or poor road conditions. In late summer, when discharges are at low stages and the mountain air is delightfully warm, early August expedition, the Labor Day expedition, and a late September expedition are dedicated to mapping and inventorying caves in White Chief Basin in Mineral King Valley. The trips to Redwood canyon are conducted earlier in the year and later in the year, owing to the cave's 5000-foot elevation.

Redwood Canyon Karst Area

Active research projects include Cartography (Peter Bosted) Hydrology (Jack Hess and Mike Spiess), Sedimentology (John Tinsley) Communications (Mike Bettencourt), Cave Restoration (Bill Frantz) and anemometer development (Richard Fellows). These are summarized below.

Cartography

Peter Bosted reports that survey parties in Redwood Canyon notched slightly more than 3000 feet, with a major new area located between the Hex Room and Lake Room areas above the Curl Passage. The surveyed length of Lilburn Cave now stands at 15.1 miles or 24.3 kilometers. We should easily surpass the 25 kilometers mark late this year or early next year, depending on the weather. Brad Hacker has proven to be a major force in completing quadrangles for the Atlas of Lilburn Cave, and this has taken much pressure off of Peter Bosted. Much of the cartography now consists of taking a quadrangle into the cave and checking the sketch against reality and pushing all indicated (and unindicated) leads. It is a small caver's bonanza!

Hydrology

Winter was especially wet, and the hydrological studies continued with a banner year. Haven't received a summary of the data for the year from Mike Spiess as they have yet to conduct their year-end expedition.

Sedimentology

The high runoff year meant that sedimentological studies received a major boost. Static sediment samplers that were relocated from the Z-Room area to the Lake Room and White Rapids areas late in 1993, but did not even get their feet wet in 1993-4, were partly submerged last winter. The Pebble Pile Creek giant sinkhole continued to fill in-some 22 feet of sediment has washed into the sinkhole, and less than 6 feet of additional fill will obliterate it. One or two more good winters should do it.

Communications

The old 4-connector communications and data transmission line had deteriorated over the past 24 years to the point that it often shorted out spontaneously. Even when it wasn't shorted, the galvanic corrosional activity occurring when the line was charged made for interesting audible static when the line was used. Mike Bettencourt procured donors to purchase 5000 feet of new 12-conductor phone line and the requisite connectors. Tinsley and friends strung the last 2000 feet this year, coming out about 200 feet short of the lower end of the River Pit Avenue, the objective. It will be easy to complete the stringing this coming year.

Anemometer

Richard Fellows has built a prototype anemometer and it has been tested and pronounced more or less cave-proof. Now that the hardware exists, we look forward to collecting some useful data in 1996 to characterize the various winds that blow through the labyrinths of Lilburn Cave.

Cave Restoration

Bill Frantz has spearheaded efforts to erase the adverse impact of cavers past and present on the well-decorated areas of Lilburn Cave. This year, the Glacier, the Junction Room, and the Red Flowstone near the Iron Ladder were cleansed and refurbished The cleaning turned out to be quite popular, as participants get to go to pretty areas and make them yet prettier. The trips into the cave are rather arduous, owing to substantial loads of water, which are packed using surplus 5-liter aluminized mylar bags from box-wine. The wine bags stop for awhile, perched upon the mantle above the fireplace at the Field Station until relieved of their initial cargo.

Mineral King Area

Cartography and Inventory

Glen Malliet reports that 6 trips scattered over 3 expeditions completed surface and subsurface surveys in Cirque Cave in White Chief Valley, a hanging glacial valley tributary to Mineral King Valley. The results of the surveys are being compiled presently, and a new survey figure for Cirque Cave should be available by the end of the calendar year. No work was done in the Panorama Cave group this year, owing to high water and a desire to complete the mapping of Panorama Cave.

Hydrogeology

Lori Schultz and John Tinsley conducted a hydrologic study of the karst areas of White Chief and Eagle Lake valleys. This included some routine dye tracing and hydrochemical sampling, which will comprise Lori's senior thesis at Sonoma State University, Rhonert Park, California. In gauging streamflow, we noticed that the resurgence at Tufa Spring was significantly greater than what could be accounted for by the inflow to the system from Eagle Lake Valley. Consulting the geologic map gave us no relief. However, a half-day of field mapping by Tinsley and Schultz quickly showed that prior geologic maps were in error with respect to the position of the marble lens that forms the karst system along the west side of Mineral King Valley. Specifically, the marble in White Chief Valley trends directly north and across the divide into Eagle Lake valley, trending toward Eagle Lake sink, and thence to Tufa Spring. Pleistocene glacial deposits mantle the marble, and prior workers overlooked the alignment of sinkholes that mark the location of marble beneath the glacial mantle. After Redwood Canyon and its mantled karst, recognition of the key landscape features in Mineral King was a trivial field exercise.

Biological Sciences

The Biological Inventory of Indiana Caves

Julian J. Lewis, Ph.D.

In 1994 progress continued on the inventory of Indiana cavernicoles. In 1992-1993 field work was conducted investigating 30 caves in Crawford, Harrison, and Washington counties (Lewis, 1993a; 1993b). During 1994 biological inventories of 20 caves in the Lost River karst (Orange County), and 21 caves at the Crosley State Fish and Wildlife Area (Jennings County) were completed (Lewis, 1994; 1995)

Barr (1963) divided the Interior Low Plateaus into areas reflecting regional cave faunas. In Indiana the southcentral karst region was divided into an extension of Kentucky's Pennyroyal Fauna called the "Bedford Fauna", comprised of Monroe and Lawrence counties; and the "Corydon Fauna", including Orange County south to the Ohio. The southeastern Indiana karst was assigned as an extension of the Bluegrass Fauna called the "Muscatatuck Fauna". Based on new information it is now possible to refine Barr's zoogeographic scenario for regional cave faunas in Indiana.

In the southcentral karst, evidence of three fauna "basins" is emerging: (1) the **Blue River Fauna** of Crawford, Harrison, and eastern Washington Counties (i.e., part of the Corydon Fauna of Barr, 1963). Some of the better known caves included are, e.g., Wyandotte and Binkley's. Examples of species endemic to the Blue River basin are, e.g., the pseudoscorpion *Kleptochthonius packardi*, the beetle *Pseudanophthalmus eremita*, and the millipede *Pseudotremia indianae*. In the Blue River basin the rare aquatic troglobitic snail *Antroselates spiralis* was found in seven caves and springs (Lewis, 1993b). The collembolan *Hypogastrura lucifuga*, previously known only from Wyandotte Cave, was discovered in Little Mouth Cave, in Harrison County. The first population of the amphipod *Stygobromus* to be found in the southcentral karst was discovered in rimstone pools in Devil's Graveyard Cave, Harrison County.

(2) Barr's **Bedford Fauna** is modified here to include Orange, southern Lawrence, and western Washington counties. The area is on the East Fork of White River drainage and its tributary, the Lost River. This area contains several well-known caves and karst areas including the Lost River, Cave River Valley, Spring Mill State Park, Bluespring Caverns, Doghill/Donnehue's Cave, and Shiloh Cave. Troglobites endemic to this area include, e.g., the beetles *Pseudanophthalmus emersoni*, *P. leonae*, and *P. jeanneli*. It is of note that it is now necessary to rethink the status of some of Indiana's *Pseudanophthalmus*, as two taxa felt by Barr (1960) to be subspecies were discovered at Lost River (i.e., sympatric) at Wesley Chapel Gulf (*P. jeanneli*, *P. stricticollis*). As subspecies are by definition, allopatric, if both are present, it is likely they are good species. Discoveries at Lost River included the finding of a new population of the pseudoscorpion *Apochthonius indianensis*, in William Cleveland Cave, added to the previous records at Donaldson's and Donnehue's caves, in Lawrence County. The collembolan *Arrhopalites bimus*, previously known only from Shiloh Cave, Lawrence County, was found in Hudelson Cave. New species discovered at Lost River included the collembolan *Onychiurus* sp. (three caves), the beetle *Pseudanophthalmus* sp. (Hudelson Cavern), and the amphipod *Crangonyx* sp. (four caves, one spring).

(3) The **Monroe Fauna**, previously included as part of the Bedford Fauna of Barr (1963), here includes Monroe, Owen, and northern Lawrence counties. Some of the fauna endemic to this area includes the crayfish *Orconectes inermis testii*, the beetle *Pseudanophthalmus mayfieldensis*, the isopod *Caecidotea jordani*, and an undescribed amphipod *Bactrurus*.

In the southeastern Indiana karst the Muscatatuck Fauna of Barr (1963) is divided here into two parts:

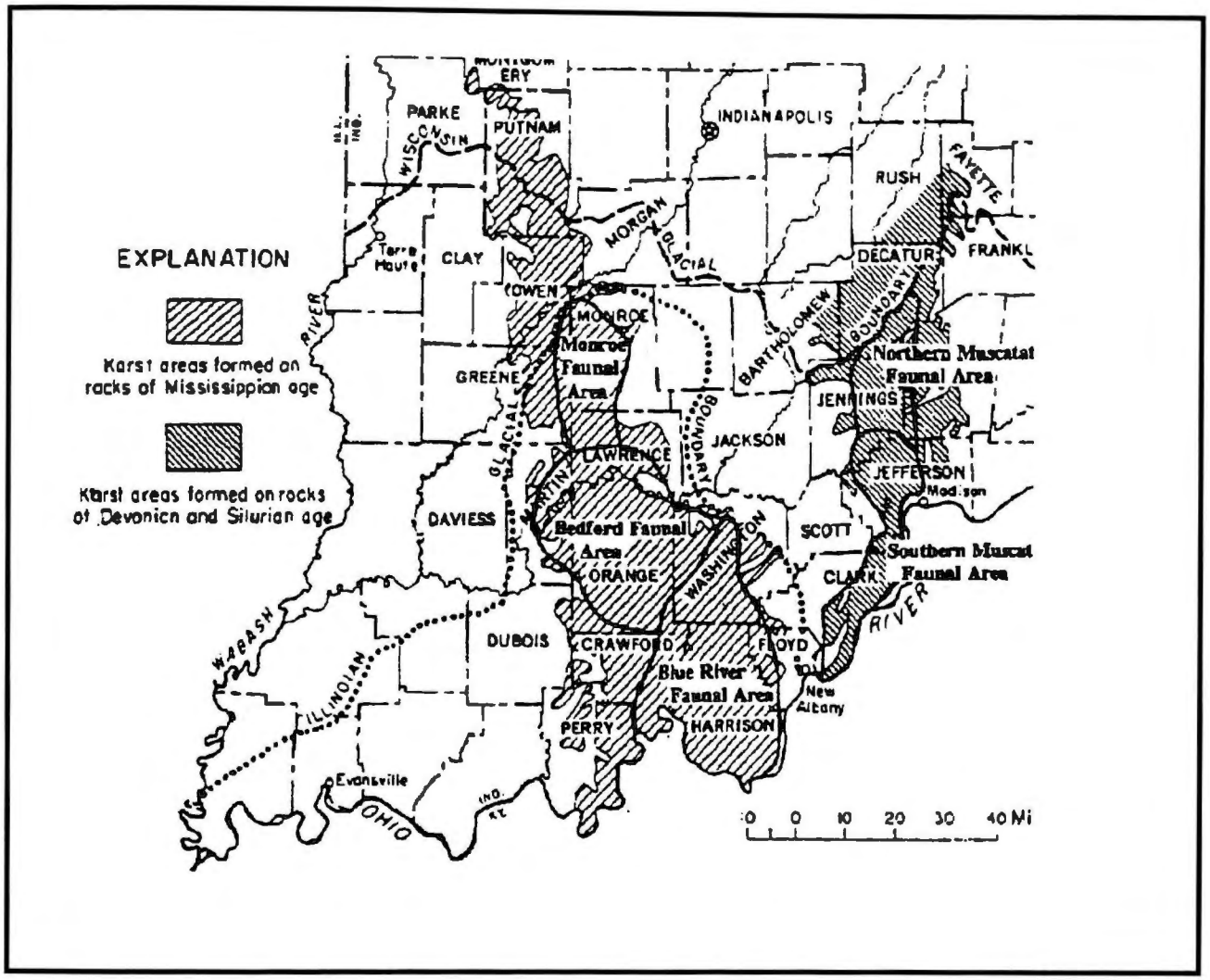

Figure 1: Approximate extent of the subterranean faunal areas of Indiana, modified from Barr (1963) - (map modified from Powel 1961)

(4) The **Southern Muscatatuck Fauna** includes caves on the Silver, Fourteen Mile and Big creeks in Clark, Jefferson and southern Jennings counties. The fauna of Clark and Jefferson counties received the majority of the attention in my previous work on the cave fauna of southeastern Indiana (Lewis, 1983). This fauna is characterized by, e.g., the carabid beetles *Pseudanophthalmus barri*, *P. chthonius*, the millipede *Pseudotremia nefanda*, the snail *Fontigens cryptica*, and the amphipod *Stygobromus mackeni*. It is of note that most of these species are restricted to Clark County, near the Illinoisan Glacier's southern boundary. Much of the karst of Clark County and its endemic cave fauna is threatened by the urbanization of metropolitan Louisville, Kentucky. Funding has been obtained from the Indiana DNR for the 1995-96 field season to inventory the fauna of these caves.

(5) The **Northern Muscatatuck Fauna** on the Vernon Fork of the Muscatatuck River (Jennings County) and Sand Creek (Decatur County), includes the caves at the Crosley State Fish and Wildlife Area. Only four species of troglobites had previously been reported from Jennings County (Lewis, 1983). At the conclusion of the 1994 survey at Crosley, 14 troglobites had been found.

Acknowledgments

Field work at the Crosley State Fish and Wildlife Area was funded by a funds from the Non-game and Endangered Wildlife Program, Division of Fish and Wildlife, Indiana Department of Natural Resources. Field work at the Lost River was funded by the Environmental Analysis Branch, Louisville District, U.S. Army Corps of Engineers, Contract DACW27-94-M-0110.

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Stable Isotope Evidence for Chemosynthetic Contributions into an Anchialine Cave System in the Northern Yucatan Peninsula

John W. Pohlman

Ecological investigations in Mayan Blue Cenote, an anchialine cave system on the east coast of the Yucatan Peninsula, indicate that the energetic demands of the resident troglobites (cave limited organisms) are partially satisfied by chemoautotrophically produced organic matter. It has been previously assumed that these ecosystems are detrital based. In other words, animals living in the dark recesses of anchialine caves were thought to depend completely on the transport of organic food material from photosynthetically productive terrestrial and aquatic habitats into the cave system. The data included in this report questions that paradigm, and inferences are made into the possibility that this chemosynthetic productivity is a common anchialine phenomenon.

By definition, anchialine caves are partially or totally submerged subterranean passages filled by a mixture of highly stratified fresh and marine waters (Stock et al., 1986) (Figure 1). These caves exhibit a circumtropical distribution (Iliffe, 1992) and are prominent geological features of most karstic, tropical, coastal regions. Their importance in the Yucatan Peninsula is especially pronounced as the caves serve as the major conduits for groundwater flow. Because the Yucatan lacks any significant rivers and streams, extensive cave systems are responsible for drainage of the entire coastal plain.

The groundwater within these caves serves as the primary water source for many Mexican citizens, a major attraction for the tourist industry, and, unfortunately, a sewage basin for developing areas. Thus, preserving and understanding this massive aquifer is of paramount importance to the many people who depend on this resource.

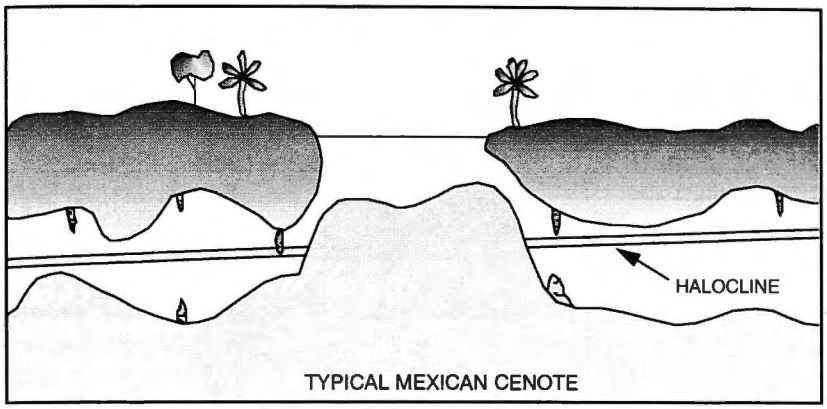

Figure. 1. Typical Mexican anchialine cave displaying open water cenote and adjoining cave passages. The distinctive halocline is labeled and becomes progressively deeper with distance from the coast.

Prior to this project, biological investigations had been limited to taxonomic and biogeographic studies. These studies have revealed a surprisingly diverse community of organisms which include 20 species of Crustacea and two species or fish specifically adapted to the cave habitat. Typically, these organisms display regressive features; lacking both functional eyes and pigmentation. This study represents the first significant data to explain how the biota from this region interacts with and survives in this dark, organically deplete environment.

Results and Discussion

Field operations approved by the National Speleological Society-Cave Diving Section began in the summer of 1993. Dr. Thomas Iliffe and I collected a suite of organisms and organic sources that could serve as nutritional sources (e.g. sediments and particulate organic carbon (POC)). Stable isotope mass spectrometric analysis of these samples refuted the possibility that the organisms in the dark reaches of the cave relied upon organic food sources of photosynthetic origin. Instead, the data suggested that the principal food source is of chemosynthetic origin.

In photoautotrophic systems from this area one would expect to find $d^{13}C$ values near -26% (Fry and Sherr 1984). This number represents $^{13}C/^{12}C$ ratio of organic matter formed during carbon fixation of photosynthesis relative to the standard, PDB Belemnite. This value (-26%) is typical for photoautotrophs utilizing the C3 photosynthetic mechanism. Further, this ratio plus a 1% enrichment factor is observed with each tropic transfer. So, one would expect the organisms collected from the cave to approximate -25%. This was not the case as the $d^{13}C$ values recorded from the organisms ranged between 26.2 and -42.5% (Figure 2).

The $d^{13}C$ values found are characteristic of bacterially mediated production of organic matter in chemoautotrophic systems. In, fact the range of isotopic values recorded from the organisms almost exactly matches that reported by (Kennicutt et al. and 1992) from numerous hydrothermal vent and hydrocarbon seep communities. This evidence led us to believe that hydrogen sulfide, the reduced compound utilized by thiotrophic bacteria to drive their metabolism, may be the energetic source that sustains the anchialine communities. Methane, ammonium and reduced metals (other possible energetic sources), however, were not ruled out as potential sources of energy.

In search of this answer, with financial support from the Cave Research Foundation, we returned to Mexico to collect additional samples. Based on our studies, methane and hydrogen sulfide do not appear to be significant energetic sources. The hydrogen sulfide concentrations were below detection (<2μM) and the methane concentrations exceptionally low (73-180μM). We did, however, find the concentrations of ammonium (NH_4+) and nitrate (NO_3-) surprisingly interesting. The high nitrate (2.75-18.64μM) and low ammonium concentrations (0-0.01μM) suggests that nitrifying bacteria may be oxidizing all of the available ammonium to nitrate and utilizing the energy from the redox reaction for biosynthetic purposes.

The following additional evidence reinforces the possibility that nitrifying bacteria may be important chemoautotrophic producers in the anchialine environment.. (1) Nitrifying bacteria prefer aphotic conditions (Ward, 1986) as is provided by the lightless caves. (2) Nitrification rates are highest in hypoxic conditions (<0.32mg O_2/l) (Elkins et al., 1985) . Oxygen concentrations are around 0.2 mg/l near the interface of the brackish and marine waters in the cave. (3) The chemoautotrophic bacteria from the genus, *Nitrobacter*, displays $d^{13}C$ values of -34 to -37‰ (Fry and Sherr, 1984), well within the range of organisms measured from Mayan Blue Cenote.

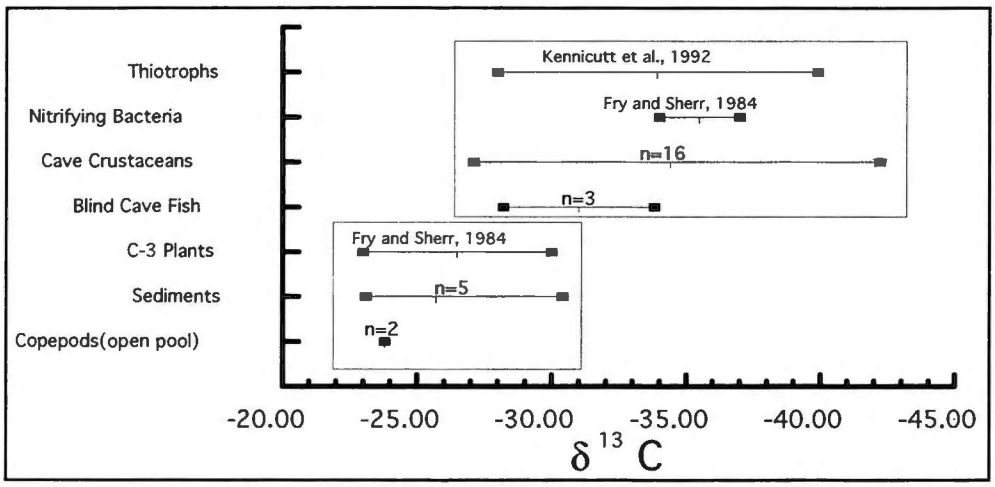

Figure 2. $d^{13}C$ isotopic variation of troglobites and sediments compared to typical reported ranges. The upper box is representative of chemoautotrophic systems and the lower box of C-3 photosynthetic systems. Note the disparity between troglobites and associated sediments, indicating dependence upon water column feeding.

Holsinger (1989) and Yager (1994) reported on the occurrence of assemblages of troglobitic crustaceans from several sites in the Caribbean similar to those found in the Yucatan Peninsula. These sites include the Bahamian archipelago and Cuba, and the crustaceans referred to are amphipods (*Bahadzia spp.*), thermosbaenaceans (*Tulumella spp.*) and remipedes (*Speleonectes spp.*). Considering the parallels in habitat and community structure, it is not hard for one to hypothesize that common biogeochemical processes conducive to chemoautotrophy may be occurring at these sites. In fact, measurements of DO, salinity and temperature from Mayan Blue resemble those reported by Yager (1994) from an anchialine cave in Cuba.

Conclusions

Although we have made great advances in understanding the processes that control the anchialine cave ecosystem, numerous questions remain unresolved. To answer these fascinating questions, additional research and support are needed. As we hypothesize that the major bacterial activity is occurring along the distinct halocline, project directives are oriented towards characterizing the chemical and physical habitat, as well as an intensive microbiological investigation. We plan to probe for a number of bacteria to identify the chemosynthetic producers and to utilize immunoflorescence techniques to quantify the bacterial populations. Furthermore, samples from other Mexican anchialine caves and a lava tube system from Lanzarote, the Canary Islands are being isotopically analyzed to expand our geographic understanding of this phenomenon. Aside from understanding the ecology of anchialine caves, what is learned from these investigations is fundamentally applicable to the understanding of other chemoautotrophic systems.

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Geosciences

Figure 1. Entrance to Embudo Cave, Cibola National Forest. Photo by Alan Hill.

Mineralogy of Embudo Cave, Sandia Mountains, Cibola National Forest, New Mexico

Carol A. Hill

Embudo Cave is a small (~100 meter long) cave located on Cibola National Forest property, Sandia Peak ski area, at an elevation of 2725 m. It has a single 4-5 m wide and 1.5-2 meter high entrance (Figure 1), and a single passage that follows the ~18° east-southeast dip of bedding in the Madera Limestone of Pennsylvanian age. Almost all of the passage has formed in shaley beds within the Madera; i.e., at the shale-limestone contact. A prominent bedding plane defines the ceiling of the cave passage (Figure 2). The cave is probably phreatic, rather than water-table or vadose, in origin. Ceiling anastomoses (Figure 3), where water came down along joints and mixture corrosion took place, and the lack of horizontal water-table development cutting across bedding, suggests phreatic development. No vadose solution scallops were noted in the cave. However, the cave has no doubt been modified by vadose rain and snow water moving into the cave from the surface.

Speleothems noted in Embudo Cave were dripstone (stalactites, stalagmites, columns), flowstone, draperies (including a fringed drapery), boxwork, a conulite, rimstone dams (microgours), calcite rafts, and popcorn coralloids (terminology after Hill and Forti, 1986). One small, incipient conulite ~5 cm in diameter and ~10 cm deep exists on the floor of the back crawl passage, with a splash rim around it (Figure. 4). The calcite around the hole has a velvety texture. The

Figure 2. Main Passage of Embudo Cave showing bedding plane ceiling. The cave passage slopes at same angle as the dip of beds; i.e., it is bedding plane- and dip-controlled. Photo by Alan Hill.

Figure 3. Ceiling anastomoses showing developmer along joint, probably the result of mixture-corrosio where solutions high in CO_2 moved down the joir and mixed with less $C0_2$-rich phreatic water, thu becoming aggressive and dissolving limestone up alon the joint. Photo by Alan Hill.

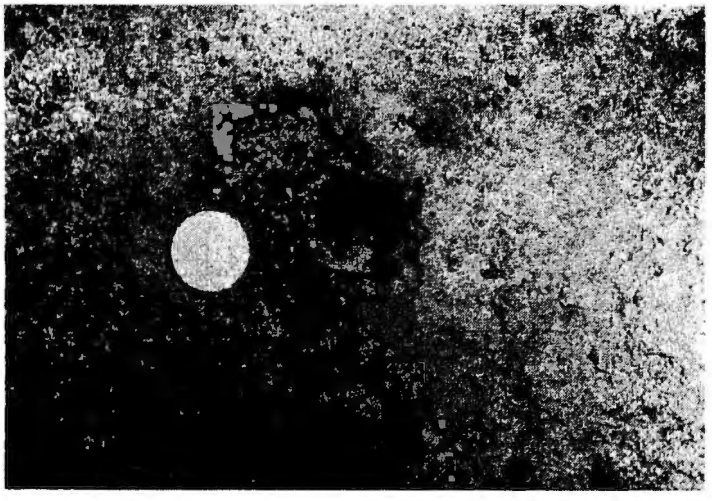

Figure 4. Small conulite in back of cave in crawl passage. Dripping water drilled hole in floor mud; calcite then precipitated over the surface of the drill hole as a coating. Quarter for scale. Photo by Alan Hill.

Figure 5. Fins of calcite boxwork, in ceiling of Main Passage. Ruler for scale. Photo by Alan Hill

Figure 6. Tiger skin-leopard skin, mud vermiculations on wall-ceiling near the cave entrance. Photo by Alan Hill.

boxwork (calcite) is exposed in the ceiling of the Main Passage: fins making up this boxwork are 2-3 cm deep (Figure 5).

The most unusual feature in the cave are mud vermiculations — relatively rare in caves around the world. These occur on the wall-ceiling near the entrance (Fig. 6), and are morphological cross between tiger-skin vermiculations and leopard-skin vermiculations as described by Hill and Forti (1986; their figure 121). Also near the entrance, on the right side of the passage near the ceiling and above the flowstone-rimstone area, is a red crustal material which is probably goethite. The red material lines fractures in the ceiling, and where breakdown of the ceiling rock has occurred, the red material is exposed. Also in the flowstone-rimstone area are "rootsicles"; i.e., roots from surface vegetation which have been calcified by speleothemic flowstone material. Calcite and goethite (.9) were the only mineral species noted in the cave; however, an unknown white mineral exists near the back of the cave. This material is not calcite (it does not fizz), it is somewhat unctuous, and it is suspected of being a carbonate (monohycrocalcite?). The mineral was not collected, as the author did not have a collecting permit.

Cave decorations in Embudo were stripped in the 1930's-1950's (as deduced from signatures on the walls dating from this time, before the cave was closed off by Cibola National Forest. The conulite may represent new growth since that time. It is recommended, from a mineralogical point of view, that the cave continue to be closed off, or that traffic be highly monitored, in order to insure the continuation of new speleothemic growth.

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Origin of the Holbox Fracture Zone: Influence of Tertiary Plate Tectonics on Morphology of the NE Yucatan Peninsula

Slawomir Tulaczyk

Application of remote sensing to analysis of karst morphology of the NE Yucatan Peninsula permitted recognition of the Holbox Fracture Zone, henceforth the HFZ, overlooked by previous ground-based studies (Weidie, 1985). Satellite and aerial imagery shows a number of large elongated low biomass anomalies that align into 50-100 kilometer chains trending roughly S-N. The anomalies correspond on the ground to <10 m deep, up to a few hundred meters wide depressions whose flat bottoms are located about at the level of the local water table and are blanketed with 30-100 cm thick layer of argillaceous muds (Tulaczyk et al., 1993). The de-

pressions contain occasional cenotes, i.e. water-filled sinkholes, and are subject to episodic/seasonal flooding. Because of their morphology and the flooding Tulaczyk (1993) proposed the name 'corridor poljes' for these features.

A few explanations for the origin of the morphologic features in the HFZ have been proposed by different authors. Southworth (1984) interpreted the surficial expression of the HFZ as "... extension fractures associated with a buried horst and graben system ...". According to Lesser and Weidie (1988) the elongated depressions in the eastern Yucatan are tectonic troughs created by dropping blocks up to 50 kilometers in length, and up to a few kilometers wide, by a mere 5 to 10 m. Both hypotheses relate the overall morphology of the HFZ to some faulting event of, however, unspecified age and character. Pope et al. (1994) suggested briefly in their recent paper that the HFZ can be related to the K/T Chicxulub Impact Crater just like another regional morphological feature, the Cenote Ring, is in NW Yucatan.

Using the published information on the HFZ and the results of my own remote sensing and field analysis of the region I propose a model for the development of the HFZ that is consistent with the geologic history of eastern Yucatan and with the available morphologic and hydrologic evidence.

The previous models invoked some faulting/fracturing event to explain the alignment of depressions within the HFZ. It was suggested that the depressions of eastern Yucatan have purely tectonic character. However, location of the flat bottoms of the depressions at the level of the local water table suggests that the features were created through dissolution for which the water table is an erosional base. In the case of purely tectonic origin, location of the bottoms of the depressions at the level of the water table would have to be regarded as a very fortunate coincident. The role of the tectonic processes has to be then secondary influencing the morphology through focusing of the dissolution.

One of the most important questions is the question of timing of the tectonic event, henceforth the HFZ tectonic event, that predetermined localization of the depressions. Since the surficial limestones, in which the forms are created, are of Mio-Pliocene age it would appear that the HFZ tectonic event should have taken place after the deposition of the rocks. Several lines of evidence can be used to constrain the age of the event. First of all, no historic seismicity is registered in northeastern Yucatan and its surroundings. The closest concentration of earthquakes is located a few hundreds of kilometers south at the Motagua suture zone of Guatemala and Belize (Lara, 1993). Szabo et al. (1979) showed that the eastern coast of Yucatan remained tectonically stable after the last sea level highstand at 125 ky BP. No major faulting is recorded in the unconsolidated deposits blanketing the offshore horst-and-graben structures of the Yucatan Borderland whose formation stopped in Late Eocene (Lara, 1993).

These facts point out to the problem with explaining the origin of the HFZ. Since the morphological features are created in Mio-Pliocene rocks that would suggest that the HFZ tectonic event postdates the rocks. However, geologic evidence implies that tectonic movements significant enough to create >100 kilometers long and 50 kilometers wide fault/fracture zone could take place at latest during the Eocene/Oligocene time. At that time the transtentional faulting related to a strike-slip boundary running roughly N-S along the eastern Yucatan ceased and the boundary shifted several hundred kilometers to the south.

I propose a model for evolution of the HFZ that reconciles the morphologic and tectonic history of the region. Two facts must be taken into account to understand the processes that shaped the HFZ. Firstly, the thickness of the Mio-Pliocene rocks in NE Yucatan is in a range of a few to several meters only, and secondly, the Oligocene through Late Miocene period was a prolonged, probably >10 m.y., period of erosion in this region. The latter is evidenced by a widespread unconformity existing between the Eocene and Mio-Pliocene rocks almost throughout the northern part of the peninsula (Ramos, 1975).

Considering the long time of subaerial exposure during the Oligo-Miocene time the surface of Eocene limestones should undergo intensive karstification. That karstification would take advantage of any preexisting fault/fracture zones that most likely developed in the Eocene rocks when the eastern Yucatan strike-slip boundary was active. I hypothesize that at that time a morphologic feature equivalent to the HFZ but prob-

ably more extensive and pronounced developed in NE Yucatan. This proto-HFZ would then be covered with a few to several meter thick layer of carbonates during the subsequent Mio-Pliocene depositional event. That event ended probably 1-3 my ago and a second period of karstification began in NE Yucatan.

During the second stage of karstification the paleokarst in the top of Eocene rocks mantled by younger carbonates was reactivated. In this way old, Eocene, structures influenced the surficial morphology of Mio-Pliocene rocks. Mantled karst is well known in Florida where an Oligo-Miocene paleokarst covered by siliclastic sediments of Mio-Pliocene age became also reactivated upon its exposure in Plio-Pleistocene (Gerstenhauer, 1969). The HFZ may then be a special case of mantled karst where the younger layers covering the old paleokarst are carbonate rocks instead of siliclastic sediments. Certainly, the exact morphologic development of paleokarst in the mantled-by-siliclastics and mantled-by-carbonates cases must be different, but the basic idea of reactivating old high permeability zones inherited from the previous stage of karstification is the same.

The above model has the advantage of reconciling the morphologic and tectonic history of the NE Yucatan. It is consistent with the existing morphological and geological body of evidence. However, knowledge of geology and geomorphology of NE Yucatan is so fragmentary that new constrains would be necessary to further evaluate and refine the model. If correct, this model of the HFZ origin points out to an interesting but previously overlooked phenomenon of reactivation of paleokarst mantled by carbonates. It is important to verify the extent to which this phenomenon occurs in karstic terrains as well as to elucidate the details of the mechanisms that are involved in such process.

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Burrows completely altered to chert. Note lens caps for scale. Photo by T. Eifert

Large Burrow Structures in Mammoth Cave National Park

Tambra L. Eifert

Some unusually large and well-preserved fossil burrows in the Saint Louis Limestone Formation (Mississippian, 360 million years B.P.) near P. Strange Palls in Logsdon River represent some of the earliest retrievable evidence for unique, large-burrow producers with complex burrowing behavior. They appear to represent galleries formed by deposit-feeding organisms, bearing similarities to burrows made by modern shrimp. Michelle Warren and I are presently studying these unique fossil burrows for a senior research project which is supervised by Dr. John M. Holbrook, Assistant Professor at Southeast Missouri State University. Our research is designed to address three primary objectives:

1) What organisms produced these burrows and why?

2) How and why were the burrows altered to chert? What is the nature of the environment and the substrate in which the burrows were excavated?

What makes these burrows so unique? The burrows at Logsdon River waterfall are predominantly horizontal and appear to have complex galleries with intricate networking, they are considerably larger than those normally found in deposits of this age, and they are older than most known burrows. In fact, complex burrowing behavior in large organisms did not become prevalent until at least Mesozoic time (65-245 million years B.P.), and most of the burrows preserved prior to then are only millimeters in diameter. Evidence of such large burrowing organisms as those seen in Logsdon river prior to Permian time (245-286 million years B.P.) consists of only rare reports of poorly exposed burrows, with simple, straight pattern which are scattered individually over a limited area. Previously known burrow exposures of pre-Permian age have not provided the opportunity to adequately chronicle the evolution of large and complex burrowing organisms; that opportunity is now provided by the Logsdon River burrows.

Due to its unique preservational environment, the research site provides unusually excellent exposure of the burrows in their original position. Almost all of the burrows are entirely replaced by a hard, corrosive-resistant chert. The easily corroded limestone surrounding the borrows is preferentially dissolved by the active flowing water of the passage, leaving the chertified burrows cleaned of their host rock and standing out from the wall in relief. Rapid flowing water near the waterfall also keeps the burrows swept clean of sediment transported by Logsdon River.

By far the largest concentration of the burrows still in their original position occurs at P. Strange Falls. Here the burrows are exposed in the upper three feet of a cherty zone in the St. Louis Limestone Formation. The burrows are visible along the walls, ledges, and floors of the cave. Approximately 50-80% of the floor is covered by these burrows. All possess a thin coating of pyrolucite (MnO_2). Some are completely altered to chert, whereas others are found with either hollow centers or alternating ring-like bands. The interior of the bands varies somewhat, but the majority contain a crystalline calcitic-chert mixture. Broken and fragmented burrows are found in the upstream passage from the waterfall.

To address our objectives, we are first photographing the site in detail using photo-mosaics. These are prepared by piecing together a series of overlapping photographs taken perpendicular to and at equal elevations from the cave floor. The completed mosaic will serve as a base map, allowing close examination of the behavior patterns apparent from the individual burrow traces. With the permission of Mammoth Cave National Park, a few of the burrows are being sampled for closer petrographic examination. Thin sections are being examined to detect changes in texture and/or mineralogy. In this way, we expect to reveal how the burrows were filled and the processes which lead to their chertification.

We are also preparing a stratigraphic column of the burrow site, emphasizing the lithology, distribution, and thickness of the St. Louis Limestone near the waterfall. From the stratigraphic column we plan to determine exactly what organisms produced the burrows and

Cross section of chert filled burrow. Photo by T. Eifert

the mature of the environment (for example, deep versus shallow water) in which they lived.

What is the important of these findings? Our research should offer insights into the origin of ancient large burrow structures as well as enhance our understanding of the organism which produced them. We hope to also further our understanding of the evolution of burrowing behavior in large organisms.

This project is funded by Southeast Missouri State University in cooperation with Mammoth Cave National Park. Field assistance has been generously provided by the Cave Research Foundation.

A Rancholabrean Cave Site in Northwest Alabama

Marla Jo Spry

Abstract

Cave Little Bear II (ACb-3) in northwestern Alabama contains a faunal assemblage interbedded with datable travertine flowstone. Uranium/thorium dates on flowstones indicate that small vertebrate remains began accumulating in Little Bear II about 228,000 years B.P. and larger vertebrates gained access to the cave from about 170,00 years B.P. to at least 115,000 years B.P.

Introduction

Before 1985, the Pleistocene faunal record for Alabama consisted of two reports from fluvial and sinkhole deposits in northwestern Alabama (Currin *et al.*, 1976; Womochel, 1982). Since that time, Red Mountain Museum, Birmingham, Alabama discovered another northwestern Alabama cave, Little Bear II. The cave contains datable calcite flowstone interbedded with faunal remains. The large faunal assemblage preserved between layers of travertine flowstone includes *Megalonyx jeffersonii* (Jefferson's ground sloth), *Smilodon* sp. (sabertooth cat), *Arctodus simus* (giant short faced bear), and over 20 species of microvertebrates. Most of the faunal remains have yet to be described. Preliminary investigation established a stratigraphic sequence of sediments and flowstones that provide a chronologic framework for the Little Bear II local fauna (Lively *et al.*, 1992). Uranium/Thorium dating of travertine flowstone resulted in dates ranging from 228,000 years B.P to 121,00 years B.P. (Figure 1). The top unit of sediment lacks a flowstone cap thus the upper age limit is undetermined. Little Bear II probably hosted a variety of animals after 121,000 years B.P. (Lively *et al.*, 1992).

Kurten and Anderson (1980) discuss the absence of Rancholabrean sites with absolute ages dating prior to the Wisconsinan Glacial (>70,000 years B.P.). Little Bear II contains faunal remains within stratified deposits predating this glacial event. Most sites of this early age rely upon biostratigraphic associations to determine successions of fauna (Repenning, 1987). However, the Pleistocene fauna associated with datable flowstone at Little Bear II allow comprehensive examinations of fauna groups within an absolute time frame.

Little Bear II

Located in the Interior Low Plateaus physiographic province of northwestern Alabama, Little Bear II, occurs in a small hill about 1 kilometers south of the Tennessee River. Approximately 70 meters long and 15 meters wide, the cave formed in the Tuscumbia Limestone 41 meters above present river level. The present entrance is a vertical chimney 48 cm wide and 5.1 meters deep.

Sediment and Bone Deposition

Three main sources account for the sediment and bone deposits. One of these is a sinkhole talus which apparently served as a natural animal trap and surface entrance after 228,000 years B.P. (Fig. 1). A second, probable late Pleistocene entrance, which is now collapsed, offered walk-in access to large vertebrates after 172,000 years B.P. Bone articulations and taphonomy of several M. jeffersonii in the main room suggest that the animals died after entering the cave. Thirdly, a long tunnel enlarged by dissolution of the limestone contains large and small mammals in Unit D (Figure 1). Articulated specimens in this unit also indicate that M. jeffersonii and other large animals walked into the cave for denning during the early Rancholabrean and died there. Hydrologic activity in this side tunnel created flowstone and rimstone pools above Unit D (Figure 1). Water flowing into the cave through this fissure probably carried sediment and faunal remains, which collected in pools between the rimstone dams. Unit E represents this depositional event and contains disarticulated faunal remains (Lively et al., 1992). Each depositional situation preserved individual animals that appear to have entered the cave either by accidental entrapment, whole as prey, or seeking shelter. A fluvial scenario probably describes the sediment and bone accumulations of Unit E. Figure 1 shows the fauna identified in Little Bear II from Units H, D, and E (Lively et al., 1992).

Unit D — Clayey sediment resting upon basal silty clay.
- At cross section Z - Z':
  - Upper Unit - may be equivalent to Unit E in other part of ACb-3.
    - *Megalonyx jeffersoni*
    - *Odocoileus virginianus*
  - Lower Unit
    - *Megalonyx jeffersoni*
    - *Odocoileus virginianus*
    - *Sylvilagus* ? sp.
    - *Sciuridae*
- At cross section Y - Y':
  - *Megalonyx jeffersoni*
  - *Sylvilagus* ? sp.
- Main cave other than noted cross sections:
  - Dasypus bellus
  - Lynx rufus
  - *Megalonyx jeffersoni*
  - *Mylohyus nasutus*
  - *Tapirus* sp.
  - *Canis* sp.
  - Felidae
  - Anura

Unit E — Rimstone pools, side tunnel
- Between X - X'
  - *Tapirus* sp.
  - *Mylohyus nasutus*
  - *Megalonyx jeffersoni*
    - Adults and infant
  - *Dasypus bellus*
  - 22 other small vertebrates

Unit H — Channel fill on basal silty clay
- At cross section X - X'
  - *Blarina* sp.
  - *Neotoma* sp.
  - *Microtus* sp. (2)
  - ? *Spilogale putoris*
  - *Sylvilagus* ? sp.
  - Sciuridae
  - Anura
  - Chiroptera (2+?)
  - Colubridae

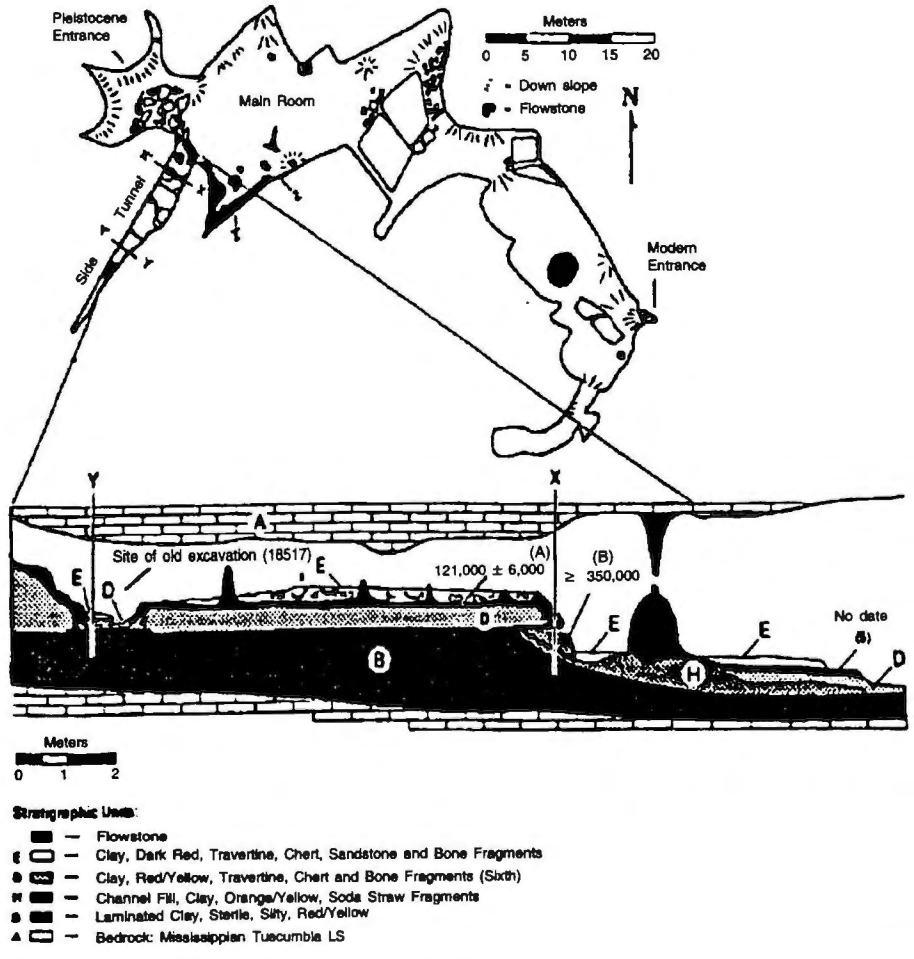

Figure 1: Cave Little Bear II with identified fauna and U-series dates (Lively et al, 1992)

Current Research

This author continues research at Little Bear II as part of the master of science requirements in the Quaternary Studies Program at Northern Arizona University. My thesis focuses on the identification of the microvertebrates contained in sediment samples previously excavated from Little Bear II. The dates obtained from flowstone overlying and underlying bone bearing beds provide a chronologic framework for the identified fauna. After establishing the biochronology, I propose to determine whether the deposits in Little Bear II represent interglacial, glacial, or interstadial climatic regimes based on climatically sensitive species.

Lively et al. (1992) demonstrate the importance of datable flowstone associated with Pleistocene fauna at Little Bear II. Their study, however, does not include reconstructions of the paleoenvironments in which *M. jeffersonii* lived. Little Bear II represents the only known site suitable for a detailed analysis of the climatic conditions that prevailed between 228,000 years B.P. and 121,000 years B.P. in what is now northwestern Alabama. An environmental reconstruction of the local faunal of Little Bear II will involve the use of microvertebrates as climatic indicators (Barnosky and Rasmussen, 1988; Graham and Semken, 1987). Because the ecological and physiological tolerances of certain species act as precise indicators of climatic conditions, the habitats and ranges of modern species provide the basis for these reconstructions.

Summary

Cave Little Bear II in northwestern Alabama contains faunal remains interbedded with datable calcite flowstone which will provide the needed chronology for analysis such as paleoenvironmental reconstructions and Pleistocene extinction studies. The investigations at Little Bear II are ongoing and many people contribute to the project.

Acknowledgments

I thank my committee members at Northern Arizona University; Dr. Jim Mead, Dr. Larry Agenbroad, and Dr. Kathryn Cruz-Uribe. Dr. Greg McDonald, Hagerman Fossil Beds, Idaho, serves as an outside committee member. My thesis receives invaluable support from Dr. Gordon Bell, South Dakota School of Mines; Susan Henson, Discovery 2000, Birmingham, Alabama; and James Lamb, Alabama Museum of Natural History.

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Cave Research Foundation Activities 1996

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Page 69 photo credit: East Side Passage, Fitton Cave, Arkansas.
Photographer: Scott Dankoff

1996 Highlights

Annual Meeting

The CRF Board of Directors meeting was held on October 18, 1996 in Prescott, Arizona. Chuck Pease and Cynthia Vann hosted the meeting.

President Phil DiBlasi presented a revised set of bylaws that he submitted to the Board for debate, revision and amendment. After careful review and consideration and with a few changes, the Board voted to accept the revised bylaws. To comply with the approved bylaws that modify membership classes of the Foundation, all CRF JV's are now classified as members. The CRF member category has been renamed to CRF Fellows.

The following individuals were elected as Fellows to the Cave Research Foundation: Barbe Barker, Lois Bergthold, George Bilbrey, Pat Copeland, Cheryl Early, Chris Groves, Barry Loucks, Rita Loucks, Dick Market, Dave McClung, Roger Mortimer, Mike Pearson, Danny Vann, Rick Toomey and Chuck Pease.

In order to better manage its time and priorities, the Board established an Operations Council. The primary responsibility of the Council is to coordinate and conduct the routine operations of the Foundation in its various areas. These functions and duties will include but are not limited to, organizing and running expeditions, drafting facility agreements and financial agreements, maintaining property audits and forwarding such documents to the Board for approval as is appropriate. The Operations Council is to meet at least annually, in concert with the Annual Meeting of the Board of Directors.

To get the Operations Council up and running, Scott House and Pete Lindsley agreed to resign their director positions and serve on the Operations Council. Pat Helton submitted his resignation to the board several months ago.

Tom Madison resigned as the Operations Manager for the Guadalupe Escarpment Area. Barbe Barker (TX), has been appointed to take his place.

Ron Bridgemon resigned as chairman of CRF's International Exploration Committee. He recommended Chuck Pease as his successor and the Board approved the appointment.

Hamilton Valley Project

The Board appointed a new Building Committee made up of Dick Maxey (chairman), Cheryl Early, Sheila Sands, David Hansen, Richard Zopf, Joyce Hoffmaster and Phil Bodanza. The charge of the committee is to develop a final set of plans and specifications for the Hamilton Valley facility, including bunkhouses. Plans and specifications that this Building Committee is to draw or cause to be drawn are to be of detail sufficient that they can be used for obtaining sound construction bids and building permits approvable by all local Kentucky authorities on the basis of reliable information. The Board authorized an expenditure to fund the operations of the committee.

"Don't Mess with Mammoth" Clean Up

Cave Research Foundation and volunteers with the American Cave Conservation Association (ACCA) and Mammoth Cave National Park (MCNP) teamed up on March 15, 1996 at CRF's Hamilton Valley site to elimi-

Hamilton Valley property, photo by Scott House

nate soil erosion problems. Seven truckloads of waste were removed from the site.

Hamilton Valley is located within the Pike Spring Basin, which is prime habitat for the Kentucky Cave Shrimp, the Northern Cave Fish and many other cave adapted aquatic species. Situated just east of the Park, Hamilton Valley is within the Zone of Cooperation in the Mammoth Cave Area Biosphere Reserve, the goals of which are to conserve biodiversity and to develop a sustainable economy.

NPS/CRF Science Conference

The Annual Science Conference sponsored by Mammoth Cave National Park and CRF was held during the weekend of August 1-2 at the Park. A total of 37 researchers exchanged their most recent data on topics that included biology, ecology, geomorphology, cave management, geology and history. CRF speakers included Stan Sides who discussed the discovery, exploration and mapping of Buffalo Creek Cave; and Mick Sutton and Sue Hagan reporting on their work with the Mammoth Cave Gazetteer of cave place names.

CRF Assists Japanese Film Crew at MCNP

From March 28 through April 1, CRF members performed some unusual fund-raising roles as guides, sherpas and bit-actors for a Japanese film crew filming at Mammoth Cave for a series on World Heritage sites. Eastern Operations Manager Mike Yocum coordinated the CRF efforts with the film company on-location work from March 28 through April 1, 1996. The film company initially contacted Mammoth Cave National Park to arrange the filming and was referred to CRF for additional assistance. NPS staff provided the first-day "walk-through" and a ranger to supervise all in-cave filming. Park Superintendent Ronald Switzer and NPS historian Bob Ward were also interviewed. Almost a full day's filmmaking was devoted to CRF archeologists Pat Watson, George Crothers and Naoko Yokoyama. Their segments involved filming in the Historic section with concentration on Native American artifacts such as a climbing pole, slipper remnants, a fairly intact gourd bowl, and a very impressive paleofeces specimen. CRF President Phil DiBlasi was filmed displaying a detailed CRF map of the upper levels of Salts Cave and the Mike Yocum, Mick Sutton and Sue Hagan did an in-cave demonstration of mapping techniques. Film segments were also shot in Hidden River Cave.

CRF's work was done on a contractual basis, the contract providing lodging and meal expenses for volunteers plus a $100 per day for each participant to be donated to Eastern Operations.

Expedition/Project Support

CRF provided a grant of $500 from the International Fund to the Gunong Buda Project who will be fielding an expedition to Borneo in early 1997. The Foundation also agreed to financially support the CRF China Caves Project so that they can fulfill their obligation to the Research Exchange facet of the project. As a result, CRF will sponsor 3 Chinese researchers to the US in the Summer of 1997.

CRF Fellowship & Research Grants

The Cave Research Foundation received thirteen proposals in 1996. Of these, one Fellowship and three Grants were funded, for a total of $8500.00. Following is a summary of the awards.

1. *An Intraspecific Cladistic Analysis of Population Structure and History in the Troglobitic Planthopper Oliarus polyphemus in Volcanically Active Regions of Hawaii Island.* Ms. Keri E. Williamson, Department of Biology, Washington University, St. Louis, Missouri 63130 1996 Karst Fellowship in the amount of $3,500.

This research uses population genetics data and behavioral and geological information to elucidate patterns of speciation and relations between populations in a cave-adapted planthopper species complex *Oliarus polyphemus*. These critters dwell in lava tubes in volcanically active regions of Hawaii Island. Consequently, they have undergone repeated expansion, contraction, and isolation events during their relatively short geologic history.

There are significant differences among mating calls of geographically close populations, an indicator of significant divergence between populations. Ms. Williamson will be using genetic data from these populations to construct a cladistic network in order to elucidate historical relations of these populations. The hy-

pothesis to be tested is that *Opolyphemus* is not limited to humanly accessible caves, but is distributed continuously throughout innumerable voids in the lava substrate. Anticipated insights to be gained include understanding of how habitat fragmentations have influenced the evolutionary history of this species, and the identification of species status in the species complex. As the identification of unique populations of *O. polyphemus* is likely to mirror similar or analogous patterns in other cave and surface organisms, this study's conclusions will help to identify crucial biological regions as key targets for conservation efforts.

2. *Faunal Resource Selection and Utilization, and the Development of Agriculture in Eastern North America* Ms. Elizabeth Monroe, Department of Biology, Washington University St. Louis, Missouri 63130 1996 Karst Fellowship in the amount of $2,000.

Ms. Monroe is a zoo-archeologist whose research addresses the transition from hunter-gatherer to farming cultures in eastern North America. Rock shelter sites located in the east-central Kentucky uplands at the western edge of the Cumberland Plateau offer sound prospects for success, because of the excellent preservation of organic materials in the shelters. Faunal diversity, bone modification practices, and body part representation in faunal assemblages of the shelters are the issues that should yield the key insights. For example, plant remains will indicate if these Late Archaic cultures practice farming and if so, then determine the relations among agricultural patterns and faunal assemblages.

Hypothetically, these cultures lived a sedentary life-style with seasonal overtones. They cultivated plants and used other resources more intensively than did previous cultures probably in response to pressures caused by an increasing population. Thus, faunal evidence should show an increase in species richness and evenness, including and increase in numbers of small mammals and other vertebrates procured, and an increase in the systematic procurement of bone marrow and grease. Bone fragmentation is expected to increase over time, reflecting evolving procurement and preparation techniques indicated by changes in bone modification patterns. Those skeletal elements prized for high-nutrient yields are likely to be overrepresented in the faunal record. Results obtained from the shelters of southeast Kentucky will be compared to results obtained by researchers working elsewhere in the eastern US to gain insight into the place of the local culture in the evolution of an agriculturally-based economy.

3. *High-resolution Paleoclimate Reconstruction in the Pokhara Valley Region, Nepal: Searching for an Asian Monsoon Signal in Speleothems.* Mr. Rhawn F. Denniston, Department of Geology University of Iowa, Iowa City, IA 52242 Karst Research Grant in the amount of $1,500.000

Mr. Denniston proposes to test if the nature and timing of fluorescent banding in speleothems reflects seasonal growth patterns and preserves the seasonal variability of precipitation-derived ^{18}O oxygen isotopic composition. If the fluorescent banding proves to be seasonal, the technique would be applied to analyzing the Holocene-Late Pleistocene climate history in eastern Nepal, where the present climate is dominated by the Asian monsoon. A high potential for a high-resolution paleoclimatic record is likely. The results from the Pokhara region could be combined with results from speleothem-based studies obtained from caves elsewhere in central and southern Asia to construct an isotopically-based view of the history of monsoon migration and associated precipitation patterns.

4. *High-resolution Temporal Variations in Ground Water Chemistry: Tracing the Links between Climate and Hydrology in a Karst System.* Ms. MaryLynn Musgrove, Department of Geological Sciences, University of Texas, Austin, TX 78712 Karst Research Grant in the amount of $1,500.00

Ms. Musgrove will examine temporal fluctuations in ground water chemistry in the Edwards aquifer of central Texas, using strontium isotope variations in speleothem calcite. The approach has yielded good results in speleothems from Barbados; the application of this new technique to a geologically distinct setting, the Edwards aquifer, will help to test the Barbados model.

Improved understanding of the Edwards aquifer and developing new ways to evaluate records of climate variability in terrestrial environments should be the principal advances afforded by this research.

Operation Area Reports

Arkansas Operation Area: Fitton Project Report

Pete Lindsley

The Fitton Cave Survey Project in Arkansas fielded six expeditions during 1996. A total of 43 cavers attended the expeditions and spent a total of 460.5 people-hours underground. Five of the expeditions were 1-day trips and one was a 3-day trip. A total of 15 survey parties worked in the cave during 1996. An additional 74 people-hours were spent topside working with GPS survey locations, ridgewalking and location of two new entrances.

Emphasis was placed on several areas in Fitton Cave during the remaining expeditions. Surveys along the East Passage tied several lower level surveys to the brass caps, which will allow closure verification on several previous surveys. An area above the Double Drop Pit complex was surveyed and an extensive lower East Passage area was continued.

A precision laser rangefinder was used on two expeditions to generate a precision profile of the Entrance Room. At the April expedition two teams worked in the East Passage. A tie was made to the upper level GS survey and a survey was placed into the upper Fossil Breakdown Room. In May three teams continued in the same area. One team worked the side leads near the RE survey, one team experimented with ceiling measurements with the DISTO unit, and one continued the survey in the Double Drop upper breakdown room area.

During the July trip two days were spent working with minor caves and one day was spent in Fitton. A wet lead was surveyed to completion under the Bat Cave Cascade, which was almost dry. A detailed field check for leads in Willis Cave was completed with no success in pushing towards the end of the Fitton Entrance Room. A survey was made of Waterfall Cave and the upper entrance was located and checked. A ridge walk out over the portion of Fitton Cave between the T-Room and Jurgends Leap allowed established improved station marking and GPS locations for the four cave radiolocations. We also worked just off the East Passage in Fitton Cave. One party returned to the Lower East complex, one party located and surveyed in the Kansas Turnpike shortcut, an one team continued surveys in the Double Drop Pit complex.

In September one party returned to continue survey of the lower levels of the East Passage just beyond the Needle's Eye. Another team started a precision vertical profile survey of the Entrance Room of Fitton.

Work continued on the profile survey in October. A standard survey line is established along the profile route in the middle of the room and the survey line is sketched to scale on large sheets. The laser unit is used to measure the distance to both the floor and the ceiling along the survey line at appropriate locations.

Eastern Operations Activities

compiled by Pat Kambesis

Eastern Operations ran 11 expeditions from Maple Springs Research station and one from CRF's Hamilton Valley property. In addition to the standard objectives which include research support and survey/inventory work (in the Mammoth Cave System and in smaller caves within the Park), CRF teams worked on benchmark restoration, film crew support, and provided manpower for a the Crystal Cave Historic Restoration project.

Archeology

Two archaeology teams were fielded to a breakdown area in Historic Mammoth during the July expedition. Team One described the collapse as the "Ner-

vous Breakdown," and reported that it was "rich in both cultural and natural prehistory." Their observations included cane torches, bat stain from roosting bats, raccoon scat full of bat bones and historic signatures (MK 1908). Strong airflow through the breakdown was noted and they reported "understanding the route and destination of this airflow is crucial to restoration of the Historic Entrance ecotone. They also completed a digital photographic panorama of what may be virgin passage with cane torch fragments. Team Two also worked in a second large breakdown area in Historic. They climbed as far up the pile as they could and then began to work their way back down, observing cane torch fragments and polish. A lot of bat staining was also observed on walls and ledges. They reported it is possible that this area saw direct aboriginal use.

Survey/Cartography/Small Caves Inventory

Survey and cartography related work continues in Mammoth Ridge, Flint Ridge, in Proctor Cave and in the Logsdon River. Teams were also fielded to Roppel Cave and Sides Cave. There was a strong emphasis on Small Caves Inventory work and the November expedition was dedicated to this project.

Geology

Sediment-mapping work was conducted in Long Cave. The first objective was to do a preliminary reconnaissance to locate sediment deposits best suited for description and paleoflow reconstruction. Three particularly good sediment exposures were identified. A "fascinating fossil coral colony" was observed as well as an unusual lilac purple wall coating. It was noted that further mineralogical work in the cave is warranted.

The bulk of the team's in-cave time during their second visit was spent mapping stratigraphy at the X-10 pit sediment exposure. An excellent sequence of infilling and excavation was documented and observations were made which further the hypothesis that the Mammoth Cave region was semiarid some 1.5 million years ago.

Richard Zopf setting brass caps during Small Caves Inventory work. Photo by Rick Toomey

Historic Signatures documentation

The recovery of historic signatures in Main Cave continued during the February expedition. Data collection grids were tied to existing survey stations in the vicinity. A second crew covered 500 feet of passage in the area of the TB huts. Photographs were taken of notable name clusters including ALFRED 1846, Stephan S. Bishop and, a drawing.

In March, three Mammoth Cave Register teams went in through the Historic Entrance to work in Main Cave. Team One began work just beyond Star Chamber and at K16 discovered two mummified bats and part of a woven slipper; it was noted that the slipper was "dangerously close to the tourist trail." Numerous obscure signatures were discovered and time was spent checking high ledges where signatures are frequently recovered.

A second crew worked their way along the dry and dusty Main Cave passage into the vicinity of Wright's Rotunda. Among the notable information gathered in the 800 feet they surveyed were the names "w Steele 1819 Nov 23,11 and "GS Gate-wood," and the Indian glyph on Map Rock. Future parties will need to use the Violet City entrance in order to continue this part of the project.

The third team went in through the Historic Entrance and proceeded directly to a crew already working in the Star Chamber. Their mission was to deliver survey station location information that was unavailable to them when they departed camp. Party Three encountered a ranger-lead tour in the Rotunda and was requested to escort a man and his two small children, who had become frightened when they stepped out of Houchins Narrows into the huge Rotunda, out of the cave. They gladly agreed and took the visitors back to the entrance, pausing to show them some airflow measuring equipment and the old ventilation shaft.

Paleontology

A crew examined the Rotunda to Gothic Avenue route in February, searching for an appropriate area to attempt a Quick Take panorama. A 16-picture series was completed. This served as an initial test to see if this type of photography may serve as a tool in documentation, presentation and education in a cave system.

During the Memorial Day expedition, two paleontology teams, with a wide range of objectives, were fielded throughout the Park. Team One rappelled into Doyle Valley Entrance to continue with data collection and photodocumentation of the burrow chert at P Strange Falls. Team Two went through the Proctor Crawl to examine vertebrate paleontologic deposits at the end of Frost Avenue. Extensive deposits of bat bones on sediment surfaces, and in the sediments as well, were observed. Surface materials yielded three identifiable bat species, the most common being Myotis. It was noted that bat bone deposits were most frequently observed in areas with cricket nursery/beetle digging habitat, possibly the bioturbation is moving bones and concentrating them on surfaces.

A paleo team went in through Mammoth Cave Historic Entrance to work in Little Bat Avenue. They photographed 15 series of 16 pictures using an Apple QuickTake 150 digital camera. The pictures will be used to construct a series of Quick-Time Virtual Reality panoramas that can be linked into a virtual walkthrough of the area. The trip was made during the October 1996, expedition for the purpose of testing the use of the camera. They downloaded the pictures into a PowerBook computer in-cave and checked to see how well the area was photographed using this technique. Hopefully the photo series will act as a model of types of things that may be done to document important cave areas and provide educational tools. The photography and downloading was very successful. Picture quality will be evaluated and the panoramas will be constructed on a computer at the Illinois State Museum.

Two teams worked in Main Cave over the Thanksgiving expedition, in order to assess the general extent of Mexican Free-tail guano in the area. They worked between Chief City and just beyond Hain's Dome to gather information to estimate the amount of time mapping the deposits will take during an upcoming paleontological inventory. The most significant deposits were photographed. They were also able to identify two areas that could be used by interpreters on ranger-led tours.

Biologic Reconnaissance

During the March expedition, Dr. Horton Hobbs delighted everyone present with another visit to Mammoth Cave. Four students involved in biological reconnaissance accompanied Dr. Hobbs on two trips during which four caves were visited.

Their objective was to locate and examine various caves as potential study sites. The first trip began with a hike from the Good Spring Church trailhead and up the Dry Prong to Forts Funnel Cave. A rappel down the entrance drop revealed high water levels and high velocity turbid water but conditions did not prevent the determined crew from seeing a rich variety of terrestrial fauna and several *Cambarus tenebrosus* in the stream. A cable ladder was used to exit the Cave. Buffalo Creek Cave was the next stop an the agenda for this busy team but the visit yielded little due to high water; the current was too swift to venture far upstream or downstream, After a hike in the rain back to the trailhead they visited Dogwood Cave. They observed a waterfall putting a "good volume of water" into the cave and plentiful fauna.

The second reconnaissance trip visited River Hall to refamiliarize Dr. Hobbs with the base level aquatic habitats in Mammoth and especially with the peculiar hydrology of the River Styx and Echo River. Water clarity was poor and no fish or crayfish were observed. Interestingly, River Styx flows toward Echo River under low stage conditions, but ripples in the sand deposited by the last high water indicate flow in the opposite direction. Photographs were taken of the sand ripples.

Recently flooded mudbanks were surveyed for terrestrial fauna and a bristletail and springtail were observed.

Training

A survey/cartography-training seminar was conducted during the Memorial Day expedition. Bob Osburn instructed the survey training class, using Mammoth Cave as the classroom. He led a group of student-sketchers into Marion Avenue where he set out survey lines for them to follow. The students sketched several stations to scale and had an opportunity to compare CRF survey books from the early 70's with those of the 1990's. Back at Maple Springs the students worked-up pencil drafts of their in-cave sketches and the results of their cartography attempts were reviewed and critiqued.

Miscellaneous

Film Crew Support: At the Memorial Day expedition, CRF escorted a Discovery Channel camera crew to two in-cave locations in the Park to shoot scenes for a show featuring Mammoth Cave which is expected to air in October. The crew went in through the Doyle Valley Entrance on their first day of work. They shot extensive footage of the ongoing work being conducted by researchers of the burrow chert project. Several shots of CRF cavers entering and exiting the cave through the Doyle Valley entrance were also captured on video. The Discovery crew's second day of caving was spent in Olivia's Dome where they documented Larry Mallory's microbiology research site and filmed a discussion of general cave biology.

Benchmark Restoration: During the July expedition, two USDI Benchmark restoration crews worked along the present-day tourist trails. Party One located and cleaned benchmarks in Main Cave, Pensacola Avenue and the Wooden Bowl Room. They noted that the benchmarks in the cave "need to have periodic care and maintenance to insure they have not been buried or destroyed. Party Two located and cleaned all benchmarks and azimuth marks from the Carmichael Entrance to the Frozen Niagara Entrance. The only caps not located were in the Snowball Dining Room and Grand Central Station. They experienced difficulty with the double locks on the Carmichael Entrance and reported the benchmarks, "need reflective tape attached nearby" for easy locating.

Crystal Cave Restoration: Mammoth Cave National Park and CRF staff met during the Labor Day expedition to visit each of the three buildings on Flint Ridge that were scheduled for demolition. The reviewed project goals, clarified objectives and overall project plans. They inspected the Austin House, the rear Bunkhouse, the Speleo Hut and the immediate environment of the three buildings. Work zones were defined. CRF-NPS coordination arranged salvageable materials noted and a preliminary work agenda was outlined. During the Thanksgiving expedition, work commenced on the Austin House where inner walls, ceiling, insulation and a large amount of loose, nail-infested wood were removed. Insulation was bagged but due to rain, work on exterior paper and roof removal was not done. Removal of the porch, kitchen, roof and exterior walls remains for future parties. In December, crews loaded demolition debris into a 30-yard dumpster. They also sorted through building remains and salvaged bricks, concrete, wood, windows and metal for use in other projects. Digital photographs were taken of the cleared site and will be included in the interim project report to Mammoth Cave National Park.

Guadalupe Escarpment Area

Carlsbad Caverns National Park

Barbe Barker

The focus of fieldwork at Carlsbad Caverns National Park has broadened to include resource inventory and restoration in addition to cave survey. Ongoing training includes hands-on instruction for geologic and mineralogic inventory, restoration methods and basic surveying and sketching. Newcomers must now participate in three restoration trips before getting involved with cave survey activities. Hands-on training sessions cover mineralogy identification, and basic knowledge of common speleothem types, secondary corrosion/dissolution features and basic clay identification. The emphasis on training and restoration allows CRF to provide more support for the objectives and needs of Carlsbad Caverns National Park.

Another significant change in operation objectives is that the Cave Resource Office at the Park has decided to organize and manage a new re-survey effort at Carlsbad Cavern. Cave specialists met with CRF officials and agreed upon a game plan as follows:

> All original survey notes will stay with the park and eventually be archived in the museum.
>
> The Cave Resource Office will provide survey designations for all areas of the cave.
>
> Survey designations will be short and concise and not change as side passages are encountered.
>
> The cave will be divided into sections to make data management easier.
>
> No single group will have exclusive access to the cave for resurvey/exploration purposes.
>
> The cave specialist must approve all sketchers before they will be allowed to sketch in any cave in the park.
>
> All groups must comply with Appendix H: Cave Survey Standards for Carlsbad Caverns National Park, (part of the Carlsbad Caverns Cave and Karst Management Plan),

To date the resurvey project of Carlsbad Cavern has been very productive. CRF, as well as other groups, have been working hard and brining back quality data and sketches. Resurvey efforts have concentrated on Left Hand Tunnel, Lower Cave, Guadalupe Room, New Mexico Room, Jim Whites Tunnel and the Painted Grotto area near the Polar Regions. Careful resurvey work has resulted in the discovery of significant segments of passage off of many of the known areas.

Restoration work is ongoing at Lake of the Clouds, Chocolate High, the Ranger Room and the Balcony in the New Mexico Room. Restoration work involves flowstone cleaning and popcorn bush reconstruction, trail reflagging, removal of hand and boot prints from trails and formation. Flowstone areas on main routes have now been designated and marked as "aqua sox only" zones - where anyone traversing the area must remove boots and wear aqua sox. Tourist route clean-up has included cleaning chips, rubble and coins from pools, cleaning flowstone along the visitor trail at numerous points, covering electrical cables, removing rocks left by trail maintenance staff, cleaning lint from flowstone, removing debris from Bottomless Pit (this harvest yielded coins, transmitters, bullets, etc.); cleaning up bottom of National Geographic Pit, including removal of coins and a battery from the pool and other related cleanup.

Lincoln National Forest—Capitan Peak Study Area

Dick Venters

Spring 1996

The April 1996 CRF-LNF-CPSA expedition was held during the week of April 20-26th. The long sought-after permit to dig in DBF arrived a few weeks before the expedition and our plans for the dig were finally

realized.

During the weekend, all volunteers attending helped with the continuing Precision Theodolite surface survey, an ongoing project, to precisely locate known cave entrances and the major karst features in the study area. All known features are tied to previously set station points and USFS quarter section monuments.

At the beginning of the expedition, we were visited by Mr. John Brown, a senior Lincoln National Forest official. During the visit our crew discussed objectives for the cave dig. We also set objectives with respect to what LNF personnel would like us to do for the protection of all the resources, and how we can work together in this effort for our mutual benefit. CRF objectives and plans were also discussed along with how we can benefit in resource information gathering and the protection of all karst features within the study area. The meeting was an extremely productive one for both the CRF and the LNF.

The dig at DBF was started along with preliminary reconnaissance within the cave. Estimations of the breakdown and debris removal was discussed and plans for "safe removal" were determined. A day was spent trying to extricate a 6x4x3 foot block of limestone (megalith!). The block was finally reduced to a few manageable pieces for removal.

With information we learned from a pair of turkey hunters who had visited our camp earlier in the week, we walked an area on the Baca Ridge to locate large paleo-sinks and caves that the hunters had previously come across. We found the sinks along with numerous large drop-sink blocks (paleo-sinks) and two small caves.

This area is one of many prime karst areas with the LNF and will be a secondary study area. Lloyd Swartz and Dr. Dennis Worthington asked for the primary responsibility for caving logging and ridgewalking the area. They will maintain a report of their activities and any karst features that they find. We plan a return trip to this area in October of 1996.

Toward the end of the week, the weather did not cooperate and we experienced one of the worst wind storms (greater than 70 mph) on DBF Ridge. These high winds made it very difficult and unsafe to work above the cave entrance and safety was our main concern. The winds finally let up during the midafternoon and work on DBF continued. After removal of the megalith limestone boulder debris, our crew selected a new approach and area for the dig. This new area looks very promising.

After our preliminary reconnaissance, we found a boulder fracture, approximately four inches wide, with very cold, moist air blowing from it. We began removing dirt, debris and breakdown for the rest of the afternoon. We knew this would be the last day for the dig, so leaving here was a bit hard to take. All in all, the knowledge we gained and the promise of a possible cave will keep our hopes high for a return trip in October.

Caver-volunteers: Dick Venters, Glenda Dawson, Glen Dawson-Rhodes, Lloyd Swartz, Dennis Worthington, Janelle Worthington, Jeffery Worthington, Loretta Worthington, Jim Hardy Fritzi Hardy, John J. Corcoran III, Dorothy Corcoran, Randy Cabeen.

Fall 1996

The fall 1996 CRF-LNF-CSPA expedition was held during the week of October 12 through the 17th, 1996. Eleven brave and hardy souls from New Mexico, Arizona and Colorado attended this year's expedition.

Our first few days were spent at Baca Ridge, ridgewalking and checking out new locations for future expeditions. Baca Ridge is an area with excellent karst features and potential. The area contains many extremely large sinks, some with small cave entrances. One of these areas showed great potential as evidenced by the fact that four or five drop-in cave entrances were discovered. All karst features on Baca Ridge were GPS'ed and logged for future reference. Other accomplishments of the expedition included:

Dig and reconnaissance started on DBF Cave. Volunteers continued removing large rock debris from the entrance pit. Biologic inventory, lead pushing, and video documentation completed at Serpentine Root Cave.

Cave-volunteers attending: Dick Venters, David Sherrow, Frank Mastrilli, Virginia Venters, Anita Pittenger, John Corcoran III, Dan Sullivan, Lloyd Swartz, Dorothy Corcoran, Bob Pape, Tom Harris.

Lava Beds Area Report

Janet Sowers

The Cave Research Foundation continues to assist Lava Beds National Monument with cave surveys, cave resources inventories and other projects. Our objectives are to thoroughly document the caves, to scientifically evaluate the caves and the resources they contain and to provide input to the management of the cave.

We document caves at Lava Beds by five steps, of which only the first two are required for every cave. The steps are: (1) a Reconnaissance Cave Inventory card is filled out, (2) the cave is assigned a number, brass marker is installed at the cave entrance, and its position established with GPS, (3) the cave is surveyed and a map prepared, (4) a General Resources Inventory is conducted, (5) special studies of specific resources or issue are conducted, and (6) a monitoring program is set up to document the conditions of specific resources.

We are presently concentrating our efforts on steps 2, 3 and 4: mapping, marking and inventorying. This past year, we surveyed 5 caves and conducted resource inventories on 3. To date, we have installed 60 brass markers at cave entrances and have obtained GPS locations for 10. We gave final copies of drafted maps to Lava Beds for several caves that had been surveyed in previous years.

Caves surveyed include Trench Bench, The Big Ice Cave, Do Drop In, Nirvana, Lyons, Sort-of-Bridge, and Gemeni. Caves inventoried include Silver, OK Corral, and Lyons Road Cave.

Mike Simms and Bill Deveraux are continuing the monitoring of ice levels in six ice caves that have perennial ice pools, a program begun in 1989. They measure from an established point on the ceiling down to the top of the ice floor. This is done twice a year, in the spring and fall, to try and record the maximum and minimum ice levels each year. Ultimately these data will be used to establish the relationships among climate, visitation, and ice levels.

Jona Perez checking a lead in Crystal Ice Cave, Lava Beds National Monument. Note that the floor is ice. Photo by Dave Bunnell

This past year CRF assisted the Monument in the preparation of individual management action plans for the Class 4 caves. These are caves that for various reasons required special management. Many of these management action plans are already being implemented. For example, new interpretive signs, new railings, and improved trails will be installed at Symbol Bridge to help protect the pictographs there.

Plans are being forged for building a small research facility at Lava Beds. This facility would house groups such as CRF that conduct research projects of benefit to Lava Beds. The facility's 1500 square feet will contain bunk rooms, equipment and file storage, work space, kitchen, lavatory and porch. Over Thanksgiving weekend we made a topographic survey of the site to enable our architect, Micheal Minert, to make a conceptual sketch of the facility.

Once the sketch is done and a "marketing brochure" prepared, the next step is to raise the money, most of which will come from donations. The monetary objective is $80,000.

Missouri Operation Area

Mick Sutton

Missouri Department of Conservation

CRF has branched out to a new Missouri project area. Crews led by Matt Beeson began a survey and inventory project in central Missouri (Boone County).

Survey and inventory work has commenced in Hunter Cave; a large and popular cave on Missouri Department of Conservation (MDC) property, along with some smaller MDC caves in the area. An initial trip resulted in 500 feet of survey starting at the Echo Entrance and including Echo Hall, the Attic, and the beginning of the main passage, Cave Avenue. Photographic documentation and a biological inventory were also begun. During a follow-up trip, the large, complicated passage resulted in slow going. The survey included a difficult climb up to Mud Dome, continued through some tricky up and down passage, and ended in the Maze just before the Duck Crawl. The party also pushed a small lead, finding a quick end in a narrow dome, which a previous visitor has labeled Fool's Dome. They recorded an unusually large population of 20 pickerel frogs. A third crew began in Cave Avenue and surveyed through the Duck Crawl and into the Pig Crawl (small and nasty with lots of water and mud). This ends in the Pigpen Room, which includes some very nice dripstone. The survey continued along the main line beyond the Devil's Bathtub to the Keyhole. The total survey length is a little over 1,000 feet.

On a later trip, the Hunters Cave crew took advantage of a warm winter day to run a 1,300-foot surface survey between Tumbling Cave and Sink Cave. The caves are hydrologically connected and will appear on the same map. There was also a preliminary bioinventory of Sink Cave.

A party mapped and inventoried Two Flakes Cave near Powder Mill, Shannon County. An NPS archeologist recently discovered the cave. It is at an unusually high elevation, and consists of 100 feet or so of unpleasantly small and contorted passage. On another trip, one party looked unsuccessfully for a vaguely reported cave on MDC property while a second team went to MDC land off the Tacks Fork River and inventoried four relatively small caves along the upstream reach of Aliens Branch (site of the notorious Aliens Branch Cave). The most interesting find was a dark-zone harvestman, only the second Missouri record of this particular species.

Powder Mill Creek Cave was extended a bit further with 350 feet of complicated new passage in the Hell Hole Series. The crew ended the survey at a T-junction with a fairly large trunk, which continues unexplored in two directions.

Mark Twain National Forest

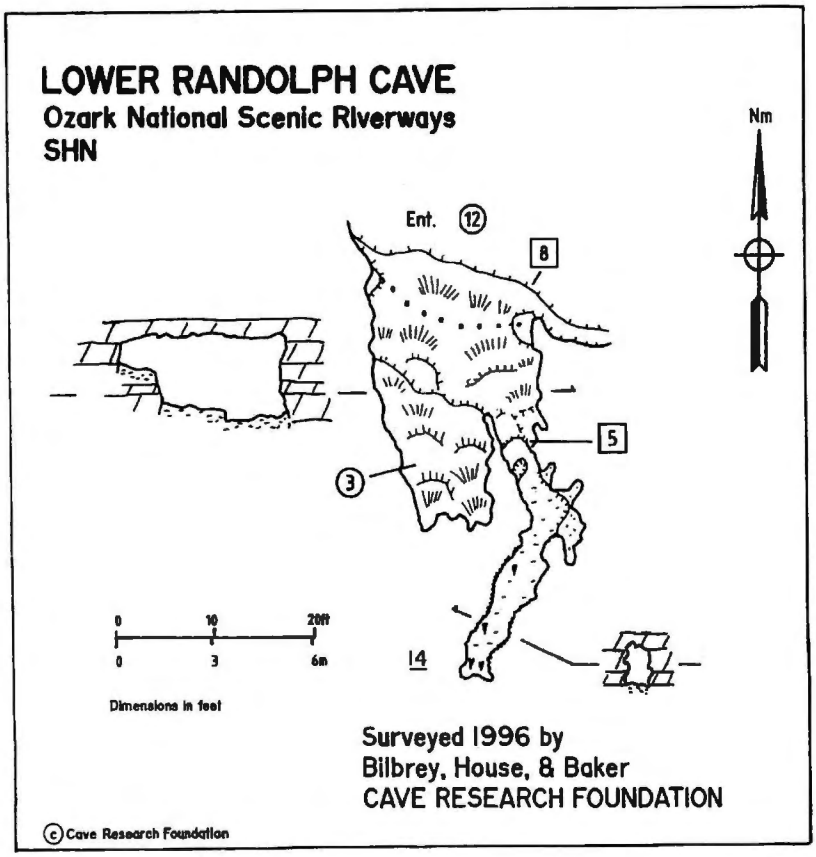
There were two trips in support of the Mark Twain National Forest Eleven Point District project. A party returned to River Level (Thundering Rapids) Cave to complete the survey. The 350-foot canyon passage mapped on this trip ended in a low and sleazy water crawl, giving a total length of 700 feet. A biological inventory was completed; the stream life was diverse and included troglobitic snails and crayfish in addition to a unique record (as far as we know) of lampreys, two of which seemed to be excavating a spawning pit in the gravel, well within the dark zone. As far as we can tell, lampreys have not previously been recorded from Missouri caves.

Whites Creek

There was another backpack trip to Whites Creek in the Irish Wilderness, where a previous crew had found a state of considerable confusion arising from contradictory earlier reports on a series of small caves. Armed with some entrance photographs from the early reports it was discovered that Beaver Pond Cave and Porifera Cave and a few other caves were mislocated. The CRF crew mapped Porifera and Den Caves, each consisting of small, mazey crawls connecting two entrances. The party also located other caves along Whites Creek, many of them unrecorded. Them Cave was an exception; it turned up at the advertised location, and 300 feet of passage was mapped. Before giving up in favor of re-

turning with a larger crew and a clipboard.

A several months later, a two-person crew spent a week camping at Whites Creek float camp along the Eleven Point River in the Irish Wilderness, where they mapped and inventoried three small unreported caves (Phoebe, Hummingbird, and Salamander), doubled the surveyed length of Them Cave to 750 feet (with more to go), found and mapped a shelter, and mapped and inventoried Flat Cave (previously unreported) for 500 feet of very flat going. Several caves (White Cave, Niche Cave and Freeman Breakdown Cave) were nowhere to be found; none of these appear to be at or near their alleged locations—the nearest object to a cave within the search area was Armadillo Pit, only 12 feet long. Drastically wet weather resulted in Creekbed Cave and Porifera Cave Annex being more or less underwater, and resulted in a fast exit trip by canoe down to Riverton.



A survey and bio-inventory trip went to Everette Chaney Cave, farther upriver on the Eleven Point. Two mapping crews worked from opposite ends of the cave and met in the middle of this approximately 1,000-foot long maze. A search for neighboring Spider's Parlor Cave was kept brief owing to hot and sweaty conditions; although the cave in question was not located, two other small unreported caves were found. On the way down-river cavers swung by the entrance to Dead Man Cave, finding that there was no sign or barrier to dissuade casual visitation to the gray bat maternity site. The survey of Davey Crockett Cave in Howell County continued. The crew, suffering from miscellaneous colds, contented themselves with 300 feet of dry mop-up survey, bringing the surveyed length to 4,082 feet. It is unlikely that the cave will prove to be less than a mile long. Elsewhere on the Mark Twain National Forest, there was another trip to Davey Crockett Cave in Howell County, where a survey crew pushed the downstream passage. The emphasis in this part of the cave is to find an alternative route around a "uncomfortable" segment of passage. The party mapped 280 feet in a passage that continues to get wetter, though not yet quite wet suit passage. Some biological notes were taken. The surveyed length of Davey Crokett Cave stands at 3782 feet.

Ozark National Scenic Riverways

The Missouri bioinventory crew began a new project at Round Spring Cavern, a large NPS tourist cave on the Ozark National Scenic Riverways. CRF will be producing a general biological assessment for help in preparing NPS educational materials, and will track population fluctuations on a seasonal basis. A reconnaissance party spent seven hours taking a preliminary look at the biota. The most noteworthy finding was the highest population density of aquatic salamander larvae any of us have seen, somewhat in excess of a thousand individuals. Other interesting findings included a small population of troglobitic spiders and a variety of bats, including an unusual cluster of what we believe to be small-footed bats (*Myotis leibii*), a species listed as rare in Missouri. During three subsequent trips,

census areas were set up for following invertebrate population fluctuations, and bait stations were established for obtaining a more comprehensive picture of the terrestrial invertebrate communities. Food sources in the cave are generally scarce, despite the occurrence of large quantities of gray bat guano; this derives from historic bat colonies which have long since disappeared, and the guano seems to be thoroughly leached out and sterile.

Current River: Also on the Ozark National Scenic Riverways, a float crew paddled down a stretch of the Current River and mapped two small caves, the larger of them 80-foot long. They also obtained more accurate locations for a number of known caves and noted three unrecorded entrances which, being in an overhanging bluff, will be difficult to enter.

Round Spring Cavern: There were three trips to this large NPS tourist cave on the Ozark National Scenic Riverways. The parties continued doing bioinventory and began a photo-documentation project. The most remarkable biological observation was that the vast population of lanral salamanders noted previously in a group of shallow pools has crashed to a total of one rather large and well-fed individual—has there been cannibalism, predation, migration, or some combination? It will be interesting to follow this cycle through a year or so.

Richard Young and Paul Hauck at Dead Man Cave along the Eleven Point River, Mark Twain National Forest.
Photo by Scott House

Pioneer Forest

A survey crew worked on the Leatherwood Creek area in the privately owned Pioneer Forest, Shannon County. The party located and mapped Boulder Cave, about 200 feet long, and Harley Patton Cave, about 400 feet long, with a large entrance and some nice speleothems.

Sequoia and Kings Canyon/Mineral King Area Report

John C. Tinsley

Lilburn Cave Survey/Cartography

CRF fielded six expeditions involving survey/cartography. There were a twenty-one trips into Lilburn Cave, with a total of 4500 feet of new passage being surveyed using about 500 stations. The total length of Lilburn Cave (excluding redundant surveys and tie-ins) is now 15.83 miles (25.48 kilometers), with a total of 7000 stations set. See Lilburn Cartography Report in Cartography/Resources Inventory section of this publication for detailed survey and cartography overview.

Sedimentology of the Redwood Canyon Karst

Sediment-related activities this year include monitoring of sediment movement through lower portions of Lilburn Cave, observations of active sinkholes, springs, and stream terraces within the Redwood Canyon karst, and monitoring rates of sinkhole infilling for selected sinks along active watercourses.

Within the cave, sediment movement this year was minimal, chiefly owing to the absence of peak runoff sufficient to entrain sediment. Static sediment samplers in the Lake Room area and near the White Rapids sampled only suspended load at the lowest level (6 inches above low water). The spacing of sample tubes was decreased from 1 foot to 6 inches in order in increase sensitivity to presence of lesser amplitude events.

Sinkhole activity was expressed as increments of sediment that accumulated on the bottom of Pebble Pile Sink, as shown by buried vegetation mats, and retreat of slopes that shed sediment into sinkholes. At risk is the Redwood Canyon trail, which currently is a minimum of 18 feet from the north lip of Pebble Pile sink, having retreated approximately 18 feet to the north since 1989. Fluvial terraces composed of fine micaceous sand that originate at Big Spring have accumulated during decreasing discharge in Redwood Creek downstream of the confluence with the spring branch.

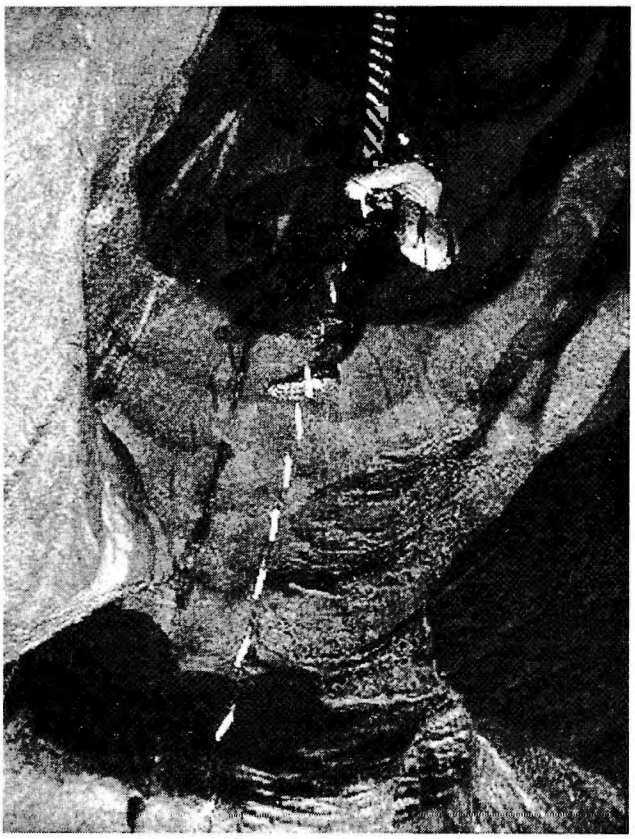
The 1996-1997 winter is already proving to involve large volumes of runoff occurring in a short time so the prospects of observing major geomorphic changes in the active parts of the karst this coming year are exciting. We look forward to conducting additional long-term monitoring of sedimentary processes in the Redwood Canyon karst.

Digging

Digging in Sequoia and Kings Canyon National Parks in 1996 was limited to two locations.

Brad Hacker and Joel Despain dug into a sand-mud-root plug in a cave on the southern side of the Yucca Creek drainage across from the entrance to Hurricane Crawl Cave. The excavated section of passage is similar in size and shape to the original passage, and remains completely blocked.

About 12 individuals participated over 4 days in the rediscovery of 'Ellis Dig' Cave several hundred meters distant from Lilburn Cave in Redwood Canyon. About 0.5 cubic meters of material blocking the entrance was relocated within 10 meters of the entrance. Half a dozen old, rusty buckets were removed from the site along with a well-preserved Estwing hammer. More than 100 feet of passage was surveyed.



Cable ladder climb in Lilburn Cave. Photo by Dave Bunnell

Rescue Update

Moderate progress in rescue preparedness in Redwood Canyon occurred this year. Reconnaissance trips was made for potential rescue routes in Lilburn Cave. Roger Mortimer, Bill Frantz, Vance Stevens, and Mike Morales, the subdistrict ranger responsible for search and rescue in Redwood Canyon, went in the Double Skungie/Corkscrew route to look at the obstacles in the route. On the way out they checked the route from Lake Room Junction past the Jefferson Memorial which had been suggested as an alternate route. They all felt that this route had too many obstacles and that the Skungie/Corkscrew route remains the best choice.

More importantly for rescue at Lilburn, several rangers underwent NCRC training this Fall. Both the search and rescue coordinator for the Park, Scott Wanek and the subdistrict ranger for Grant Grove. Mike Morales took Level I training along with several other SEKI personnel. This now makes for several key players in SAR in the park with a much better knowledge of the

issues involved in cave rescue. Significantly, Mike has now been underground at Lilburn and seen the obstacles there. Several CRF fellows and members were involved with the NCRC training at SEKI.

1996 Wire-Stringing and Plans for 1997

In 1996, the job of replacing the Communications and data line within Lilburn Cave was completed. The final 1500 feet was installed bringing the total footage of 12-connector telephone line to 5000 feet. The new, high capacity line runs generally next to the old phone line along the principal north-south trunk route from the Meyer Entrance to River Pit Avenue with a new spur leading up to Crevice Way. Ultimately this line may be extended to the Old Entrance. The line will be used to collect measurements of wind velocity, drip rates, and various chemical parameters as required by the hydrology project in addition to the traditional use of the line for voice communications and safety purposes.

The project to replace the wire was organized and financed by Mike Bettencourt and his friends, with some final assistance from the National Park Service. Although Mike's employment frequently kept him out of the state during the past year and a half, he supervised all of the early cave trips and participated in as many expeditions as his work schedule permitted. The effort required two and a half years of work by several teams of joint venturers. Tasks included stringing the wire, splicing the 1000-foot long sections, and removing debris from the cave. This year should see the entire system completely installed and tested.

The two phases of work remaining include installing the phone drops and adding the proper connectors to connect the in-cave portion of the wiring to the Lilburn Field Station and to connect the River Pit Avenue data logger at RI. These final connections will occur later this year, following selection of the best route from the cave to the Field Station. The phone line will be buried, perhaps inside PVC tubing for increased protection.

The Cave Research Foundation is grateful to Mike Bettencourt for his support of this project and to the National Park Service for supporting the research effort at Lilburn Cave.

Lilburn Restoration Project Report

The Lilburn Restoration Project ran three trips in 1996. Restoration activities were concentrated in the Jefferson Memorial/Blue Passage and the Angel's Tears areas.

The north end of the Blue Passage was cleaned and restored and the passage left in a pristine state. The Jefferson Memorial, in an area with white rimstone dams covered in mud, was also cleaned. Unfortunately, the mud has been there long enough so additional calcite has formed over it. Cleaning formations at the Angel's Tears and the Untouchable above the West Stream was accomplished and most of the dirt was removed..

Mineral King Area

The activities and research near Mineral King, California are conducted under the auspices of CRF and the National Park Service. The research builds directly on earlier studies conducted by Bruce Rogers in the late 1970's and a major cartographic effort in White Chief basin coordinated by Bob Richards (then of the Southern California Grotto, now of Union Oil Company of Houston, Texas.)

Mineral King Valley is drained by the Kaweah River, the principal drainage for the western Sierra Nevada at this latitude. Several caves are associated with the Kaweah drainage. Lost Soldier's Cave and Clough Cave are located on the South fork of the Kaweah, Redwood Creek which include, Lilburn Cave, drains South into the north fork of the Kaweah River: and the Yucca Creek karst area which includes Crystal Sequoia Cave (tile show cave operated by the Sequoia Natural History Association) also nourishes the Kaweah basin. Mineral King itself is a former mining camp and presently is a major trailhead for the southern Sierra Nevada. The rocks underlying the Mineral King valley area are mainly non-carbonate pre-Cretaceous metamorphic rocks and Cretaceous granitic rocks of the Sierra Nevada. These petrologic assemblages have inspired several Ph.D. and M.S. studies. A series of Pleistocene alpine glaciations have stamped the landscape with textbook alpine glacial geomorphology. A classic U-shaped main valley is flanked by smaller tributary valleys that

are, in turn, U-shaped and hang hundreds of meters above the main valley and head in bowl-like arcuate depressions (cirques).

The caves occur in several folded and faulted bands of marble that crop along either side of the main Mineral King Valley for several kilometers. In the south, caves occur (1) in White Chief basin and Eagle Lake basin on tile west side of the valley and (2) in the Panorama Creek basin (in the cast side of the valley. The marble exposures are white or light gray in color and stand in marked contrast to the darker metamorphic rocks and gray granodiorites that comprise most of the area's non-carbonate rock. There are also caves near Timber Gap in the northern end of the valley, and beyond but these are not discussed here. As the Mineral King caves occur at high elevations, the air temperatures within them are chilly — in the 30's of degrees F. Cave streams are also chilly, for the melting "white stuff" from which they derive lies but a short distance further up slope for much of the year. The vegetation is sparse and soil mantle thin or absent in the recently glaciated cirques, so rainfall during intense convective thunderstorms adjacent to the Sierran crest is intense and runoff, rapid. Parts of some of the caves thus pose a flood hazard to cavers.

White Chief Basin and the White Chief Cave Group

Cirque Cave (10.000-foot elevation) and caves below it are a present focus of CRF research in White Chief basin. In 1995-6 field seasons the mapping of Cirque Cave was completed and field-checking is underway: surveying of White Chief Cave has commenced. Other caves in the system are being mapped as time and attendance permit. Baseline hydrologic studies were completed by Lori Schultz in partial fulfillment of her senior thesis requirement at Sonoma State University. Dye traces conducted in the late 1970's and repeated in 1995 show Eagle Lake drains to Tufa Spring, a major resurgence and local water supply located near Mineral King. Geologic mapping by Tinsley and Schultz showed that the marble band in White Chief Valley is not separated by faulting from other karsts of the western side of Mineral King basin. Rather, the marble trends northward beneath a mantle of glacial deposits (shown by a string of shallow sinkholes) and traverses beneath the ridge that separates Eagle Lake basin from White Chief basin (shown by aligned sinkholes that mark the glacial mantle). This year we plan to confirm the hydrologic connection that is compelled by the geologic mapping.

Panorama Basin and the Panorama Cave Group

Alto Cave. Bathing Cave, Sink Cave, Panorama Cave, and other karst features of the Panorama Valley lie above 10,000 feet in a small hanging valley on the east side of Mineral King Valley. This hike is physically more demanding than the hike to White Chief basin, because the karst is at a slightly greater elevation and the trail sports a steeper finishing kick. Panorama Cave was the site of an experimental karst inventory conducted by Carol Vesely. The survey of the system is largely complete, exceeds 3800 feet and has linked Sink Cave with Panorama Cave. Surface surveys have been completed to tie together the principal karst features of this valley. Smaller caves in the area also have been surveyed. Tony Troutman of the University of Southern California is undertaking a study of the hydrology and structural setting of the Panorama system as a component of his M.S. research.

Cartography/Resource Inventory

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

Scott House

Introduction

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 vast majority of these less-extensive caves. Management of these resources cannot 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 seeks to establish an inventory system that will produce usable data on these caves on an ongoing basis.

An initial study area, selected by the National Park Service (NPS), consists of several drainage basins on the north side of the Green River. Included within this area are at least 5 caves longer than 1,000 feet and approximately 35 other, mostly unverified, locations of smaller caves. Previous work in the study area includes 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, the first year of which has been completed.

Objectives

The project has 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 first year. One larger and approximately 12 smaller caves were selected for developing the system the first year.

Field work has taken place on a regular basis every month for the past twelve months. Virtually all of this field work has taken place during regularly scheduled CRF expeditions at Mammoth Cave National Park. The field work has had three important objectives, which are occurring simultaneously: the field work is being accomplished, the methodology is being refined, and training of personnel is ongoing.

Over the last year, field work has been extremely successful and above expectations. One large cave (Running Branch Cave) and 19 smaller caves have been inventoried. Nineteen GPS locations have been obtained and a brass cap, with identification number, has been placed at the entrance of 21 caves. In cooperation with the CRF cartography program, 13 caves were mapped during the past year; in addition, survey data from 14 caves that were previously mapped were utilized. There was also survey and inventory work done in four larger caves, which are still in progress. Inventory data was collected on the entrances and at approximately 200 data points (survey stations) within the caves. Entrance photographs were taken at 22 inventoried caves. Additionally, another 25 cave locations were visited and found to be in error, there were no caves at these locations. Sometimes these locations were springs, sinks, blowing holes or other karst features; many times, however, the locations were apparently just errors or mistakes in transcriptions from other sources.

Field Methodology

The process for a single cave usually involves two separate visits. An inventory/mapping crew visits the location first. This is a priority since so many of the locations are in error. The entrance is photographed, described, and located on a topographic map. The cave is then surveyed using standard CRF techniques.

As the cave is surveyed, it is also inventoried by several of the team members. The inventory process is somewhat free form, which is a different approach from earlier inventory processes. In these earlier approaches the cave is inventoried using checklists which are done either for the entire cave as a single entity or are done at each survey station. These approaches were rejected for a variety of reasons: 1) quality control is very difficult with the checklist format since anyone can make a check mark whether it is appropriate or not, 2) the whole cave approach is not appropriate because the data is to be incorporated in the MACA GIS utilizing the cartographic data as the link, and 3) we want for inventories to concentrate on the features of the cave, relating those features to a survey station rather than focusing on the survey station and then looking for a feature to be checked off. This final reason is a philosophically different approach: we wish for people to go into the cave with their eyes wide open for features, not survey stations. As the cave is inventoried a notetaker records the inventory information and notes what station the features are found near. The goal of the inventory is to obtain as much information as possible within the restrictions of time and money. The data are qualitative but only relatively quantitative; that is, standard transect sampling techniques useful for surface work are not being used. Further, the biological sampling is restricted to field identification; no specimens are collected.

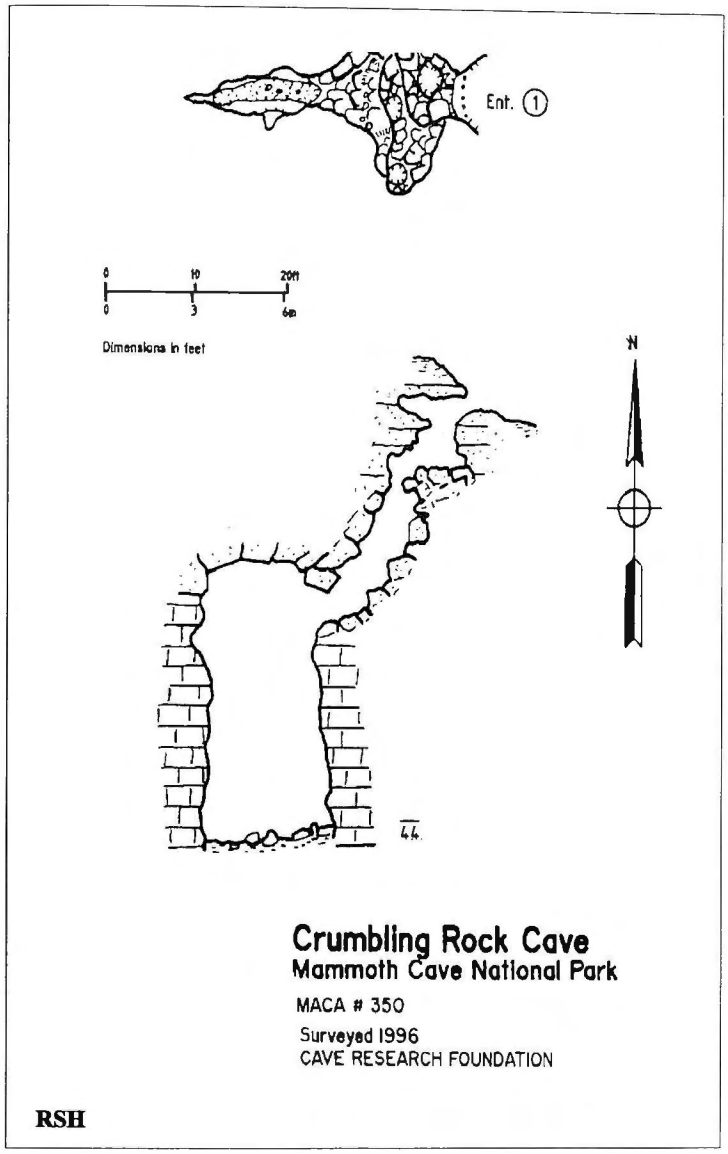
After the inventory, another crew will visit the locale to obtain the GPS location and monument the entrance. The GPS equipment used is a Trimble Pathfinder Professional Plus with an MC-V datalogger. This equipment can, under ideal conditions, give locations to within 5-meter accuracy for the horizontal elements. The vertical (elevation) element is not very accurate, however, giving up to 40-foot elevation errors at control points. An altimeter was also tried but failed to give useful readings either due to instrument errors or operator inexperience. At present the elevation data is extrapolated from field observations and comparisons of the different topographical maps available of the park.

An important part of this project is discovering what works and what doesn't work. The following items that didn't work are educational and important to discuss. We tried cheap cameras for taking entrance photos. Due to the problem of shadows and contrasts this was found not to be successful. We will now either use more expensive, adjustable cameras or investigate digital cameras. The electric drill used for placing the brass caps did not have enough power for a great deal of drilling causing some delays and wasted time. This was mitigated somewhat by using a smaller drill to set a pilot hole and by constantly resharpening the drill bit. It would be best, however, if caps with a smaller shank diameter were used. These may be difficult to find and might have to be custom ordered. The elevation data obtained from the GPS unit is not very accurate; certainly not accurate enough to base cave surveys from. Elevations can be obtained from topographic maps as accurately. Alternative methods of obtaining this information, such as digital altimeters, will be investigated in the second year. Overall, however, we experienced great success with our methodology.

Data Entry

The inventory data are entered into two separate databases, which can be relationally linked. The first consists of one record per cave with 42 fields primarily describing the entrance and its location but also including a very brief narrative description of the cave. The second database consists of one record per inventoried station (not all survey stations have noteworthy features) and has 11 fields with inventoried contents grouped by category. This database can be linked to the cartographic survey output (they share the survey station numbers) for utilization in the park's GIS. Currently these databases are in the cross-platform program FileMaker Pro that can also export the data in a variety of formats. The current data and an examination copy of FileMaker Pro have been installed on a computer at the Division of Science and Resource Management. The park's GIS data will probably be handled through ARC/INFO but the conversion of the data has not yet been tested.

Entering the inventory data into the database requires familiarity with the process and the subject matter because the data enterer must be able to put the data



into the correct fields in the correct format. This may be seen as a drawback since it requires technical knowledge and restricts the use of part-time clerical help. On the other hand, this process serves as a final filter for data integrity and, rather than a drawback, insures a higher degree of accuracy. The process can be speeded up through a selection of pop-up menus and spell checkers but still must be done by experienced personnel. Since the integral data is the final, desired result, this step is seen as very important.

Preliminary Findings

The project is not hypothesis-driven and yet some patterns are beginning to develop. Probably the most important finding is a negative one; that is, the previous data were very bad.

The caves are mostly formed in two geologic units: the Girkin and the Haney limestones. Haney caves tend to be low and wet while Girkin caves 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. Most of these are collapse or corrasional features rather than solutional.

Biologically, the caves are quite diverse. The large Girkin cave inventoried, Running Branch, is very similar biologically to Mammoth Cave with beetle - cricket communities in the upper levels 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 materials and latrines. The Haney caves are the most active with streams rich in organic materials.

At least half of the inventory records include crickets, either Hadenoecus or Ceuthophilus. Isopods were found in 6 cliff different caves. Bats, usually pipistrelles (*P. subflavus*) were found in only a few caves but nests, usually fresh, of the rapidly-declining wood or cave rat Neotoma was found in 6 caves. Some caves had several cave salamanders (*E lucifuga)* but other species of Eurycea (*E tongicauda* and *E bistineata)* were also found. One cave was found to harbor red salamander larva (*Pseudotriton rubeo).* 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.

Project Status

Currently, work is continuing on the project. The databases have already shown themselves to be useful tools even without full GIS integration. Testing of that integration is dependent on NPS personnel but should occur within the next several months. Survey data on one large cave (Running Branch) and one smaller cave

(Big Spring) have been provided to the NPS. In addition, the inventory feature and cave entrance data have been provided to the NPS. All other aspects of this project are on or ahead of schedule. We anticipate that additional caves and drainage areas will be added to the study area for full testing of the methodology and system. NPS personnel have already taken part in the field work (all GIS locations have been obtained by John Fry of the NPS) and we anticipate further involvement in the process. Training of inventory personnel is continuing at a rapid rate thus assuring us of a body of trained personnel. The great objective of this project is to spread the inventory 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.

Second Year Plans

Survey and inventory work will continue in three large caves: Ganter, Lulu Mart, and Buffalo Creek. Surveys will be completed in Running Branch (water levels permitting). A new survey (and inventory) of Forts Funnel will be initiated. Survey and inventory of most of the remaining known small caves should be completed. In the past year we expanded the project area to include one additional basin (Sal Hollow) and the caves in it have already been inventoried and mapped. The project area may be expanded further to officially include the Bat Cave area, However, access to Bat Cave is very restricted and it is problematical whether or not sufficient field trips can be taken there. Other areas that might be included in project expansion include Cow Ford Hollow, Wilson Cave, Saunders Cave and Dossey Domes Cave. The field guide will be completed and published and a paper on the project will be presented at the 1995 Cave Management Symposium. Training will continue on both a formal and informal level.

Acknowledgments

Appreciation is expressed to the National Park Service and Cave Research Foundation. From the NPS John Fry and Rick Olson have been particularly helpful. Project co-leader Mick Sutton and Richard Zopf of CRF have been prime components of the project. Numerous other CRF joint-venturers have taken part.

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Lilburn Cave Cartography Progress in 1996

Peter Bosted

This was another good year for cartography at Lilburn Cave, in Redwood Canyon, Kings Canyon National Park, California. CRF fielded six expeditions involving cartography. There were a total of twenty-one trips into Lilburn Cave, with a total of 4500 feet of new passage being surveyed using 500 stations. The average shot length of only 10 feet is indicate of the relative small and tight nature of the new passages being discovered. Another 800 feet of resurvey was done for various reasons (tie-ins to existing survey points, improving sketches, accidental re-surveys, etc.). The total length of Lilburn Cave (excluding redundant surveys and tie-ins) is now 15.83 miles (25.48 kilometers), with a total of 7000 stations set.

Most of the new discoveries in Lilburn were the result of having newly-available quadrangle maps of the relevant region. Having the cave split into various levels allows better determinations of what leads have been surveyed compared to the previous map where all levels were put on a single map. At the very upstream end of the cave, several new passages were mapped in the West Stream area and a new connection was made with the Kleinbottle Complex. An aid climb was made up a dome to reach several hundred feet of new passage that ended in granite boulder chokes. Several passages north of the Hex Room were surveyed, and another aid climb up a 60-foot chimney was made (unfortunately the passage at the top didn't go very far). Two new passages were found near the Lake Room: one with tantalizing air movement at the small hole at the end. Quite a bit of mop-up survey was done in the South Seas Junction area. The largest number of new stations set was in the southern end of the cave. The upper maze south of Davis exit was re-investigated after many years of no visits, and several connections were found back to the lower level. High level passages near the Yellow Floored Domes continued to yield quite a bit of virgin passage (as judged by the extremely unstable boulders in some of these areas). A circuitous route was found on the last trip that led to a large room near the top of the Yellow Floored Domes. Many leads remain to be checked out in this area, although aid climbing may be needed to pursue the largest-looking one.

One survey trip was made into the 140-foot long, newly reopened, Ellis Dig Cave, with a complementary survey being made of the surface terrain above this cave.

The map-drawing effort continued well in 1996. With both Peter Bosted and Brad Hacker each producing about ten more quadrangles as well as updating the existing quads with the new surveys. Presently there remain about 10 quads to be drawn in the Attic area (part of the D series). three in the Curl Passage (F series), the Pandora area quads, and some of the River Pit quads. Thus the quadrangle project is about 75% complete. Plans for 1997 include finishing the quadrangles and making computer-generated color plan and profile maps of the entire cave to fit on an 8" by II" sheets. in which the colors indicate depth below the entrance (for the plan), or distance from the viewer (for profile). This would be similar to the greyscale map produced previously, but now using color.

Eastern Operations
Cartographic Activities Report - 1994-1996

Bob Osburn

Cartographic work on the Mammoth Cave system is a long term effort and in many respects reports on this effort are repetitive. It is fair as in previous reports, to say, that for the past 3 years the big cave has kept getting longer although at a fairly slow rate. A new graphical format index of this progress is included in this and is available for future reports. In addition to incremental progress on the big system, tremendous progress has been made in the surveying of smaller caves of Mammoth Cave National Park, particularly that area north of the Green River. Work there has been in conjunction with a parallel Lesser Caves Inventory project but the survey and cartography are part of the main cartography program. This is a recognition, to the level of the project design, that there is only one set of surveyors and cartographers and that when their time is spent on one project they do not work as much on the other. A report of the inventory portion of the project is included in this volume in a report by Scott House.

Length of the System.

The field survey book database now shows Mammoth Cave to be 346.01 miles in length. The methodology in arriving at this number consists of summing the new survey values for all survey books. Inherent in this method are several sources of error which may in my estimation equal one to a few percent. This process separates out all resurvey as a separate category whereas a methodology that adjusted the cave length to that of the current survey net would be more accurate and desirable. Once all Mammoth data are in a single data reduction system a new figure based on this survey net should become available (see the data reduction section below).

Index of Map Sheets

Mapping in Mammoth Cave has long followed a systematic and orderly plan based on a grid of map sheets covering sections of the cave 2000 feet wide and of variable length. This grid was first envisioned over 10 years ago, has been described in previous reports and continues to be refined today. Figure 1 shown below is an index map that portrays these map sheets superimposed on the post- card map portrayal of the passages of Mammoth Cave. Table 1 supports this map in listing coordinates, cartographers, and state of progress for each of the sheets. Each sheet is listed in one of six categories (planning, loop rectification, manuscript drafting, final lead checking, survey finished, and map inked) which portray a combination of the state of both survey/resurvey and drafting. Hence, this index which is really a cartographic effort is placed here to serve as a basis for discussing survey progress. The working definition of each category is included in the caption for Figure 1. Implicit in the production of the 1:600 series of maps is the concept that old surveys not meeting current standards of either survey accuracy or cave feature portrayal must be enhanced or redone. This process at work is responsible for the large proportion of the survey effort that goes to resurvey and sketch enhancement. Since January 1993 only 4.07 miles of new survey have accumulated whereas during the same time 14.5 miles of resurvey was accomplished. Resketch footage is not recorded. Resurvey is not as exciting as surveying new passages but is absolutely necessary in producing high quality maps.

The categories of the index map represent six increments in the progression of a map sheet from conception to final inked version. Initially (planning), map sheet boundaries are fitted to the cave and to the surrounding sheets to insure efficiency of effort and continuity of the grid system; sheets may overlap but no gaps may be left. Once manpower is available the quality of survey and closure of main loops are evaluated, missing sections and those without vertical control or adequate sketches or with known defects are redone (loop rectification). When confidence in main passage loop closure is sufficient and when cartographer time is available a pencil draft on 42 inch wide gridded mylar is begun (manuscript drafting). Survey and concurrent drafting continue for most of the effort until essentially all known passage in the area is surveyed. When most leads are done (final lead checking) effort is concen-

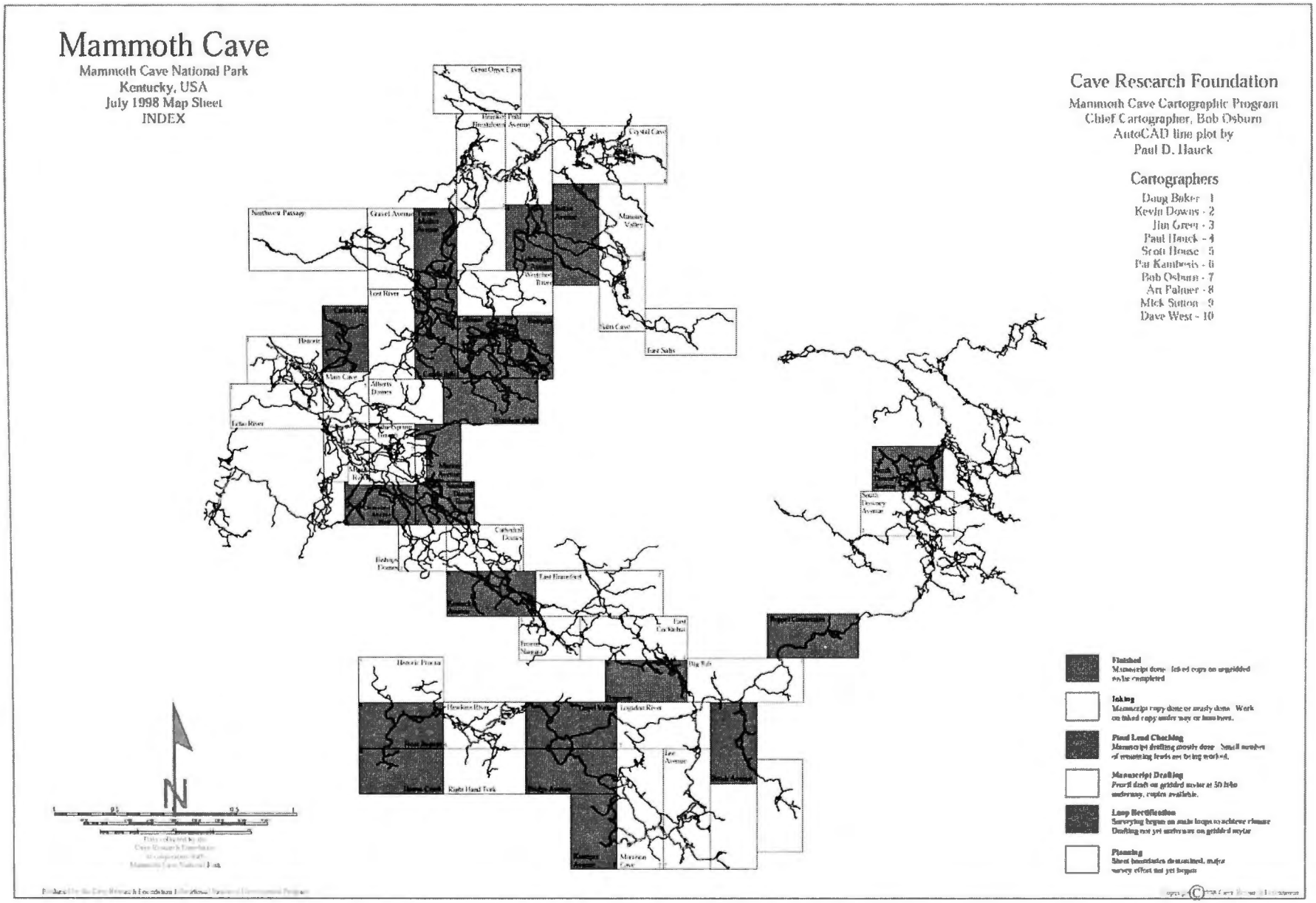

Figure 1 - Index Map of Mammoth Cave Quadrangles

trated on the area to bring the survey effort to a finished state (survey finished) and the pencil draft is finalized. When all details are done the map is utilized as is until a large increment of cartographer time is available to trace the map onto a new non-gridded mylar in ink, letter it properly and bring it to a truly finished state. Table 1 lists the status of all named map sheets as of July 1997.

Field Work

Survey has been concentrated for these three years in several sections of Mammoth Cave and on lesser caves north of the Green River within Mammoth Cave National Park. Work is summarized by main area below beginning with the main system working from south to north.

Morrison and Proctor cave (Hawkins River area): The most dramatic activity in this section of the cave was in the Proctor Cave section. The historic section resurvey was essentially complete by the end of 1993. That work has been completed and the resurvey line pushed through the Proctor Crawl (a 1000 foot fairly tight belly crawl), past Mystic River Pit and into the upper level Proctor Trunk. Survey/resurvey work concentrated on the south end of Proctor Trunk and to the beginning of Frost Avenue to the north. Of note was a minor extension of the U-Survey in the south Proctor Trunk area. Over 850 feet of new passage was documented beyond a narrow and wet breakdown constriction and down and around a 30-foot pit. Passages ended in mud-coated sandstone fill indicating that it had intersected the edge of the ridge. A total of 948 feet of new passage was mapped in Proctor Cave and 7800 feet of resurvey was completed. Proctor was during this time divided into three map sheets (Historic Proctor, Frost Avenue, and Hawes Creek sheets) and manuscript drafting only awaits final closure of ties through Hawkins River to the Doyle Valley Entrance.

Activity in the Hawkins River concentrated on several areas. On the Doyle Valley sheet, the passages long known to exist below P Strange Falls were explored and surveyed to the present limits of air and most leads were finished in the nearby Babbling Brook passage. Work farther upstream concentrated on resurvey and sketch enhancement of parts of the upstream trunk stream passage carrying a new survey line toward existing radio location stations near the connection with Roppel Cave (Big Rift and Roppel Connection sheets). South of the "River" work concentrated on side passages along Bridge Avenue (formerly referred to as the "T" survey, Bridge Avenue and Morrison Cave sheets), and in reworking segments of Fritch Avenue (Fritch Avenue Sheet) whose loops fail to close satisfactorily. Climbing leads were evaluated in several areas but no major discoveries were made.

Mammoth Cave Ridge: Field work in the Mammoth Ridge area comprised over 3.5 miles of survey (new and resurvey). More effort was concentrate on the Historic area (Historic, and Echo River sheets) including Gothic Gallery, River Hall, Dead Sea and related areas. The drafting of Historic Sheet was advanced enough to aid with the planning a new trail for the Rotunda area. In the middle part of the ridge, essentially all leads are done in the Blue Springs Branch and adjoining Marion Avenue sheets. Work has shifted downward into the underlying Mystic River level of the cave: the active stream level here. Finally most leads have been exhausted in the Bishops Domes sheet and work has begun in the Cocklebur and Bransford Avenue sheets.

Flint Ridge: The focus of attention under Flint Ridge has been in Salts Cave where intensive resurvey and drafting is occurring in conjunction with and as part of an archaeology project. Teams were fielded to Salts Trunk, in the lower branch of the Q survey and in the upper levels and southwestern sections of Dismal Valley. Teams also worked Tom Wilson's Accident and the Incredible Salts dig. Work continued in Unknown Cave (Pohl Avenue sheet and t, the D, G & C surveys were reworked and new passages mapped in the upper canyons of the X-survey. New work was also begun in the complex and difficult Upper Union Shafts area, in Ralph Stone Hall, off of Huber Trail and in a series of tubes beneath the Unknown entrance. Further work is pushing southward toward and through the Salts Link into the Lehrberger Avenue sheet.

Roppel Cave: The extremes of Roppel Cave in the areas of Transgression Trail, New Hope Creek and the BWOB were intensely pushed, and mapped. Survey work also continued in the Lower Elysian Way, Toms Tubes, Walters Way and in the Nexus Domes. Concerted efforts were made to extend the system into Toohey Ridge via the Rift, with little success.

MAP NAME	EAST	WEST	NORTH	SOUTH	AUTHOR	STATUS	SYTEM
Alberts Domes	4000	800	5700	3700	Undecided	Manuscript Drafting	MC
Bedquilt	6800	8800	8400	5700	Dave West	Loop rectification	MC
Big Rift	14500	19500	-6750	-8750	Bob Osburn	Manuscript Drafting	MC
Bishops Domes	2000	3750	- 850	-2850	Kevin Downs	Manuscript Drafting	MC
Blue Spring Branch	2800	800	3700	1100	Mick Sutton	Final Lead Checking	MC
Bridge Avenue	7500	11500	-10750	-12750	undetermined	Loop rectification	MC
Brucker Breakdown	6900	4900	17150	13000	Jim Greer	Loop rectification	MC
Carlos Way	800	-1150	8750	6000	Undecided	Planning	MC
Cathedral Domes	3750	6900	-850	-2850	Scott House	Survey finished	MC
Cleaveland Ave West	2800	-400	1100	-850	Doug Baker	Loop rectification	MC
Colossal Cave	4800	6800	8400	5700	undetermined	Loop rectification	MC
Crystal Cave	13600	9600	16350	14350	Art Palmer	Manuscript Drafting	MC
Doyle Valley	11500	7500	-8750	-10750	Bob Osburn	Final Lead Checking	MC
East Bransford	7700	13500	-2850	-4850	Kevin Downs	Manuscript Drafting	MC
East Cocklebur	9650	14500	-4850	-6850	Kevin Downs	Manuscript Drafting	MC
East Salts	12800	16800	8700	6700	undetermined	Planning	MC
Echo River	-1150	-5150	5500	3500	Doug Baker	Loop rectification	MC
Ferguson	11000	14500	-6850	-8850	Kevin Downs	Loop rectification	MC
Fritch Avenue	17500	15500	-8750	-12000	Bob Osburn	Loop rectification	MC
Frost Avenue	3700	-300	-8750	-10750	Pat Kambesis	Loop rectification	MC
Frozen Niagara	7000	9650	-850	-2850	Scott House	Manuscript Drafting	MC
Frozen Niagara - Upper	7000	9650	-850	-2850	Scott House	Manuscript drafting	MC
Gravel Avenue	2800	800	13000	9800	undetermined	Planning	MC
Great Onyx Cave	7900	3900	19150	17150	undetermined	Planning	MC
Hawes Creek	3700	-300	-10750	-12750	Pat Kambesis	Loop rectification	MC
Hawkins River	7500	3700	-8750	-10750	Pat Kambesis	Manuscript Drafting	MC
Historic	-1150	-4500	7500	5500	Doug Baker	Manuscript Drafting	MC
Historic Proctor	3700	-300	-6750	-8750	Pat Kambesis	Manuscript Drafting	MC
Indian Avenue	8900	11800	13350	9800	undetermined	Loop rectification	MC
Indian Cave	19500	17500	-11000	-15000	Bob Osburn	Loop rectification	MC
Kaemper Avenue	9500	11500	-12750	16000	Bob Osburn	Loop rectification	MC
Kentucky Avenue	3750	7500	-2850	-4850	Mick Sutton	Map inked	MC
Lee Avenue	15500	13500	-10750	-16000	Bob Osburn	Manuscript Drafting	MC
Lehrberger Avenue	6900	8900	13350	9800	Paul Hauck	Loop rectification	MC
Link River	8800	4800	10400	8400	undetermined	Loop rectification	MC
Logsdon River	15500	11500	-8750	-10750	Bob Osburn	Manuscript Drafting	MC
Main Cave	800	-1150	6000	1100	Scott House	Manuscript Drafting	MC
Marion Avenue	4800	2800	4300	1100	Bob Osburn	Manuscript drafting	MC
Morrison Cave	13500	11500	-10750	-16000	Bob Osburn	Manuscript Drafting	MC
Mummy Valley	10800	12800	14000	11000	Mick Sutton	Loop rectification	MC
Mystic River	3300	0	2900	900	Mick Sutton	Manuscript Drafting	MC
North Downey Avenue	25300	22700	2500	500	Bob Osburn	Loop rectification	MC
Northwest Passage	800	-4200	12400	10400	undetermined	Planning	MC
Pohl Avenue	6900	8900	17150	13350	Paul Hauck	Manuscript Drafting	MC
Right Hand Fork	7500	3700	-10750	-12750	undetermined	Planning	MC
Roppel Connection 18000	22000	-4750	-6750		Bob Osburn	Loop rectification	MC
Salts Cave	10800	12800	11000	7800	Mick Sutton	Manuscript Drafting	MC
Snowball Dining Room	5300	2800	1100	-850	undetermined	Loop rectification	MC
South Downey Avenue	26000	22000	500	-1500	Bob Osburn	Manuscript Drafting	MC
Turner-Mather Avenue	2800	4800	9700	5700	undetermined	Loop rectification	MC
Woodson-Adair	4000	8000	5700	3700	Pat Kambesis	Loop rectification	MC

Table 1: Status of all named map sheets as of July 1997

Lesser Caves of Mammoth Cave National Park: Over the past 3 years, dramatic progress has been in smaller caves within Mammoth Cave National Park. During that time part or all of 47 caves have been surveyed. Table 2 lists these caves. Most are north of the Green River and were surveyed in conjunction with the Lesser Caves Inventory Project. At this point in time, the great majority of known caves north of the Green River have modern surveys. Many of these caves are small but others would be substantial caves in a different environment. Survey of these has taken some time and the surveys of several of the larger were begun before this report period and some continue. Wilson Cave has become the longest cave north of the Green River at about 13500 feet followed by Ganter, Buffalo Creek (not listed), Running Branch and others. Survey of lesser caves will continue into the future but at a lower rate as the intensive part of the inventory project ends.

Data Reduction

To date the survey data collected for Mammoth Cave does not yet exist as a single data set. For the past several years the dominant method for input, reduction and plotting has been via the commercial programs SMAPS program (versions 4.3, and more recently 4.4 and 5., 5.2). This program is no longer being supported by the developer, and while it is still used, other programs are being evaluated for future use. CRF's Cave Map Language (CML) continues to be used for archiving and error tracking purposes and a new more user-friendly interface is being tested. One of the project's important goals continues to be working toward achieving a seamless transfer between CML and other programs that suit our data entry, reduction and plotting needs.

The Field Survey Book database now contains 3338 entries and has proven to be an invaluable resource not only for determining the length of the Mammoth Cave System but also in terms of archiving, information tracking and statistical applications. CRF continues to work with the National Park Service and other data collecting groups towards integrating all available survey information into a single network.

Cartography

The 1:600 base maps continue to be the major focus in CRF's main system cartographic objectives. Lesser caves are surveyed to the same standards and maps of these produced at 1:600 or greater scale; very small caves are often drawn larger to keep the map from being too small. The number of finished maps ideally marks progress and this is certainly true for the lesser caves. This test is a less accurate indication of progress for sheets of the big cave. Map sheets here take a lot of effort and may remain in the same status level for several years. For example, the finished Kentucky Avenue sheet was about ten years in progress.

Lesser Caves: Of the 47 lesser caves surveyed, 22 have finished maps. Maps of several others are in progress as pencil drafts and will receive cartographer attention over the next year or more. For example, the maps of Running Branch and Buffalo Creek are finished as pencil drafts and of others such are Bat, Ganter, and Wilson are caught up with survey. Since these are the larger of the caves and they contain a bulk of the necessary cartographic effort the drafting is further advanced than the proportion of finished maps suggests.

Mammoth Cave: The reader is again referred to Figure 1 for a graphical representation of Mammoth Cave map sheets and the accompanying Table 1 for a list of cartographers and other sheet characteristics including progress. This map is best-viewed color coded by attribute but this was beyond our printing capability at this time. The interested reader should color code the map by status to fully appreciate the present state of Mammoth Cartography. Only one sheet (Kentucky Avenue) is truly finished as an inked final map. Close behind this in progress is the Cathedral Domes sheet that is finished but not inked. (The cartographer for this sheet has been responsible for most of the drafting on lesser caves.) Several sheets are at or near the final lead checking state (Marion Avenue, Blue Springs Branch, Doyle Valley, Main Cave, and Bishops Domes). Many areas have shown significant progress during the past three years; a few have changed sufficiently so that they make dramatic improvements in our view of the cave. The two most dramatic for this period have been the Historic sheet which now includes Audubon Avenue and the Rotunda shown for the first time as it should be drawn.

Geosciences

Extracting High-Resolution Climatic Signals from Speleothems

Rhawn Denniston

Introduction

While great success has been achieved in using the stable isotopic signatures of speleothem calcite as low-resolution paleoclimatic indicators (10-100 year intervals) (see Dorale et al., 1992), little work has been directed toward extracting evidence of high-resolution climatic change. Therefore, the goals of this research have been to (1) extract a monsoon signal from the carbon and oxygen isotopic signature of speleothems from the Pokhara Valley region, Nepal, and (2) delineate the climatic signal contained within fluorescent banding in speleothem calcite. These investigations are still underway but have yielded some interesting preliminary results.

Nepal

Many stalagmites that form in monsoonal climates contain banded milky calcite/clear calcite couplets. The milky bands appear to be the result of fast calcite growth during monsoon events, while denser, optically clear calcite results from slower growth during intermonsoon months. This interpretation is supported by microsampling and isotopic analysis of adjacent milky/clear couplets. Multiple isotopic measurements were made from upper, middle, and lower portions of individual milky bands, and appear to show a cyclical isotopic enrichment pattern which may be linked to the development of yearly monsoonal events (Figure 1). The importance of this cycle is that it allows us to dissect the paleomonsoon and to potentially examine factors such as monsoonal intensity as well as to investigate inter-monsoonal precipitation events.

Fluorescent Banding: Recent research has linked fluorescent banding in speleothems to annual/seasonal calcite growth. This may provide the means to extract climatic signals of extremely high temporal precision from an inorganic continental paleoclimatic record (Baker et al., 1993; Shopov et al., 1994). Fluorescence in speleothems is produced by organic acids incorporated along with the calcite (White and Brennan, 1989; White, 1995) and is believed to be the result of calcite precipitation from fluids which percolate through the soil zone when temperatures and organic activity are high, i.e. late Spring, Summer, and early Fall. This hypothesis is supported by the observation that fluorescent bands are typically narrower than non-fluorescent bands, which is believed to be a consequence of elevated evapotranspiration rates during the warmer months.

Fluorescent banding can be potentially utilized to extract seasonal climatic and/or environmental signals. Because the oxygen isotopic composition of precipitation in regions with pronounced seasonality (temperature and/or precipitation) is markedly different throughout the year, the temperature in deep caves is constant throughout the year, and infiltration residence time is less than six months in most cases, the isotopic composition of fluorescent and non-fluorescent calcite layers (if they reflect climatic seasonality) should preserve the seasonal variability of precipitation $^{18}0$. Utilizing microdrilling sampling techniques (Dettman and Lohmann, 1995) growth bands with greater than 20 μm thickness can be sampled toy isotopic analysis thus allowing an examination of the nature and timing of fluorescent growth banding in speleothems.

Research I conducted over the past year suggests that the isotopic composition of individual fluorescent/non-fluorescent bands may hold important paleoclimatic information. Fluorescing and non-fluorescing zone pairs were photodocumented using Laser Scanning CONFOCAL Microscopy at the University of Iowa Electron Microscopy Research Facility. As sub-per mil *in situ*

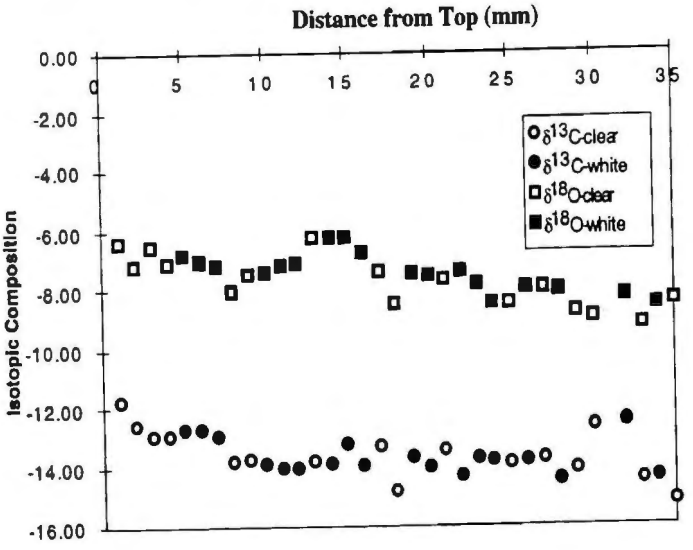

Figure 1: Cyclical nature of $d^{13}O$ and $d^{18}O$ in speleothem from monsoonal regimes. Adjacent sets of filled and unfilled squares represent one year of growth. Data obtained using microsampling.

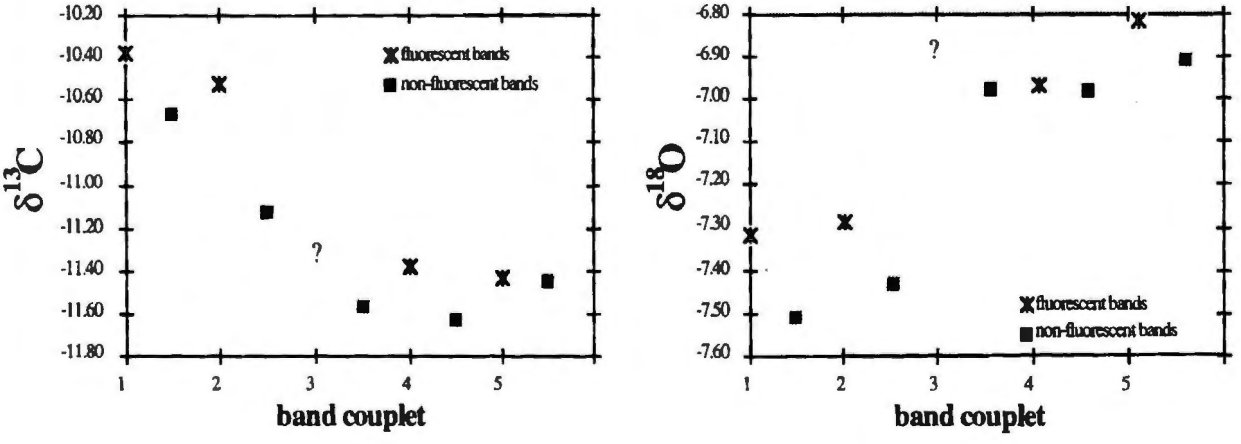

Figure 2: Seasonal shifts in stable oxygen and carbon isotopic values obtained from a stalagmite from Wisconsin. Micro-sampling was conducted using the sampling station developed and maintained at the University of Michigan's Department of Geology.

stable isotopic measurements have not yet become reliable, mechanical separation of individual fluorescent bands was required. I attempted this using a laser with a 1 μm spot in order to cut away growth bands, but as appropriate laser conditions are difficult achieve, the calcite tends to shatter rather than cut cleanly. Moderate success was achieved using a computer-guided microdrilling apparatus which, although extremely time-intensive, did allow me to isolate a small number of adjacent fluorescent and non-fluorescent bands from a Midwestern speleothem. (Figure 2)

The results are that fluorescent bands are heavier isotopically heavier in $\delta^{18}O$ than adjacent non-fluorescent bands, suggesting that fluorescent calcite crystallized from fluids that infiltrated during the summer months. A similar shift in $\delta^{13}O$ between adjacent fluorescent and non-fluorescent bands may reflect (1) the influence of temperature on Soil $C0_2$ ^{13}C composition and/or (2) variations in the relationships among soil temperature, Soil $P_{CO2,}$ and $C0_2$ solubility throughout the year. The shift in $\delta^{13}O$ and $\delta^{18}O$ between adjacent fluorescent/non-fluorescent bands is small, but this may be attributable to mixing of fluids along infiltration pathways (Denniston and Gonzalez, 1997).

Future Research: The paleoclimatic information derivable from fluorescent banding, therefore, may be more valuable in understanding interannual variability than in constraining absolute yearly or seasonal temperatures, but much more research is required before any conclusions regarding systematics can be drawn. Future research will involve calibrating isotopic records of fluorescent and non-fluorescent zones in speleothem calcite to known historical climate records and precipitation isotopic compositions. In addition, microsampling techniques need to be refined for narrow, curvilinear fluorescent bands (Figure 3).

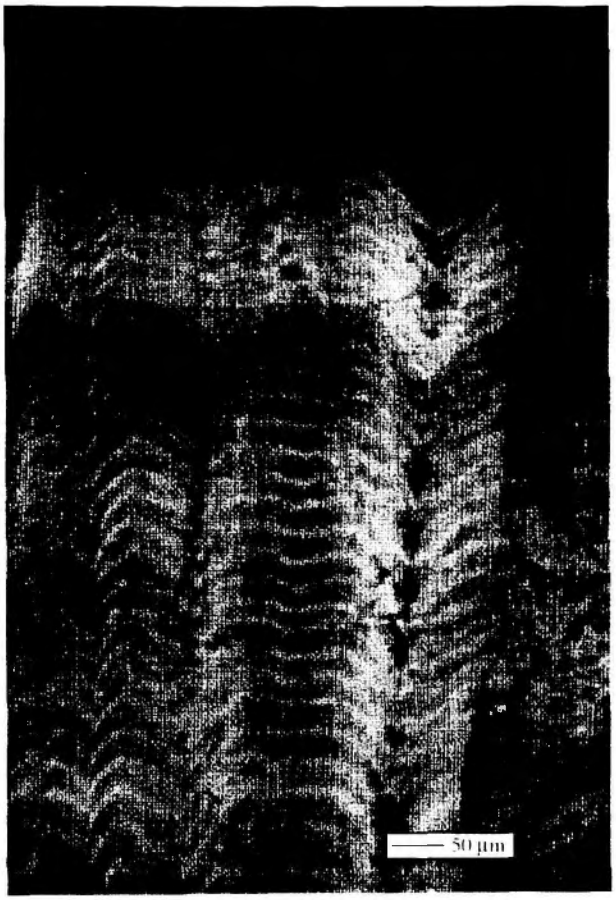

Figure 3: Fluorescent banding in a stalagmite from Southern Wisconsin. Distance from top to bottom encompasses approximately 33 zones. Dark area at top is upper edge of sample

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Preliminary Continental Paleoclimate Averages from Oxygen and Deuterium Isotopes in Secondary (Paleokarst)/ Silica from the Mississippian Redwall Formation, Arizona

Ray Kenny

Kenny and Knauth (1992) established a methodology whereby approximate, long-term, continental paleotemperatures can be inferred from oxygen and hydrogen isotopic analysis of authigenic silica precipitated within chert lags on (and within) paleokarst horizons. This methodology was successfully used for determining approximate, long-term, continental paleotemperatures for two late Proterozoic (- 1.0 Ga) formations (Kenny and Knauth, 1992). In this paper, the methodology is being applied to authigenic or "secondary" silica precipitated during a regionally extensive paleokarst at the top of the Mississippian (-325 Mya ?) Redwall Formation, Grand Canyon, Arizona. Preliminary data suggest continental weathering temperatures of around 27-28°C.

Geologic Background

During the Upper Mississippian, the Redwall I (limestone) Formation of north and north-central Arizona was extensively karsted. The karst event produced red residual (terra rossa) soils and extensive dissolution zones of rubble-filled, caves and sinkholes. Secondary silica phases consisting of drusy, fibrous, microlaminated, botryoidal, and void-fill silica are locally present in residual paleokarst chert lags. Kenny and Knauth (1992) argued that these authigenic or "secondary" silica phases formed during continental karst events and are physically and petrographically distinct from silica phases in marine cherts. Samples of secondary silica from the Redwall Formation have been collected for analysis from a paleokarst chert lag near the South Bass Trail, Grand Canyon, Arizona (Figure 1; NPS Special Permit #WRO GRCA 6000 2043).

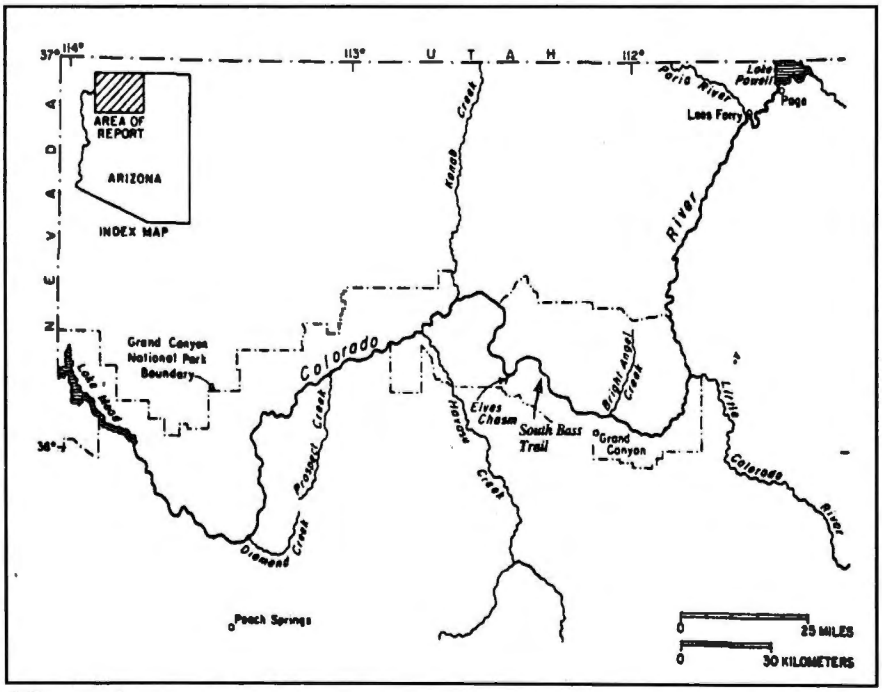

Figure 1. Location map of study area and south Bass Trail Grand Canyon National Park, Arizona

Results

Preliminary results are given in Table 1. Secondary silica (from the karst dissolution zone) is depleted in both deuterium and oxygen-I 8 relative to the unaltered (marine) cherts beneath the karst dissolution zone.

The depleted isotopic values for the secondary silica are consistent with silica that crystallized in the presence of meteoric water (i.e., under a continental, subaerial exposure surface).

The secondary silica phases were meticulously and physically separated from the marine chert portion of the samples, and then

Sample#	Dsmow(%)	18smow(%)	description
GC590-10	-86	25.8	secondary silica
GC590-14	-78	27.0	secondary silica
GC590-25	-92	25.7	secondary silica
LPK-24	-58	29.3	early chert

Table 1: Preliminary data on the Redwall (limestone) Formation Chert

isotopically analyzed according to the method of Knauth and Epstein (I 976). It is probably inevitable that some of the secondary silica concentrate contains inseparable fragments of the original, primary chert. The separates analyzed, therefore, are considered as concentrates and some spread in isotopic values is expected. The oxygen- I 9 value is for total oxygen in the chert; the deuterium isotope value is for included (micro) water extracted from the silica.

Line A (Figure 2) is the inferred locus of isotopic composition of cherts in equilibrium with modem sea water at various temperatures (Knauth and Epstein, 1976). The preliminary data from the Redwall Formation plot off Line A and are roughly parallel to the meteoric water line. The Redwall data plot in a part of the diagram which suggests that meteoric waters were involved in the crystallization history of the silica (the samples that plot farthest from Line A contain the greatest meteoric water component). The Redwall data yield preliminary, paleotemperature estimates of about 27-28'C. The preliminary isotope data is also consistent with field and petrographic evidence, which suggest that the secondary silica formed in the karst dissolution zone.

Discussion

The derived isotopic values can be interpreted in terms of long-term, paleoclimatic temperatures by comparing them with temperature lines drawn parallel to the meteoric water line (reproduced in Figure 2). Using these temperature lines (determined by Knauth and Epstein, 1976), the paleotemperature estimate of 27-28'C was obtained.

Temperature assignments made with the method of Knauth and Epstein (I976) are subject to several uncertainties. The curve for quartz-water isotope fractionation with temperature is not known well for low temperatures. The temperature lines, used in this method, are extrapolated from better-understood, high-temperature, quartz-water curves (Knauth and Epstein, 1976).

Another assumption, used in the method established by Knauth and Epstein (1976), is that the isotopic composition of sea water has not changed significantly over geologic time. Geochemical arguments suggest that the ocean water has maintained isotopic equilibrium for at least the last 600 million years (see Holland and Petersen, 1995, for further discussion).

The question of preservation of original values is always of significance when dealing with isotopic analysis of ancient material. One process that could produce the observed isotopic depletions in the chemically and physically stable chert, is metamorphism. In this case, it is not likely that the observed isotopic depletions were caused by metamorphism, because: (1) the study area has not been metamorphosed nor subjected to any igneous intrusions (e.g., dikes and sills); and, (2) the textural preservation of the samples is excellent and there is no evidence of recrystallization.

Conclusions

The Mississippian Redwall Formation was subaerially exposed and developed recognizable and extensive karst features. Locally, resistant chert nodules accumulated as a lag deposit and were cemented, replaced, and infilled by authigenic or "secondary" silica. The secondary silica is depleted in both deuterium and oxygen-18 relative to unaltered cherts collected well beneath the karst dissolution zone. Application of the Knauth and Epstein (1976) method (for assigning paleotemperatures to isotopic analyses of chert) yields preliminary, continental paleokarst temperatures of about

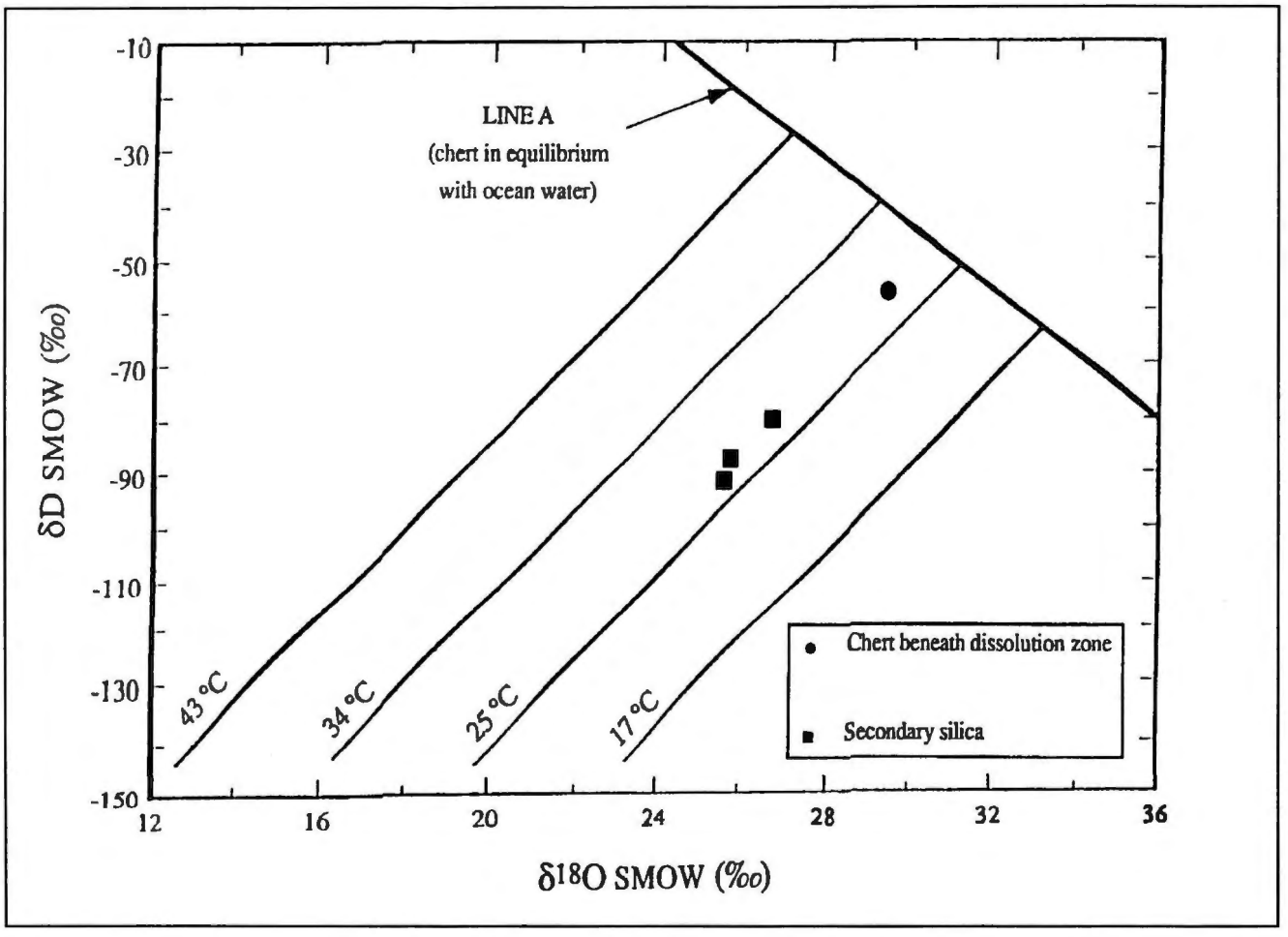

Figure 2. Isotopic composition of the Redwall (limestone) Formation cherts. Lina A. represents cherts in equilibrium with Standard Mean Ocean Water (SMOW), from Knauth and Epstein 1976). Temperatures of chert crystallization are from Knauth and Epstein (1976). Early coastal (marine) chert values plot closest to Line a: secondary silica values plot farther away.

27-28°C. The paleotemperature estimates are significant because, until recently, it has extremely difficult to quantify terrestrial paleoclimatic conditions. The accuracy of these temperatures is subject to certain assumptions and estimates inherent in interpretation of the isotopic data.

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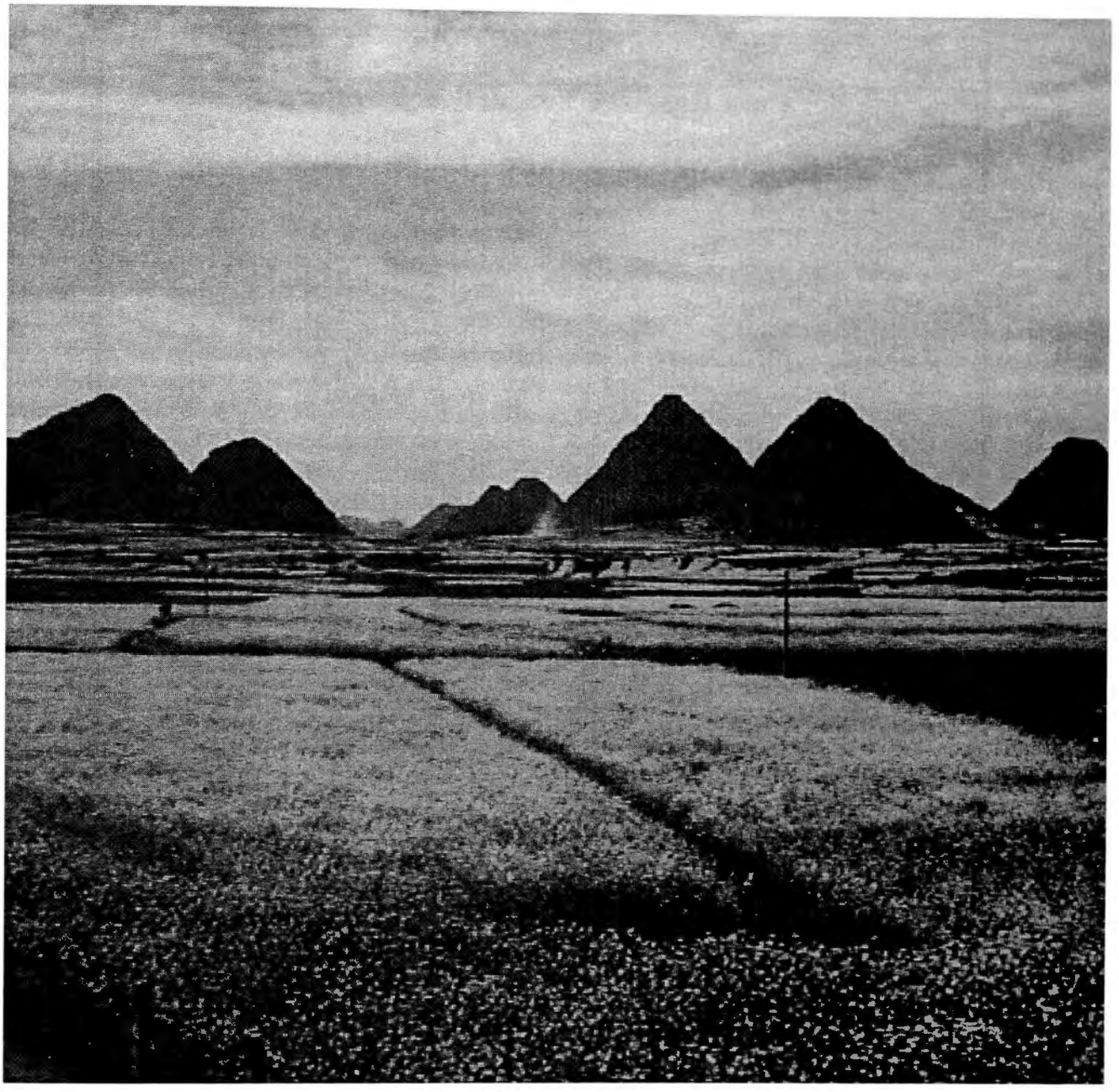

Cave Research Foundation Activities
1997

Cave Research Foundation Directors

1997

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Guadalupe Escarpment Area (NM): Barbe Barker

Lave Beds Operation Area (CA): Janet Sowers

Missouri Operation Area: Scott House

Sequoia Kings Canyon/
Mineral King Operation Area (CA): John C. Tinsley

Page 103 Photo credit: Tower karst in Guizhou Province, Peoples Republic of China
Photographer: Paul Massey

1997 Highlights

Annual Meeting

The 63rd meeting of the Board of Directors convened at the Maple Spring Research Center at Mammoth Cave National Park, on November 22, 1997.

John Tinsley resigned from the Board, from the office of secretary, and as administrator of the Fellowships/Grants program after 15 years of service. The CRF Board appreciates Tinsley's long-term service to the Foundation. Replacing him as Fellowships/Grants administrator is Rick Toomey. Peter Bosted was added to the Board after the Annual Meeting and assumed secretarial duties.

Phil DiBlasi stepped down as president of the Foundation. The Board elected Pat Kambesis as new president. Mike Yocum resigned from the position of Eastern Operations Manager. He was later replaced by Dave West. Candace Leek was appointed as the Newsletter Editor.

The following individuals were elected as fellows of the Cave Research Foundation: Michael Ray Taylor, Ann Scavarda, Kevin Justus, Jerry D. Vineyard, Dr. Brad Hacker, Cindy Heazlit and Sheila Sands. The board acknowledges and appreciates the contributions and accomplishments of these CRF members.

Hamilton Valley Project

The newly appointed Building Committee consulted with two independent architects to discuss the Voelker-Winn Plan for the Hamilton Valley Facility. Some alterations have been made to the original plan, however, overall, the original plan was reported to be sound. Since the Building Committee envisions the main building as a multiuse space for various outside organizations, the facility must meet commercial code.

The next step for the Building Committee is to contract with Voelker Winn to make the indicated changes to the original drawings and then to obtain bureaucratic approval among pertinent local Kentucky agencies. At some point, bids will be secured by the Committee.

"Don't Mess with Mammoth" Cleanup

The "Don't Mess with Mammoth" clean up took place in March of 1997. Clean up was conducted in the Pike Spring Basin, specifically at the old Job Corps site Mammoth Cave National Park. About 50 people from the Park, CRF, local residents, ACCA and the Evansville, Windy City, Cincinnati and Nashville Grottos participated in the clean up.

Mammoth Cave Science Conference

In collaboration with Mammoth Cave National Park, CRF cosponsored the Sixth Annual Mammoth Cave Science Conference at Mammoth Cave National Park at the end of July. CRF President Phil DiBlasi joined Park Superintendent Ronald Switzer in welcoming participants to a two-day agenda featuring 22 presentations that spanned ecology, cultural resources, hydrogeology, and cave conservation and management.

China Caves Project Exchange

CRF co-hosted a contingent of 4 Chinese scientists from Guizhou Normal University to fulfill the Foundation's end of the China Caves Exchange Program. Ian Baren, China Caves Project director, acted as translator and main host for the visiting scientists. The group attended the NSS convention in Sullivan, Missouri, then made their way down to the southern Missouri Ozarks where they were hosted by CRF members Mick Sutton and Sue Hagan.

Two New Foundation Programs

Two proposals for new Foundation programs were submitted to the Board by Mike Yocum. They are the Educational Resource and Development Program and the GIS Resource Development Program. The Board voted unanimously to accept both programs. Mr. Yocum will be acting as program director for both and

will be providing the Board with regular updates on program activities.

USGS National Spatial Data Infrastructure Project

In the autumn of 1996, a grant was awarded to CRF by the US Geological Survey for the development of tools that contribute to the USGS National Spatial Data Infrastructur (project directed by Mike Yocum). The Cave Research Foundation, in cooperation with Mammoth Cave National Park, the American Cave Conservation Association (ACCA), and Kentucky's Barren River Area Development District (BRADD), have been jointly developing a minimal content standard for the collection of cave survey data on federal land.

In April 1997, Ron Kerbo, NPS National Cave Management Specialist, hosted a meeting between Yocum, Jim Nepstad (Wind Cave) and Mike Wiles (Jewel Cave) where they drafted an initial document that formed the basis for an email discussion group involving personnel from CRF, the NSS, the National Park Service, the Bureau of Land Management, and the National Forest Service. The results of this discussion were presented by Yocum and Wiles and the 1997 Karst and Cave Management Symposium at Bellingham, Washington.

For another part of this project, Peter Yocum and Mike Yocum, working with Mel Park, have modified Park's CML (Cave Mapping Language program), adding a Windows interface to make it more accessible. A third aspect of the project is to evaluate biological data from Hidden River Cave, and develop biological thematic data sets for correlation with the geospatial cave data for presentation in a GIS format that will be available to the public at the American Cave and Karst Center. At the request of the ACCA, this part of the project has been extended for an additional three months to allow for adequate funding. Other contributors to the project were CRF cartographers Scott House, Pat Kambesis, Bob Osburn and Mick Sutton, and Mammoth Cave National Park's Division of Science and Resources Management's Michael Franz.

Restoration of Crystal Cave Historic District

In July of 1996, with Mike Yocum as Project Director, CRF entered into a Cooperative Agreement with Mammoth Cave National Park to restore the cultural landscape of the Crystal Cave Historic District by removing the Austin House, the Back Bunkhouse and Spelee Hut.

CRF volunteers salvaged windows, doors, hardware, electrical and plumbing fixtures, and a large quantity of wood was saved for re-use. The Spelee Hut was saved completely by dismantling it and moving it to Hamilton Valley. CRF workers also removed the old well house and water tank adjacent to the well house and filled both sites, ensured that the septic tank at the rear of the Ticket Office was left in an environmentally sound condition; and removed the mountain of iron pipes and plastic pipe liners left from the old Job Corps sewage system. To accomplish this, 63 CRF members traveled a total of 63,246.9 miles and donated 1,550 hours in labor, in addition to their travel, food and lodging costs.

1997 Fellowship & Research Grants

Cave Research Foundation received ten proposals in 1997. Three proposals were funded: one Fellowship and two Grants. A total of $5,000.00 in awards was distributed as follows:

1. *Speleogenesis of Movile Cave, Southern Dobrogea, Romania: A continuation of studies about a place lost in space and time.* Ms. Annette Summers Engel, Department of Biology University of Cincinnati, Cincinnati, OH 54221-0013, $2500 Karst Research Fellowship

2. *Reconstructing Seasonal Climatic Shifts for the Upper Midwest Using C and O Isotopes of Fluorescent /Non-Fluorescent Band Couplets in Speleothem Calcite.* Mr. Rhawn F. Denniston, Department of Geology, University of Iowa, Iowa City, IA 52242 $1000.00 Karst Research Grant

3. *Simulation Of Ground Water Flow In A Mature Karst Aquifer: Application Of Fractal Geometry And Hydrograph Separation Techniques.* Mr. William D. Howcroft, Hydrological Sciences University of Nevada at Reno, Reno, NV 89132. $1000.00 Karst Research Grant.

Operation Area Reports

Arkansas Operation Area
Fitton Cave survey Project Report

Pete Lindsley

The Fitton Cave Survey Project in Arkansas fielded five expeditions during 1997. A total of 53 cavers attended the expeditions and spent a total of 565 people-hours underground. The five expeditions were all one-day trips. A total of 11 survey parties worked in the cave during 1997.

We continued the use of a precision laser rangefinder (a Leica DISTO unit) on several expeditions to generate precision profiles and cross sections of major rooms in the cave. Our survey techniques are continuing to evolve as we discover the optimum way to use the precision rangefinder. Basically, we try to lay as straight a line as possible along previously surveyed passages because we want to generate high quality data that shows the ceiling features of the passages being profiled or cross sectioned. The technique is to "fix" or sight a survey line along the passage in a manner that allows access to this line-of-sight with the laser rangefinder. A standard survey shot is made using either Suuntos or Bruntons and the survey chain is held in place at each end while the "laser person" walks the tape and shoots both the ceiling height and the floor distance. A note-taker records the data and a sketcher draws a precision profile or cross section sketch to scale in the cave. Although we are generating elevation detail, the in-cave technique must be similar to the old plane table surveys done years ago in Carlsbad Cavern where detailed contour lines were placed on the original mylar sheets while in the cave.

The scales being used are usually one inch equals 20 or 25 feet and we presently are making the sketch on 8 1/2 x 11 inch grided paper "landscape" format. During one trip between three and four sheets are generated, perhaps more if additional cross sections are made. Depending on the ceiling and floor smoothness, floor and ceiling measurements are taken at every five to ten feet along the line-of-sight. The majority of the ceiling heights being surveyed are 20 to 40 feet, however we feel that the range of the laser rangefinder unit we are using is perhaps two or three times that distance for standard limestone ceilings. The sketch person must first draw the survey line to scale so both a ruler and a protractor are needed as well as a clipboard drawing surface. The line-of-sight is drawn lightly at the proper inclination and as the precision laser measurements are announced by the laser person a dot is placed on the sketch for both the ceiling and floor marks.

Where appropriate, the precision left wall and right wall measurements are also measured and all the data is recorded by the note person in case the sketcher has a question about a missed point or location. Since you can see the laser dot on the ceiling one can precisely sketch in small ledges or changes in the limestone layers as small as an inch or so. The survey party just described uses five cavers which also helps to provide sufficient side light on the ceiling to show the small changes in the ceiling structure. If there are only four in the party, one end of the survey chain can often be tied in place allowing both the sketch person and the note person to roam about the passage for best visibility. If there are an additional one or two cavers in the party they can be put to good use scouting out the best location for precision passage cross sections. These cross sections may be sketched while the team is in the vicinity and are either sketched by the profile sketcher or by one of the additional party members defining the cross section location.

The May trip concentrated on an improved survey of the Inverted Bell Room. Numerous cross shots were made on this re-survey in order to clean up a previous error in the survey. We returned to the New Maze area on the May 31 trip and surveyed an area

noted on the May trip. In addition, teams were sent to complete a survey in Lower East Passage and in the Double Drop Pit areas. A tie was made between the upper levels down a pit to the lower Double Drop passage leading to a small waterfall we called Shower Chambers.

The July trip took advantage of the summer access of the Bat Cave passages (the Bat Cave entrance is closed except for a few months during the summer to prevent unnecessary disturbance of the bats) and fielded two teams to the 41-foot waterfall area. A detailed passage profile was started just upstream from the waterfall. We intended to carry the profile down the waterfall drops, but the precision laser rangefinder was not adequately charged (due to a charger malfunction) so additional passage cross sections were recorded instead. We plan to return next summer to complete the Bat Cave waterfall profile in the high ceiling areas. Two other teams concentrated on the upper levels around the T-Room, where the Bat Cave passage intersects the East Passage. Three surveys were tied together in this area and a cross section was surveyed at the T-Room.

Four teams were fielded on the September trip expedition, three into Fitton and one to check out a spring lead and do some ridge walking. Although it was extremely dry at the end of the summer, we hoped that the spring could be pushed to determine if it could possibly be an overflow route from Fitton Spring. Although we penetrated the spring 40 feet with our survey, the name assigned to it (Misery Hole) explains the "final" status until we can find some smaller cavers. The spring was tied by survey to Fitton Spring and GPS locations were obtained as the hillside above the spring was checked for other karst features.

Meanwhile three other parties were working in the East Passage. We attempted a multi-level passage cross section starting at the lowest level of the Double Drop Pit intersection with Lower East Passage, working our way up to the East Passage. Two other teams started a precision profile through the Out Room and the Roundhouse Room. Laser rangefinder ceiling heights were made in the areas where the ceiling was higher than 10 to 12 feet. On the October trip another precision profile survey team was fielded to the same area to complete the Out Room to Roundhouse Room profile.

Cartography will be high on our list for winter 1997-8. The bulk of the major passage 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) was provided to the Park Service early in 1997 and copies of the field notes from each expedition have also been provided at the request of the Park Service. The first cartographic task is to update the whole cave database into several smaller sections which will allow us to correct some errors. Then we plan to verify closures on multiple tie points by using the WALLS program.

Eastern Operations Report

compiled by Pat Kambesis

Eastern Operations ran a total of 11 expeditions in 1997, and supported a variety of different objectives including exploration/survey, archeology, paleontology, small caves inventory, restoration and rescue training. The Memorandum of Understanding between Mammoth Cave National Park and CRF was renewed for another 5 years. The new MOU is the result of much lengthy discussion between CRF personnel and NPS staff, as well as extensive internal review by both parties.

Survey/Cartography/Small Caves Inventory

During most all of the 1997 expeditions, survey teams continued with field work in Historic Mammoth, Salts, Unknown, Crystal Cave, Bedquilt, Proctor and Logsdon River sections of the Mammoth Cave System. Survey work involved producing more detailed sketches, improving vertical control, fixing closure errors and continuing with the exploration and survey of

previously undocumented areas. Small Cave Inventory objectives were also worked during most expeditions. These objectives included resource and bio-inventory, exploration and survey, photodocumentation and GPS related work. Survey teams also provided exploration and mapping support for Roppel and Sides Caves.

Eastern Operations members contributed almost 2500 hours to 66 trips that resulted in over 23,000 feet of resurvey and over 4400 feet of new footage.

Support was also provided for the Lesser Caves Inventory. A total of 37 trips contributing over 960 hours of work resulted in new GPS locations, brass caps, inventory and survey accomplishments in over 40 small caves in the park.

Archeology

Two teams photographed artifacts in the S-Bend area in support of the Names without Faces Project and Earthwatch. Using a compass and tape to locate artifacts from provided coordinates, they photographed with and without scales in both black and white and color. The artifacts photographed included mussel shells, paleofeces, torch ties, burned cane and mining area.

Paleontology

A new project, under principal investigator Rick Toomey from the Illinois State Museum proposes to identify, map, characterize and analyze bat roosts near the Historic Entrance of Mammoth Cave.

During the Memorial Day expedition two paleo teams worked on bat study objectives. A preliminary visit was made to Audubon Avenue and Olivia's Bower area of Mammoth Cave. The purpose of this trip was to prepare for the upcoming inventory of bat remains. A second team did inventory work in Bat Cave. During the Thanksgiving expedition and in December, paleo crews worked in the Historic area. Their objective was to inventory paleontologic resources and survey aboriginal trail. Resources located included bat remains, bat guano, raccoon scat, and chicken bones. A very significant partially mummified and skeletonized bat was found in the area.

Gazetteer and Bibliography of Mammoth Cave

Sue Hagan and Mick Sutton began work on their Gazetteer and Bibliography of Mammoth Cave in 1988. Since then the project has grown into an impressive database that has become so large it can no longer be transferred from the computer housing it. Eastern Operations provided funding for the purchase of a data storage and transfer equipment to enable work to be shared with other researchers.

Restoration/Clean-up

Eastern Operations continued to field teams to work on the restoration of the Crystal Cave Historic Area District (which includes the entrance to Crystal Cave the ticket office, and the Collins house.) CRF members removed the Austin House, Spelee Hut and the Back Bunkhouse from the area adjacent to the cave entrance. Many items were recycled from the Austin House and the Back Bunkhouse including doors, windows, hardware, plumbing, paneling and much of the lumber. The Spelee Hut was dismantled, moved to Hamilton Valley and reassembled. The project, which was conducted through a Challenge Cost Share program was completed in July.

Training

The Columbus Day Expedition was dedicated to cave rescue training. In addition to CRF personnel, other participants included NPS staff, local rescue agency personnel and interested members of the caving community. CRF coordinated and directed the expedition in order to provide the platform from which NCRC conducted the actual rescue training. The weekend session consisted of classroom training, practical field exercises, obstacle courses and a full mock in-cave rescue.

Guadalupe Escarpment Area

Carlsbad Cavern - Restoration Field Camp

Barbe Barker

CRF's Carlsbad Restoration Field Camp took place from June 15-19, 1997. Prior to restoration activities, an organizational meeting was held to set up the trip leaders and all of the restoration tasks Carlsbad Caverns National Park (CCNP) Cave Specialists wanted us to accomplish.

Ann Scarvada designed the 4 color, 1997 Restoration Field Camp tee-shirts which show a design based on Lake of the Clouds; each participant received a shirt.

Pat Copeland, Trip Leader, headed up the Green Lake Area Restoration Project. With her were Lois Lyles, Kevin Justus, Deb Runyon, Barbe Barker, Tracey VanEps, Bart Rapp, Ann Scavarda, Meliene Davis, Melynn Conway and Phyllis Boneau. Iggy and Travis, volunteers with NPS, joined us for a couple of days. There were two areas across from each other which needed serious cleaning. Trail water run-off had left 4 inches of a thick, greasy, black "mud" in one little alcove area. It had to be scooped out before anything else could be done. The adjacent area was covered in black but the team uncovered white flowstone and cave coral.

Across the trail a large area was covered in mud, rubble, crushed popcorn and aragonite. After picking everything up, a beautiful white pool was uncovered and cleaned. The flowstone floor was restored and a main power cable was camouflaged with loose bits of cave coral.

Bill Bentley, Trip Leader, and Brad Blackburn joined Tom Bemis with CCNP, to pull the old communications coax cable throughout the Big Room, starting at The Bottomless Pit, working their way to the Lunchroom. They then proceeded from the entrance of the cave down to Iceberg Rock. You should have seen the huge pile of coax cable that was hauled out (rolling it up as they went) and put on the back steps of the Visitor's Center.

Jim White, Trip Leader, along with Dave Milhollin, Martha McArthur, Jill McArthur, Donna Mosesmann and Bryan Alley, continued in the quest to restore the Old Lunchroom. After hauling out tons of blast rubble, they uncovered beautiful rimstone dams and had to be drained before they could be restored. Other areas of flowstone were cleaned, swept and rubble hauled off.

Paul Rodriquez along with Jed Holmes, worked between all the teams picking up the 5-gallon buckets of rubble, placing them in wheelbarrows and hauling them to Left Hand Tunnel. Paul had to hand-carry all the buckets of rubble from the Green Lake Area up a flight of stairs before he could place them in a wheelbarrow.

CRF volunteered a total of 680 restoration hours to Carlsbad Caverns National Park.

Lincoln National Forest—Capitan Peak Study Area Project - 1997 Update

Dick Venters

Spring 1997

The spring 1997 CRF-LNF—CPSA was held during the week of April 19 through 22, 1997. Seven caver volunteers attended. Thanks to John Corchoran III, our crew started a new adventure in surficial cave survey with the use of USGS Aerial Photographs. Areas that were covered in the photographs were Capitan Peak, Baca Ridge and Lincoln National Forest.

The nine-by-nine inch black and white aerial photographs show a greater delineation of the areas mentioned and their surficial karst features (major sinks and geologic structure). Through the direct interpretation of the photographs, we hope to broaden our knowledge base for the different karst features, cave locations, and to increase our ridgewalking expertise.

In our first "trial-by-fire", an area to the southwest of Arabela, New Mexico between Chavez and Tinnie Canyon (Trail Canyon), was proposed for field testing this mode of reconnaissance. The aerial photograph of this trial area showed a large longitudinal ridge with nine large sinks running north south on a linear trend. The hardest part was finding a road or trail to the ridge that did not go through private land. As luck was on our side, we remarkably hit the right spot the first time. It was a three and one-half mile trek up steep slopes and canyons to the ridge. We finally located all nine large sinks along with three new caves. The ridgewalk took most of the day and everyone came back to camp very tired and satisfied with the new experience. In the following three days, our crew visited four different sites with karst-related features. A total of 19 sinks and four caves were found and logged during the expedition.

Caver-volunteers supporting the project: Dick Venters, Dennis Heiffenstein, Jeffery Worthington, Randy Cabeen, Lloyd Swartz, Leroy Trujillo, Glenda Dawson, Glen Dawson-Phodes, Lloyd Swartz, Dennis Worthington, Janelle Worthington, Jeffery Worthington, Loretta Worthington, Jim Hardy Fritzi Hardy, John J. Corcoran III, Dorothy Corcoran, Randy Cabeen, David Sherrow, Frank Mastrilli, Virginia Venters, Anita Pittenger, John Corcoran 111, Dan Sullivan, Lloyd Swartz, Dorothy Corcoran, Bob Pape, Tom Harris.

Lava Beds Project Report

Janet Sowers

This year was a productive one for the Lava Beds project. We fielded five expeditions involving a total of 32 people, logging in 639 volunteer hours. Below is a summary of our activities.

Cave Survey, Inventory, and GPS Location

Our major efforts this year have been 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.

Cave survey continues at a steady pace. In 1997 we surveyed Reunion Cave, Coral Reef Cave, Jumble Cave, Downtown Cave, and Bypass Cave. Two of these are now drawn up in final form. Several caves surveyed last year remain to be drawn up.

We are experimenting with a new way of plotting azimuth data to correct for the magnetic anomalies that seem to be a constant problem in these caves. Foresights and backsights are found to differ by as much as 20 degrees in some caves. The correction method assumes that the anomaly at any given station is constant regardless of the direction the compass is pointing. Thus, the angle between the foresight and backsight taken from a single station is correct, regardless of the direction or amount of the anomaly. The Coral Reef Cave azimuth data were the first cave data plotted using this new anomaly correction procedure, however, because the cave had only one entrance and no interior loops, we had no way of knowing whether the corrected plot was a better representation of the cave geometry than the uncorrected plot.

On a later trip Janet Sowers and Bill and Peri Frantz conducted a test of the magnetic anomaly correction procedure by surveying a loop in the front and out the back of a short segment of Hercules Leg Cave, closing the loop over the surface. Foresights and backsights differed by 4 to 6 degrees in this survey. We plotted up the data, both corrected and uncorrected, and found that the corrected plot closed the loop best. We conclude that it is worth the effort to correct the bearings.

Monitoring

We continued with long-term monitoring of ice levels in the ice caves, and winter bat population counts. An interesting phenomena in Merrill Ice Cave was observed this fall. The ice at the base of the ice pond apparently melted and drained out, leaving a small ice cavern beneath the ice slab that once was the top of the pond. As far as we know this has not been observed at Lava Beds before. This coming February we will thoroughly document the status of the ice in Merrill and try to understand what happened.

In the fall of 1998, CRF will assist the USFS Modoc National Forest in the "Klamath Basin Cave Workshop", a cave management workshop for USFS biologists in the northern California, Oregon, Washington area. We have agreed to give a presentation on lava cave geology, and to conduct some cave tours at Lava Beds for workshop participants.

The Lava Beds Research Center

We are moving, slowly but surely, toward the dream of a field research facility at Lava Beds! If you haven't been following this story, 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.

This year we took several significant steps. First, Richard Minert (of SFBC and Minert Architects, Inc.) made drawings of the proposed facility showing the floor plan and front and side elevations. The building, as drawn, is 1300 square feet with a simple, elegant design that is inexpensive and fits in with the rustic setting. It has a wrap-around 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. In a March meeting Richard presented the sketches to Lava Beds Superintendent Craig Dorman and Chief of Resources Management Chuck Barat. They were very pleased. Richard will proceed with the construction drawings as soon as these sketches get final approval.

Second, a Memorandum of Agreement (MOA) was prepared among the three parties involved: the National Park Service (NPS), the Cave Research Foundation (CRF), and the Lava Beds Natural History Association (NHA), to be signed early in 1998. It states, briefly, that CRF will be responsible for design, fund raising, and construction (in short, almost everything). 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.

Missouri Operation Area Activity Report

Mick Sutton

Mark Twain National Forest

The preparation of maps and reports for the recently completed Phase 2 of our Mark Twain National Forest mapping and inventory project continued to occupy large amounts of time. The backlog is now down to reasonable proportions (for example, 26 maps have been drafted this year, while 3 remain to be completed), and field work has begun on Phase 3 of the project.

During Phase 3, work continues in the original study area, the Doniphan-Eleven Point district, but we are also branching out to other areas. As part of this process, a mapping project in east-central Missouri has been revived. Cave Hollow Cave is a relatively large and complicated stream cave on the Salem-Potosi ranger district adjacent to the Viburnum trend lead mining region.

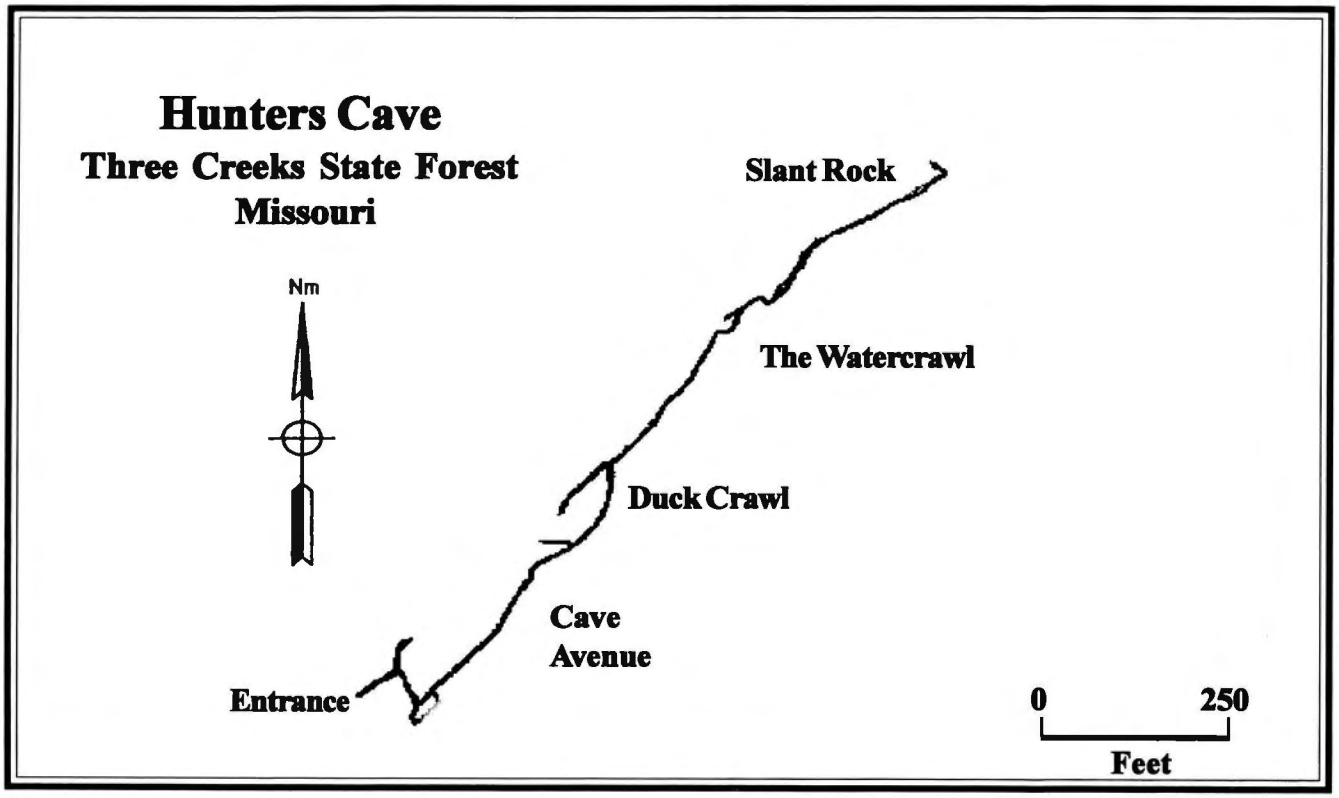
We had begun mapping it in 1988, prior to CRF's involvement in Missouri caving, but the project was postponed in late 1991 owing to higher priorities, namely the beginning of the CRF Project in the Eleven Point area. We are pleased to finally return to this project. Two mapping trips took place. The first was confined to the near reaches of the cave owing to threatening weather. A series of narrow canyons and high domes off the main trunk was mapped for a total of 300 feet. As expected, the passages led to an airy overlook of the main trunk which we had been unable to reach from the latter. A second trip took place just prior to the seasonal closure for a small Indiana bat colony that we discovered in 1991. This trip went far upstream and knocked off a sequence of high- level loops, some of which were more difficult to enter than others, for a total of 230 feet. These all appear to be sections of an intermittent small canyon that parallels the main passage slightly out of phase with it. With the surveyed length at 4,550 feet, one lead remains for next year, a low, wet tributary stream.

Back in the Eleven Point area, there was a trip to complete another project from long ago. The two Spout Spring caves were also mapped back in 1988, but had never been drawn up as some elevation data needed to be collected. We took care of that and also ran a bioinventory of the two caves, the longer of which is about 500 feet. The names of these caves are slightly puzzling as Spout Spring itself is almost a mile farther downstream along the creek, a small gravity spring on private property. We took a look at this area and found that there were two rather obvious caves, one of them almost above the original Spout Spring Cave. The misplacement is of long standing, as it appears in J. Harlan Bretz' classic, " Caves of Missouri" of 1956.

Finally, there was a return trip to Bliss Camp Cave to complete the bio-inventory of that fairly large system. We took along two biologists from the Missouri Department of Conservation to examine the southern cave fish habitat. Cave fish ranged in length from 7 cm down to 2 cm, indicating the likelihood of a stable, reproducing population. The population is probably small and isolated, as it is unlikely that there are hydrological connections to the region's deep phreatic networks. One other biological question concerned the twilight zone crickets. A cricket collected earlier appeared to be an unusual specimen of *Ceuriropirilus divergens*, which doesn't normally enter the area's caves. However, the specimens collected this time were the commonest local twilight zone species, *C. williamsoni*

Ozark National Scenic Riverways

Round Spring Cavern: There were two faunal census and/or photography trips to this large tourist cave on the Ozark National Scenic Riverways. The cave salamander population we have been monitoring repeated last year's pattern: the hordes of small larvae present from late fall through mid-spring had essentially disappeared by April. An observation of larvae in the stream of Round Spring Resurgence Cave suggests that dispersal to the outside may be part of the reason. By early June, fairly large numbers of grotto salamander larvae were present, while the only sign of adult cave salamanders was within the entrance zone.



In the same general area, Shaft Cave (a.k.a. Round Spring Pit), was relocated. This site had eluded searchers for many years. Later, a survey crew mapped and inventoried the cave, which is similar to other small upland pits in the region. A 40-foot entrance shaft leads into a fairly large room with 100 feet of passage leading from it. The entrance to deeper and presumably greater voids is thoroughly blocked by the debris collapse which caused the pit to open up in the first place.

Powder Mill Creek Cave: There were two radically different trips to this cave, a long-term project within the Ozark National Scenic Riverways (but owned by the Missouri Department of Conservation). CRF members assisted a 6-person TV crew in filming a typical survey and bio-inventory operation for the MDC series, Missouri Outdoors. The film crew used a canoe to ferry in the large quantities of equipment.

Highlights of the filming included a shot of beaver kits in their den, and a visit by the producer (with hand held camera) into the somewhat aquatic entrance of the Hell Hole. There were follow-up interviews using Round Spring Resurgence Cave as a backdrop. The story is scheduled for broadcasting in 1998.

A survey trip resulted in completion of a loose-end lead beyond Snowball Dome in the Hell Hole series of Powder Mill Creek Cave. The notorious (and long and complicated) Hell Hole series was finally completed with a trip in July. The next trip visited the Third Watercrawl where a party finished off a group of leads in a fairly long side passage featuring a scenic area of rimstone dams. The leads varied from dry and easy to low, muddy and claustrophobic. Survey and inventory work continue in Powder Mill Cave which is now known for 36,069 feet.

There were two tourist trips and one faunal census trip to Round Spring Cavern. The first tourist trip was in connection with the US visit of a Chinese cave science contingent from Guizhou Province, China. Following the NSS convention in Sullivan, Missouri, the four Chinese scientists and theirAmerican hosts visited CRF's study area in the southern Missouri Ozarks. Big Spring was interesting, but not overwhelming; the biggest karstic spring in the US would rank approximately number eight in Guizhou province! Of more interest was the Round Spring trip, where the Chinese got their first view of the US underground. The wildlife, even the

troglobitic cave maggots, proved quite a hit. The following day, the whole contingent was treated, courtesy of the National Park Service, to a float trip on the upper Current River. The second Round Spring tour trip was a demonstration of cave ecology for a local Audubon Society group.

Bob and Maggie Osburn at Harley Patterson Cave, Pioneer Forest, Shannon County, Missouri, Photo by Scott House

In November, a routine faunal census took place. The biggest surprise was that the pool which showed a peak of salamander activity the past two winters was almost completely dry. However adult cave salamanders were still active in many of the other mud-bottomed pools in the cave; as before, adult salamanders are diving into deep mud, and small hatchling salamanders are starting to appear. With the main pool apparently out of action, we expect to see a more modest build-up of larval numbers this year. The obvious conclusion that the salamanders are laying eggs in the deep mud has several serious problems: I) in all recorded instances, cave salamanders deposit eggs under rocks in clear free-flowing streams; 2) amphibian eggs should not do well buried in fine sediments, owing to limited gas exchange, i.e., they would be expected to suffocate.

A new project was started on the Riverways, mapping and inventory of a group of caves in the general area of Round Spring. Like the Forest Service project, this study was inspired by the continuing threat of mineral prospecting within the Big Spring watershed. We will be doing detailed bio-inventories and setting up permanent census plots. The first cave visited was Panther Spring, opening at river level on the lower Current. Two mapping and inventory trips succeeded in mapping most but not all of the 1,000+ foot cave, which features some low and slimy passage. In a dome at the farthest end were some very odd clay sculptures, possibly of historic interest. The wildlife includes small but significant numbers of gray bats, troglobitic isopods, and two species of epigean or troglophilic amphipods.

Pioneer Forest

This is a privately held property (180,000 acres) which continues to have CRF activity. CRF has surveyed and inventoried 100 caves and CRF continues to provide assistance to the Missouri Department of Conservation.

Three Creeks State Forest

CRF Missouri has mapped 6000 feet of Hunter's Cave. Work is slowed due to the fact that this is a maternity gray bat cave.

Sequoia and Kings Canyon/Mineral King Operation Area

Lilburn Cave Restoration

Bill Frantz

Lilburn Cave, with 25.6 kilometers of passage, is one of California's two largest caves. With its very unusual flushing and gushing resurgence spring, it has attracted cavers and speleologists since the 1940s. Over its long history of use, some of the formation areas in Lilburn cave have suffered damage. Fortunately there is little formation breakage, but the very muddy nature of some passages has resulted in dirty formations.

In 1993, the Lilburn Cave Restoration project started to try to undo some of that damage and prevent further damage. Since then several trips each year have been dedicated to cleaning formations, flagging trails, and installing direction signs.

During the course of our cleaning, we have had the opportunity to experiment with many techniques. We have made extensive use of water from spray bottles and brushes for removing mud from formations. We have found the dry brushing is frequently sufficient to remove carbide soot from walls. In cases where mud has become embedded in calcite, we have used both sulfuric acid (H_2S0_4) and hydrochloric acid (HCl). Our experience is that the hydrochloric acid is more effective.

We have also tried more unusual techniques, such as: Pieces of tape on the end of polls to pick mud off formations are not very effective. Eyedroppers and turkey basters to suck dirt out of pools are reasonably effective. Sponges to soak up soiled water are necessary to protect unsoiled formations. We even once used a stream of water from a caver's mouth when no spray bottles were available which was quite effective.

The value of flagged trails through sensitive areas is well understood and many caving areas have adopted the practice. In Lilburn, some of the damage comes from parties who have become confused about the route. Installing signs (written on flagging tape) at junctions likely to cause confusion has reduced the impact of route confusion on passages people did not even intend to enter.

We have progressed from having to clean formations, which were dirtied many years ago, to the point where exploration teams, which dirty formations, help organize restoration trips to clean those areas. A quick cleanup is a lot more effective than one that must remove years of calcite deposition.

In 1997 we ran three restoration trips. There were two trips to the area under the Jefferson Memorial, and one trip to survey restoration sites and determines their current condition.

Historic Entrance Renovation

Roger Mortimer

The years have not been kind to the historic entrance to Lilburn Cave. At a later expedition Saturday, John Tinsley and I added more rocks and poured the first course of concrete. The next day we continued the process with several more concrete sherpas helping out. At the same time Peter Bosted solidified the base of the second ladder.

Currently there is a first step poured as a base. It sits between bedrockish boulders delimiting the passage as one goes in the cave. The form has been moved and a second step has been started. The design is impromptu, depending on what was on hand at the time but it has followed several principles. The new floor structure should be aesthetic as well as durable. It should send water down the bypass and not down the main passage. It must be ready to support the new ladder when one is ready. It must allow easy passage of a stretcher in the event of an emergency. It should include anchors in case one is needed in an emergency.

The next operation will finish the second step and the pouring of the floor. This floor will probably be at the level of the concrete walls currently in

place. When the it is poured we will leave two holes in contact with the underlying dirt which will allow some extra drainage but more importantly be in position to accept the legs of the ladder so they cannot swivel while someone is climbing it. There is still cement at the cabin but winter humidity may make it less than useful. We will reassess the situation and try to complete the project this Spring.

Digging

Brad Hacker

Digging occurred in Sequoia National Park in 1997 at one location. During the winter of 1996/1997 a tree in the bottom of a sinkhole ("Meatbug Sink") northwest of Lilburn Cave toppled, revealing at its base a too-small cave opening. In one morning of May 1997, four Cave Research Foundation members moved about one dozen head-sized cobbles up from the hole into the bottom of the sink and then entered a body-sized chamber beneath the former tree. From that perspective it was clear that the "passage" terminated in a tightly packed boulder choke, and the site was abandoned to let the winter of 1997/1998 finish the job.

Cave Diving 1997

Bill Farr

There were a number of trips in August through October during which Bill Farr and Jim Brown set up and dove in Big Springs, the resurgence for Lilburn Cave, and in the Rise, where Redwood Creek enters Lilburn Cave. Nine hundred feet of new underwater survey was accomplished at each of these sites under difficult conditions of low visibility, cold water, long dive times and depths of up to 260 feet.

Diving accomplishments for 1997 include:

First mixed gas diving in Big Springs including custom dive tables for mixed gas decompression at altitude

Big Springs bottomed at -248 feet at 900 feet in. Currently we are at -243 feet

depth at 1000-foot penetration, with the way on through a 10-inch high crack, 4 feet wide.

Refinement of techniques for extended deep diving at high altitudes in cold water, including first test of a battery operated chest heater for decompression.

Breakthrough in the Upstream Rise. Beyond a previous sand block 250 feet. in, entered a phreatic borehole that has continued to 1200-foot penetration with no apparent side passages. Maximum depth (at the ceiling) is -163 feet. Currently back up to -141 feet in a 15-foot diameter tube.

Objectives for 1998 include determining if the underwater conduits are still open after winter 1997; continued exploration in Big Springs and Upstream Rise; rechecking of the South Seas Sump.

Mineral King Area— 1997 Activities Report

Roger Mortimer, Project Coordinator

In 1997 CRF saw important advances in the project at Mineral King. The Cirque mapping project is effectively completed and the preliminary map has been field checked. Jeff Cherez made an exciting new find in the Panorama side of the valley.

After 5 years of survey there is a map of Cirque Cave. One hundred fifty three stations gave 1704 feet of survey (519 meters) with a vertical extent of 72 feet (22 meters). While field checking the map this summer we did find one high lead which gave us another 100 feet of passage near the Green Pool. There are a few more feet that could be squeezed out of the cave by the desperate but no known lead of any significance remains.

The most exciting occurrence in Mineral King this year is the survey of a new cave found by Jeff Cherez. Beulah Cave is on the Panorama side of the valley near Cascade Creek. Jeff was ridgewalking the Panorama side with Merrilee Proffitt when he found the entrance. He did not have adequate time to explore it. This year he returned with Brad Hacker to survey 1021 feet (311 meters) with 83 stations. The vertical

depth is 158 feet (48 meters).

Survey continues in White Chief. This year's one expedition completed the B-survey in the upper stream passage. A new survey took off towards the insurgence but ended up much higher than that. The last team did upper level passage above the big room. So far we have set 151 stations for 2348 feet (715 meters) and a depth of 317 feet (100 meters). This coming year we need to continue the C-survey towards the insurgence, follow the water downstream towards the resurgence, and start to work on the maze around the Meyer entrance.

Other survey work to be done includes the smaller caves of the valley such as Batslab and Seldom Seen as well as surface surveys linking more of the caves together. Eventually we want to have all the caves linked together either by surface survey or by GPS and include the sinkholes that lead toward Eagle Sinks.

Sedimentology of the Redwood Canyon Karst

John C. Tinsley

The winter of 1996-1997 was a banner year for sediment movement in Redwood Canyon and within Lilburn Cave. The wet, deep, early-season snowfall of November and December, plus an El Nino (Pineapple Express) weather pattern, extending from Hawaii to the southern Sierra Nevada, that dumped near-record quantities of warm rain during the first week of January, 1997, resulted in levels of runoff in Redwood Canyon that were sufficient to blow the sediment plug from the Upstream Rise and Big Spring sections of Lilburn Cave, and erode all fine sand that comprised the low set of fill terraces extending downstream of the Big Spring resurgence in the bed of Redwood Creek. There was no fine sand to be found in Redwood Creek channel; only pea-size gravel could be found among the coarse boulders in Redwood Creek. At Big Spring (the resurgence of Redwood Creek below Lilburn Cave) water boiled up through the tree roots upslope of the normal single spring orifice and a thin deposit of coarse sand was deposited on the previous season's forest soil.

Within the cave, the elevation at which cavers' footprints disappeared on the floor of the Hexadendron Room and in the lower part of the Corkscrew, as well as the points of inundation measured on static sediment samplers deployed in the Lake Room and White Rapids areas indicate that approximately 130 to 140 feet of head was attained above the Z-Room piezometer maintained by Jack Hess. Hess reported that the instrumentation was inundated, owing to the extreme pressures. Every southward-oriented passage from the level of the Bicycle Passage and below bore witness to the movement of large volumes of sediment.

The Pebble Pile sinkhole became filled with sediment to its downstream lip, and water flowed in the creek channel across the former sinkhole for the first time in nearly a decade. The progressively infilling the sinkhole has taken 9 winters to complete, with contributions of sediment having been derived from backwasting of the hillslope as well as from bedload transported by Pebble Pike Creek. The original sinkhole collapse represented a volume of about 140 cubic yards of sediment dumped into Lilburn Cave near the Yellow Floored Domes area.

The impact within the cave was immediate, with the standing water level raised approximately 12 feet in the South Seas and an aggradation of the bed of the cave stream of approximately 10 feet was observed at the Z-Room area the same season the sinkhole was observed by Howard Hurtt. Inspection of the 5 dozen sinkholes upstream of Lilburn Cave revealed that winter runoff had dropped the floor of Meat Bug Hole about 1.5 meters, and a body-sized passage could be observed extending downstream. Brad Hacker led an exploration effort there that terminated in a boulder choke after a couple of body lengths of passage had been stabilized.

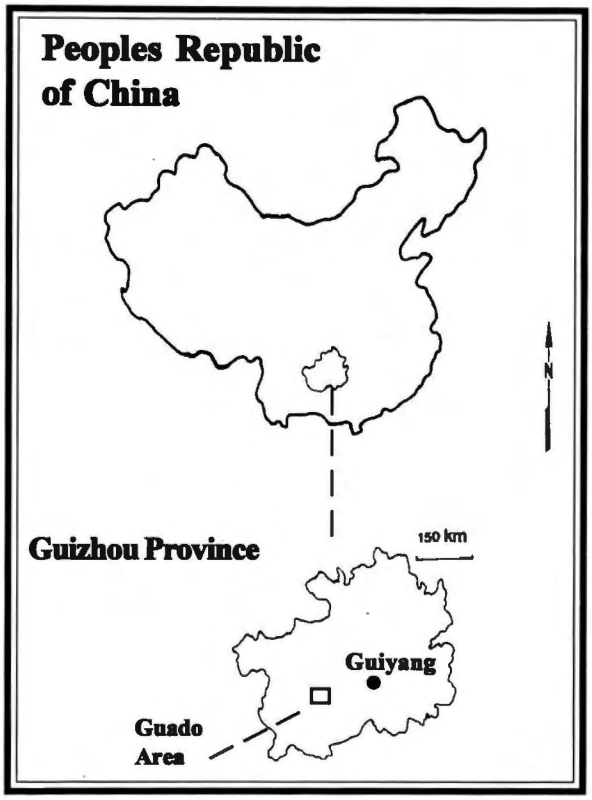
Farther north above the Great North Cave, a landslide is feeding a large sinkhole along an unnamed tributary approximately one mile up canyon from the field station. In summary, the 1996-7 winter proved to be a wholly remarkable performance by a dynamic karst hydrologic system.

China Caves Project

China Caves Project/ Exchange Program - Update

Ian Baren

For the past 8 years, the China/USA Caves Project, supported by the Cave Research Foundation, has explored the caves and karst regions of China in cooperation with several Chinese institutions. Since 1990 the Cave Research Foundation has been working with scientists from the Guizhou Normal University to explore, survey and photo-document some of China's largest cave systems. Each expedition to China is followed by a return visit to the US by Chinese cavers and scientists, to continue the work of a true exchange of research, exploration and experience. Since 1991, expeditions have been fielded to Guizhou Province, an area in south central China consisting of over 170,000 square kilometers of limestone and karst formations.



Spring 1995

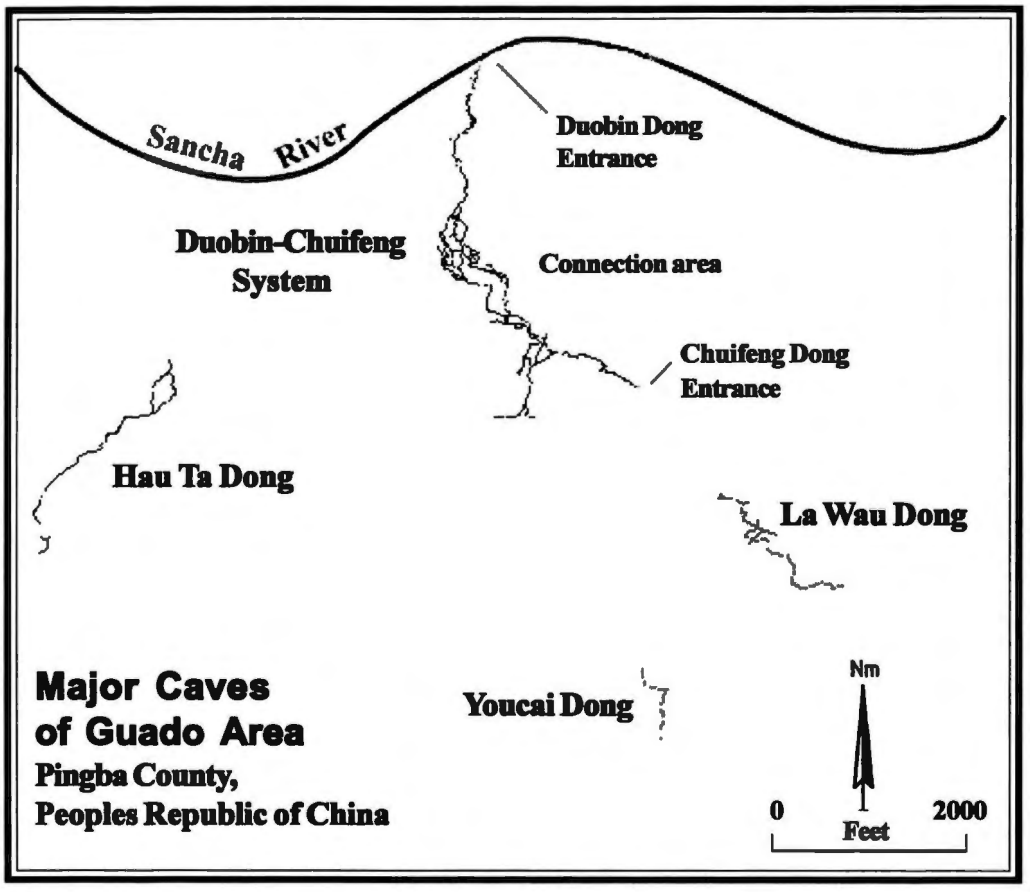
In March and April of 1995, Bob Cohen and Mike Newsome made a three-week follow-up trip to the 1993 Guizhou Province expedition. They participated in a field excursion along with faculty and students from the Geography Department of Guizhou Normal University. The field trip visited Guado and the Maoian Karst Preserve in the south of the province. In Guado, they worked primarily in Chuifeng Dong (Blowing Cave) were they set up an underground camp in order to explore passage that was trending toward Duobin Dong (Hiding from Soldiers Cave). They worked in a small canyon passage and surveyed to a series of three drops. At the third pitch, where the sound of water was louder, they had run out of rope.

Winter 1996 in Guado

A second expedition went back to Guado from December1995 - January 1996. Five Americans joined a team from Guizhou Normal University in continuing the exploration in the Guado area. They were, Ian Baren, Don Coons, Bob Cohen, Molly Lucier and Mike Newsome. They spent a total of thirty days in the field, and more than 18 days underground during three camps.

Beginning in Chuifeng Dong, where Cohen and Newsome were turned back in 1995, the connection was made to Duobin Dong on the first trip. Rappelling the connection rope, the team of four was pleased to land on top of the flagging tape marking the final station in Duobin Dong. Exploring upstream, they quickly found a good site for a base camp on a wide sandbar in the stream. Over the next several weeks, the teams explored upstream in the Duobin Dong river towards a hoped-for connection with either Xiaolu Dong or Youcai Dong to the south. Instead of finding one or both caves, or even the downstream sumps of either, they found three sumps upstream of the connection. In addition, more than three kilometers of additional passage was mapped in dry upper levels of Duobin Dong.

When the team was on the surface, they took the opportunity to do extensive surface survey work to tie in the various cave entrances (Hua Ta Dong, Lau Wa Dong, Youcai Dong, Chuifeng/Duobin System) to el-



evation benchmarks on the topographic map of the area. Many water samples were taken, both in the caves and on the surface, in order to study the hydrology and water chemistry of the area. Preliminary results show the water that enters the insurgences is extremely acidic, which helps to explain the huge size of many of the cave passages. While in the field, the team had the opportunity to help train several graduate students and instructors from the University in safe caving techniques. At the end of the trip, it was decided that for the most part, the cave system in Guado had been thoroughly explored - though there was one more upper lead in Chuifeng Dong. Future expeditions will move on to other areas.

Exchange Program, June 1997

In the summer of 1997, 5 Chinese researchers/ cavers were sponsored to the US by the Cave Research Foundation and the National Speleological Society. Both NSS and CRF members hosted the Chinese delegation before, during and after the NSS convention in Sullivan, Missouri.

The Chinese delegation arrived in Chicago where Ian Baren, Mike Newsome and Bob Cohen met them. The group spent an evening in Chicago with Windy City Grotto members and then worked their way south, with a stop at the farm of Don Coons. They spent two days in the area, socializing with local farmers, driving Don's tractors and showing how kareoke is really done in the local bar in Rutland, Illinois. After a community-sponsored potluck the delegation made its way down to the NSS convention in Sullivan, Missouri where they spent the next week participating in various NSS functions, giving papers at the geology session and meeting with the NSS Board of directors. After the convention, the group was hosted by Mick Sutton and Sue Hagan who showed them the sites in Missouri, including a float trip on the Eleven Point River. The delegation headed east, to spend a day at Mammoth Cave before heading off to New York for the last few days of their visit. Mike Newsome entertained the delegation for their last few days, taking them to various museums, cultural exhibits, and standard tourist venue.

The next China Caves Expedition is slated for spring of 1998.

Biological Sciences

Biologic Inventory in the Southern Missouri Ozarks

Mick Sutton

We have now almost completed fieldwork for the second phase of an extensive cave mapping and bioinventory program in the Mark Twain National Forest (MTNF) between the Eleven Point and Current Rivers in Oregon and Shannon Counties, Missouri. The first phase of the project began in 1990, and was based on concern over the potential effects of mineral prospecting in a highly karstic area. Following completion of that first study (Sutton, 1992, 1997), the project expanded to cover other caves within the MTNF Eleven Point District, and to caves owned by other agencies, notably within the Missouri State Forests and within the privately owned Pioneer Forest. Background on the program is given in the CRF Annual Reports for 1990-1993.

Within the study area, CRF crews have examined a total of about 160 caves, ranging in length from 25 ft. to 1 1/2 miles. Of these, 40 were previously unrecorded; since we have made no systematic effort to search for unknown caves, it is certain that many more unrecorded caves exist in the area. Although some of the major caves had already been mapped (primarily by personnel later involved in the CRF project), a total of almost 10 miles of mapped passage have been added to our cartographic database of the study area. In addition, this attempt to look comprehensively at all known (and some previously unknown) caves in a relatively large area is helping to build a broad overview of the regional cave fauna.

Highlights of Phase 2

The longest caves mapped during Phase 2 were Bliss Camp Cave at 4,020 ft. and Bluehole Cave at 2,520 ft. Both caves proved to be interesting, structurally and biologically. Bliss Camp has a large entrance along the Eleven Point River and is heavily visited by recreational floaters. However, entry beyond the short entrance tunnel is well guarded by a low-airspace stream crawl, and visitation to the beautifully decorated upstream trunk has been very light. An overflow tube led unexpectedly to a separate stream passage, which the survey crew followed to another wet crawl exiting to the river (Outflow Cave). Each water crawl is only a foot or two above normal river level, making for a serious flood hazard, and precluding trips whenever there is even a small chance of a rise in river level. At a breakdown zone forming the apparent upstream limit, access was gained to a dry upper trunk, diverging from the main stream trunk and ending eventually in a flowstone choke.

The cave is biologically rich and has showed some interesting variations in the three years we have visited it. In 1993, the river-level passages near the entrance had a large population of spot-handed crayfish, a common surface species that occasionally wanders into area caves. In 1994, following severe winter flooding, the crayfish disappeared, to be replaced by a population of southern cavefish, which had not shown themselves the previous year. An aftermath of the winter floods was also apparent-several dozen pipistrelles had drowned in the long, wet overflow tube. These results are giving a hint of the dynamic aspects of the region's cave ecology.

Another example is furnished in nearby Sand Cave. A State-sponsored inventory by Gene Gardner in 1986, when the cave was dry, showed little of interest. When re-examined by a CRF crew when the cave was in flood, revealed an unsuspected population of troglobitic crayfish. Persevering past a tight section into unentered trunk doubled the known length of Bluehole Cave. The cave was already known to be a summer gray bat site, but the "new" section revealed a high dome with the floor knee deep in fresh bat guano, evidently the main summer roost. A subsequent trip found the colony in a transitional roost near the entrance, with the population conservatively estimated at 10,000.

An attempt to map newly reported Crewse Cave was stymied by the inconvenient fact that the pit entrance had become a completely flooded spring. We still managed some bioinventory, as a large water snake (*Nerodia sipedon*) objected to our presence and shot up out of the flooded entrance fissure in an apparent attempt to drive us off. A return trip during the late summer groundwater low point found a dry 15-foot pit leading to a muddy but dry horizontal passage 100 feet long, with no obvious continuation-an unusual opportunity to see the innards of an intermittently active spring. Presumably, the water forces its way up through the fine sediment when the spring is flowing.

Nearby Panther Cave was another unusual situation, as the entrance is a large sink-in the Ozarks almost all caves are entered through a resurgence or paleo-resurgence. As a result, the cave is nutrient-enriched with washed-in leaf litter to an extent we rarely see, and is biologically diverse, including southern cavefish and Salem cave crayfish in the cave's terminal pool. The survey showed an unusual spiral structure, with the terminal sump almost directly below the entrance. The cave's fauna also included a genus of gnat (Cecidomyiidae: Lestremia sp.) rarely reported from caves. Elsewhere, we have picked up another unusual gnat from a different family (*Mycetophelidae*, but not the common webworm), and a species of "hump-backed fly" (Phoridae) apparently known only from Missouri, and not previously reported from caves.

Whites Creek in the Irish Wilderness has a large number of reported caves, most of them small, but CRF crews found that the names and locations were in a state of utter confusion. A comprehensive mapping and locating program, occupying several multi-day backpack and canoe trips, sorted out the mess and added a few caves to the list. One of the remoter caves turned out to be unexpectedly large, with 1200 feet of sizeable trunk. Many of the Whites Creek caves are multi-entrance mini-mazes, with main passages running parallel to the creek; presumably, these are a species of abandoned meander niche. Two caves were spongework mazes, another unusual form for the area. Root Cellar Cave, 1100 feet long, included a previously unknown second entrance featuring nests of both eastern phoebe and turkey vulture.

River Level Cave is yet another site where a low, wet entrance leads into pleasant, larger passage-this had been vaguely reported but not documented. The cave had a rich and unusual assortment of stream fauna, with populations of troglobitic isopods and crayfish, surface crayfish, troglophilic snails and salamander larvae, and a unique record of lampreys in a dark zone site; moreover, two of the three lampreys seemed to be engaged in spawning activity.

State Forest and Pioneer Forest caves

Work also continued on two other mapping and inventory projects in the same general area: on Missouri Department of Conservation (MDC) land, and on the Pioneer Forest, the largest privately owned forest in Missouri. Both of these areas are in Shannon County, within the watershed of the Current River.

The remote and beautiful Leatherwood Creek on Pioneer Forest has an unusual concentration of caves, at least one of which (Big Cave) may be fairly long-we failed to find out because, not for the first time, we ran into an off-season concentration of gray bats. This was not a known bat cave, but appears to have a significant summer colony, judging by the quantities of guano. A large number of caves were mapped and inventoried along Leatherwood Creek.

Round Spring Cavern. Another program, begun in January, 1996, takes a more detailed look at seasonal changes in the biology of Round Spring Cavern, a large cave within the Ozark National Scenic Riverways, where CRF crews have been conducting faunal censuses at relatively frequent intervals. Part of the cave is shown to the public during the tourist season with lantern-lit tours. The cave is a large, massively decorated paleo-trunk with re-invasion by two separate small streams. Its most obvious biological features are large populations of cave salamanders together with smaller numbers of grotto and long-tail salamanders, and a large mound of old bat guano. No colonial bats now use the cave, but there are historic accounts of past bat use. The guano appears to be old and biologically sterile. Relatively small numbers of various bat species hibernate in the cave, including an occurrence of what appear to be small-footed bats (*Myotis leibii*), with a cluster of a dozen or so hibernating close to the entrance. This bat has been recorded from the area, but is locally rare.

The salamander populations undergo an interesting annual cycle. In the winter of 1996, hundreds of larvae were present in the many muddy backwater pools. We tracked the largest pool, finding a few large grotto salamanders in addition to 300-400 small larvae, presumably cave salamanders. The larval numbers gradually declined over the spring and summer until in late summer only one large untransformed grotto salamander remained. Beginning in October and extending through November, adult cave salamanders started appearing in the pools (for most of the year, they are more commonly seen out of the water). The adults were observed burrowing into deep mud. Shortly afterwards, the adults left and small black Eurycea larvae started to reappear, in small numbers at first but peaking at the end of the year with numbers back to the original level. At the same time, large larval grotto salamanders have moved back in. Thus it appears that the pools are nurseries for cave salamanders, with the larvae subsequently undergoing predation by grotto salamanders.

The author conducting biologic inventory. Photo by Scott House

The terrestrial fauna is very sparse, owing to a dearth of obvious food sources. To document the species present, we have resorted to baiting with natural or near-natural foodstuffs (leaf mold, dung, etc.). This also gives the opportunity to follow the succession of species. The first customers at fresh, high-energy food are the troglobitic flightless flies *Spelobia* , and the food soon contains a dense mass of Spelobia larvae. Almost as quickly, the common beetle *Ptomophagus* shows up, and predatory Ptomophagus larval populations rise as numbers as the fly larvae decline. Lower energy foods also attract Ptomophagus, but are more quickly colonized by two species of springtail, millipedes, and diplurans. The Round Spring study is ongoing.

Acknowledgments

Approximately thirty people took part in the fieldwork for the above projects. The most consistent participants were Sue Hagan and Scott House. Thanks also to Scott, Doug Baker and Bob Osburn for contributions to the cartography.

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Cartography/Data Management

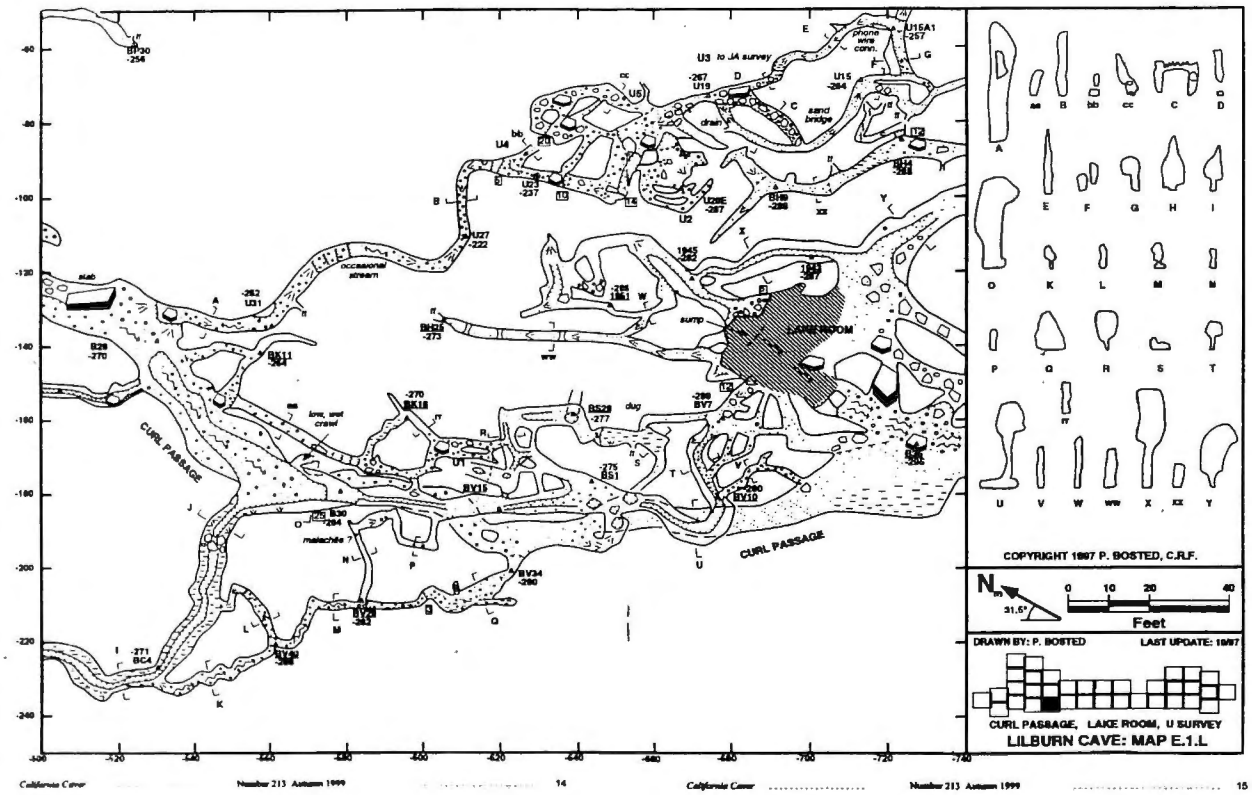
Redwood Canyon Cartography Project 1997

Peter Bosted

The year 1997 saw good progress in the effort to completely explore and survey Lilburn Cave and the other small caves located in Redwood Canyon, Kings Canyon National Park, California. Surveying of dry parts of Lilburn took place on eight different expeditions in 1997. In addition, there were numerous trips in August through October during which Bill Farr and Jim Brown set up and dove in Big Springs (the resurgence for Lilburn Cave) and in the Rise (where Redwood Creek enters Lilburn Cave).

Due to the fact that almost all the easily accessible leads in Lilburn have been pushed and surveyed, there were only ten trips into the cave during which new dry passage was surveyed. Two trips accidentally surveyed passage done late in 1996 that was not marked as being done on the quadrangles they were using. Three other trips were not able to find any unsurveyed passage, although some digging was done on at least one of these trips (near the Carrot Stalactites at A48). Checking of quadrangles was also done on some of the dive tank hauling trips.

Starting at the north end of the cave, a lead in the Kleinbottle Complex was pushed for about 100 feet to a pinch. Much potential remains in this area, but all leads require digging or total immersion in a watery belly-crawl. Near the beginning of the Crystal Crawl, a team surveyed 270 feet of vertical maze, reaching an elevation only 50 feet below the Meyer entrance, and leaving a few leads. This was rather a surprise, as initially the lead was thought to end after 30 feet, but



the team was able to push through a tight slot. About 112 feet of mop-up survey was done in the lower West Stream Complex. Up in the Angel's Perch area above the West Stream, where many discoveries were made in 1996, an additional 145 feet was surveyed, with a few small leads remaining.

In the Curl Passage, 390 feet was surveyed, starting in a previously explored passage that went parallel to the Curl, but then crossed over it into virgin passage that choked in flowstone. A trip to the Mud Club area first mopped up two leads, then did a short dig to access 300 feet of new passage, mostly fairly tight. On a return trip, a rock was moved and about 200 feet of large passage was accessed. The passage can be seen continuing past a granite boulder choke.

Carol Conroy, Carol Vesely and Nancy Pistole mapping near Grand Central Station in Lilburn Cave. Photo by Dave Bunnell

A trip to the seldom-visited Fallen Soda Straw room found all leads blocked, but did find 25 feet of unsurveyed passage near the nearby Jefferson Memorial. About 200 feet was surveyed near the Z room. On the last trip of the year, an attempt to reach the Mousetrack area was foiled when it was discovered that the normally sandy entrance passage was almost filled with water, with a strong cool breeze blowing across it. This likely indicates that a new entrance to the cave has opened up in this area. Several hours were spent digging in a lead near by, leading to 100 feet of nice, sandy stooping passage and another dig. Another lead in this area was checked and found to lead to an upper level complex with large, loose boulders. Beyond these, a canyon was followed heading south for several hundred feet, ending at a pit where a rope is needed, and good airflow was noted. This pit is in a blank part of the map, and only 300 feet from the known southern end of the cave, so has interesting potential that will have to wait until 1998 to explore. Altogether 2280 feet of new dry passage was surveyed, using 236 stations, with and additional 200 feet of resurvey. This brings the surveyed length of Lilburn Cave to 26.4 kilometers (16.4 miles).

Progress continues on the quadrangle maps. The northern maps being drawn by the author were updated and several new ones finished, bringing the total to 28. Ten more maps remain to be drawn. Of the southern maps, 33 are now more or less up to date, being drawn by Brad Hacker. Two other cartographers have each promised to draw four quadrangles each. In addition, the author made a color map of the entire cave that was printed in the July *NSS News*, along with a description of the survey and exploration project through 1996.

USGS National Spatial Data Infrastructure Projec

The Development and Dessemination of Standards and Tools for Collecting and Managing Cave Survey Data

Mike Yocum

In 1996 the Cave Research Foundation, in partnership with Mammoth Cave National Park, the American Cave Conservation Association and the Barren River Area Development District, entered into a Cooperative Agreement with the U.S. Geological Survey to contribute to the National Spatial Data Infrastructure by developing a standard for cave survey data collection.

Background/Project Summary

The Cave Research Foundation (CRF) Competitive Cooperative Agreements Program (CCAP) project proposed to accomplish the following objectives:

A. develop standards for the collection, documentation, evaluation, archiving, cataloging, report generation (search and query) and transfer of base line cave survey data;

B. modify and develop software for implementing those standards;

C apply the standards and software to an existing set of base line cave survey data from a selected cave system as a test and demonstration of the standards and software;

D. evaluate biological data from that selected cave system, correlating it with the geospatial data in a user-friendly GIS interface, and

E.. make the results available to the public at the American Cave and Karst Center, and on a National Geospatial Data Clearinghouse node.

At the suggestion of FGDC staff, objective A was modified to narrow the focus of standard development activity exclusively to the collection of base line cave survey data.

Project Activities/Results

A. Standard development

After discussions with FGDC staff the standard development activity was modified to focus exclusively on the collection of cave survey data. In December 1996 a letter announcing the standard development process, and soliciting comments and contributions, was sent to 21 individuals around the nation who were known to be actively involved in surveying caves on federal lands. At the same time an email discussion list was established with these individuals to facilitate the process. All comments and contributions to the discussion were shared with all of the participants in the discussion list. This list was used continuously as a development tool for the duration of the project.

In April 1997 a three-day work group facilitated by the National Cave Resource Coordinator for the National Park Service met in Denver, Colorado. This group reviewed the goals of the project and its current status. They produced a document outlining a minimal set of data that should be collected by all surveyors working in caves on federal lands. This was shared with the email development group and refined through subsequent discussions and comments by members of that group.

A final draft of a proposed National Cave Survey Data Collection Standard was presented by the Project Director in October 1997, at the National Karst and Cave Management Symposium in Bellingham, Washington. Although this objective was accomplished, the standard content is minimal and will be reviewed for additions and modifications.

B. Modification and development of software.

This objective involved developing a user-friendly interface for CML (Cave Map Language), an existing cave survey data reduction and management program, as well as minor modifications to CML deemed necessary to make it more useful. Most of the task consisted of coding a Windows interface for CML. After the initial design was completed, a three-day meeting of Cave Research Foundation personnel involved in writing the code was held in March 1997 at Mammoth Cave National Park. Some of the CML code was revised, and more extensive revisions were made to the interface, which was named WinCML.

The metadata tool chosen for incorporation into WinCML was CorpsMet, a Windows 95 version of the U. S. Army Corps of Engineers public domain metadata entry software. This program was chosen because of its relatively small file size, compatibility with Windows 95, ease of use, and public domain status. It generates a metadata text file that can be imported into mp to create SGML files.

C. Application of the cave survey data collection standard and WinCML software.

As a test and demonstration of both the cave survey data collection standard and the newly written software, an existing data set from the survey of Hidden River Cave was imported into WinCML. Although most of the data was found to comply with both the draft cave survey data collection standard, and with the metadata items in CorpsMet, some of the earliest data did not meet either the draft data collection standard or the metadata standard.

D. Evaluation of biological data from Hidden River Cave, correlation of that data with the geospatial survey data from Hidden River Cave, and integration of both data sets into a user-friendly GIS interface.

This objective was not completely accomplished. The available biological data, a four-year census of *typhlichthys subterraneus*, was located and evaluated. Because of a lack of survey data and/or detailed cave maps during the census period (1993-1996), most of the census locations were only approximate and could not be precisely correlated with the geospatial data. An even greater difficulty was encountered in integrating the survey data into a GIS program.

At the completion of the project period, a temporary, compromise solution was the creation of a graphic presentation, "Spatial Data and the Conservation of Caves and Karst," for use in the American Cave Museum This presentation introduces and explains the importance of geospatial data in preserving caves and karst terrain, with a generalized graphic display of the application of geospatial data to the restoration of the Hidden River Cave drainage basin, and a brief overview of the role of the NSDI initiative in making geospatial data more readily accessible to the public.

E. Making the results of this project available to the public.

This objective is not yet completely accomplished. It called for making the results of the project available to the public at the American Cave Museum, and on a National Geospatial Data Clearinghouse node.

The draft proposed National Cave Survey Data Collection Standard, along with WinCML, survey data from Hidden River Cave, and the program, "Spatial Data and the Conservation of Caves and Karst," are available on the National Geospatial Data Clearinghouse node at http://www.bradd.org.

However, one of the partners in the project, the American Cave Conservation Association, encountered fiscal problems and was unable to fulfill its obligations to the project by the original project completion date. An extension was requested, and received, from the FGDC, but the American Cave Conservation Association was still unable to meet its commitments at the end of the extended project period. It is currently anticipated that the display in the American Cave Museum will be completed and installed by the summer of 1998.

Geosciences

Summary of 1997 Hydrologic Investigations at the Redwood Creek Karst Aquifer, Kings Canyon National Park, California

William Howcroft and Jack Hess

The following report describes efforts made in 1997 to better understand the hydrology of the Redwood Canyon karst aquifer located within the General Grants Grove section of Kings Canyon National Park, Tulare County, California. In short, two main tasks were accomplished in 1997:

1) the installation of a hydrologic monitoring station upon Redwood Creek, and

2) the collection and analysis of water samples from springs, surface streams, and cave drips. Each of these tasks is described in detail in the following paragraphs.

Redwood Creek Monitoring Station Installation

On November 1, 1997, a hydrologic monitoring station similar to that currently existing at Big Spring was installed on Redwood Creek. The monitoring station was constructed a short distance downstream of the point at which the Hart Tree Trail crosses Redwood Creek to join the main foot path through Redwood Canyon. Permission to install the monitoring station at this location had previously been obtained from the National Park Service earlier in the year. This particular site was chosen for a number of reasons including:

1) its location upstream of the contact with the marbles,

2) the relatively straight stream channel in which to conduct discharge measurements, and 3) ease of accessibility.

The purpose of installing a monitoring station at this location is to gain a better understanding of the amount and character of the main water input into the Redwood Canyon aquifer. Towards this purpose, a staff gauge and Campbell Scientific 21X datalogger with a pressure transducer, water temperature, specific conductivity, and air temperature probes were installed at this location. The datalogger is currently powered by 12-volt batteries with data recorded onto a storage module. In 1998, stream discharge measurements will be conducted within the stream channel at varying flow rates with which a rating curve may be constructed to convert the continuously recorded stage measurements to flow rates. A trip is scheduled for Martin Luther King holiday weekend to check upon the continued operation of the monitoring station.

Water Sampling and Analysis

For the purpose of identifying a natural tracer which might be utilized to conduct hydrograph separation of Big Spring discharge, two rounds of water sampling were conducted in the Redwood Canyon karst aquifer during 1997. The first sampling round was conducted over the weekend of September 26-28, 1997 whereas the second sampling round was conducted during the weekend of November 1-3, 1997.

During the first sampling round, water samples were collected from four surface water locations: Redwood Creek, Volvo Creek, Mays Creek, and Pebble Pile Creek. In addition, water samples were collected from two drip locations within Lilburn Cave: within the East Stream area and at the Yellow Hungas Thing formation. Lastly, water samples were collected from the East Stream itself, at Big Spring, and at a small spring along the Hart Tree Trail. During the second sampling round, a water sample was also collected from a drip within the Hex Room. Collected water samples were analyzed for pH, electrical conductivity (EC), major cations and anions, bromide,

strontium, nitrates, trifluoroacetate (TFA), and the stable isotopes of oxygen-18, strontium, deuterium, and carbon-13. Isotopic analyses, excluding strontium, were conducted at the Desert Research Institute (DRI) Isotope Laboratory in Las Vegas, Nevada. Strontium isotopic analyses is being conducted by the U.S. Geological Survey but is not yet complete. Major parameter analyses were conducted at the DRI Water Resources Center Water Laboratory in Reno, Nevada and TFA analysis was conducted at the Center for Environmental Sciences and Engineering laboratories, University of Nevada, Reno. With the exception of strontium isotopic data, complete laboratory data is available for the first set of water samples collected. For the second set of samples collected., only trifluoroacetate (TFA) results are thus

TABLE 1: Analytical Results, September 1997 Sampling Round

	pH (lab)	EC (field)	EC (lab)	HCO_3 (lab)	SiO_2	Cl	SO_4	NO_3
RC	7.78	N/A	68.1	39.3	23.2	0.67	0.76	0.13
VC	7.83	N/A	58.3	33.8	33.8	0.89	0.60	<0.04
MC	7.49	40.4	31.6	17.7	23.8	0.73	0.37	<0.04
PPC	7.00	20.2	17.7	9.9	16.8	0.60	0.33	0.04
BS	8.27	227	237	150	23.1	1.48	1.92	0.22
HTS	6.86	N/A	50.4	28.1	24.6	1.11	0.38	0.13
ES	8.10	343	346	212	12.4	8.29	0.34	0.22
ESD	8.19	324	296	194	10.2	0.77	0.43	0.18
YH	8.13	371	315	204	13.0	0.95	0.49	0.27

	Na	K	Ca	Mg	NO3 as Sr	Br	TOC	N
RC	3.60	1.10	8.98	0.74	0.03	0.06	<0.01	0.5
VC	6.12	1.20	4.83	0.67	<0.01	0.04	<0.01	1.0
MC	4.13	0.82	2.11	0.28	<0.01	0.02	<0.01	0.5
PPC	2.71	0.37	0.85	0.20	0.01	0.01	<0.01	0.4
BS	4.13	1.04	41.4	2.06	0.05	0.21	<0.01	<0.1
HTS	3.44	1.04	5.19	0.69	0.03	0.05	<0.01	0.5
ES	2.31	0.90	72.8	1.63	0.05	0.10	<0.01	<0.1
ESD	1.35	0.82	66.2	1.98	0.04	0.11	<0.01	<0.1
YH	2.11	0.82	86.7	2.81	0.06	0.13	<0.01	0.2

All concentrations reported in mg/l. RC: Redwood Creek, VC: Volvo Creek, MC: Mays Creek, PPB: Pebble Pile Creek, BS: Big Spring, HTS: Hart Trail Spring, ES: East Stream, ESD: East Stream Drip, YH: Yellow Hungas Thing formation, HRD: Hex Room Drip.

Laboratory analytical results for the first round of water samples collected, excluding those for TFA and stable isotopes, are presented in Table 1. Bearing in mind that the water samples were collected for the purpose of identifying a natural tracer suitable for hydrograph separation, the laboratory results were examined for analytes which are present in relatively unique concentrations relative to their input type, i.e., surface water vs. epikarstic (drip water) inputs. With this in mind, a number of analytes can be neglected: bromide, which was undetected in all samples; strontium and sulfate, which are non-conservative; and total organic carbon (TOC), whose concentration is below detection limit at Big Spring. In addition, calcium, magnesium, bicarbonate, nitrates, and potassium are all non-conservative and cannot be used as tracers. Likewise, pH and electrical conductivity are indicator parameters and are unsuitable as tracers. This leaves silica, chloride, and sodium as possible tracers. Silica, chloride, and sodium should be relatively conservative in a karst system. However, the observed chloride concentration in the East Stream is remarkably high in comparison to the other inputs. The reason for this high concentration is not known but suggests that the

stream has a unique source. Sodium and silica concentrations are generally lower in drip waters than in surface waters. Therefore, the two analytes may prove to be useful tracers; however, additional sampling is required to required to ascertain the time invariance of the concentrations.

Laboratory results for trifluoroacetate (TFA) for the two sampling rounds are presented in Table 2. TFA is a primary breakdown product of chlorofluorocarbons, is suspected to be detrimental to plant growth and aquatic environments, and has been detected in moderate concentrations in fog, rain water, surface water, and snow at locations within Sequoia National Park. TFA was considered to be potentially useful as a tracer in that it should be present in only younger waters. Examination of Table 2 reveals extreme variability in results, in terms of both water type and over the course of the one month time period between sampling events. This indicates that TFA is not a suitable tracer for hydrograph separation. Nevertheless, the high concentrations observed in drip samples collected from the East Stream area and in the Hex Room are of interest. TFA concentrations at these locations are among the highest recorded in the Kings Canyon/Sequoia Parks area. With the exception of the East Stream Drip, TFA concentrations decreased at all locations during the one month time interval between the two sampling rounds. At the East Stream Drip, TFA concentration increased by almost an order of magnitude. The reason for this variability is at present unknown, but may have to do with the complexity of epikarstic flow mechanisms.

Results of isotopic analyses conducted on water samples collected in September, minus those for strontium, are presented in Table 3. With the possible exception of deuterium, the isotopic signatures appear to be rather variable among input type, making it unlikely that isotopes can be utilized as a tracer. Somewhat interesting among the results, however, is the strongly depleted carbon-13 signatures displayed in samples collected from Pebble Pile Creek and the Hart Trail Spring.

Pebble Pile Creek is fed by a non-carbonate spring located at a high elevation below the summit of Big Baldy. Since the Hart Trail Spring is also a high elevation, non-carbonate spring, the two waters ap-

Table 2: TFA Analytical results

Sample Site	Nov. 1-3 1997	Sept 26-28 1997
RC	197.2	84.7
VC	104.0	69.3
MC	95.6	66.6
PPC	133.8	102.2
BS	76.3	49.5
HTS	144.1	54.1
ES	66.2	47.8
ESD	136.5	1,309
YH	131.9	104.0
HRD	N/A	344.8

Table 3: Isotope analytical results

Site / Analyte	Oxygen-18	Deuterium	Carbon-13
RC	-11.9	-82	-12.9
VC	-12.0	-81	-12.1
MC	-11.6	-79	-12.5
PPC	-11.1	-76	-21.8
BS	-11.1	-81	-12.5
HTS	-12.2	-84	-20.1
ES	-11.5	-77	N/A
ESD	-11.3	-77	-12.0
YH	-11.5	-77	-12.3

Isotopic signatures reported in per mil VSMOW (O-18, D), per mil PDB (C-13). RC: Redwood Creek, VC: Volvo Creek, MC: Mays Creek, PPB: Pebble Pile Creek, BS: Big Spring, HTS: Hart Trail Spring, ES: East Stream, ESD: East Stream Drip, YH: Yellow Hungas Thing formation.

pear to be similar and vegetation associated with these high elevation areas may be responsible for the depleted signatures.

Future Work

In 1998, a number of tasks are planned for the purposes of better understanding the hydrology of the Redwood Canyon aquifer. Continued sampling and analyses will be conducted with the hopes of identifying potential tracers suitable for hydrograph separation. In addition, stream discharge measurements will be conducted at each location for the purpose of constructing or improving existing rating curves. Further, dataloggers at Redwood Creek, Big Spring, and in the Z Room of Lilburn Cave will be maintained and/or repaired. Floods in early January of 1997 induced hydraulic heads greater than 100 feet within the Z room. Consequently, the datalogger at that location was inundated with water and is no longer operable.

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Late Proterozoic Paleoclimate, and Land-based, Microbial Organism Survival: A Discussion

Ray Kenny

Continental paleotemperature estimates of 30-43 degrees C for the late Proterozoic (~ 1 Billion years ago, or -1.0 Ga) from two low-latitude localities indicate a warm-to-tropical paleoenvironment (Kenny and Knauth, 1992) The warm paleotemperatures estimates are consistent with: 1) development of observed paleokarst horizons: 2) increased silica dissolution and reprecipitation: and, 3) postulated paleoenvironmental conditions deemed necessary for sustaining land-based plan communities. Extensive low latitute glaciations after 0.9 Ga, possibly resulting from unusual paleoclimatic conditions (including 4-10% lower solar luminosity, low land elevations, and low solar greenhouse effects), may have provided a severe setback to early, previously-established, land-based communities.

Geologic Background

Evidence that warm-to-tropical paleoclimatic conditions existed in the Middle to Late Proterozoic (-2.2 GA and 0.9 Ga), includes: 1) paleokarst horizons (Shride, 1967): 2) extensive bedded salt deposits; and 3) continental paleotemperature estimates from terrestrial silica *Kenny and Knauth, 1992). Stratigraphic evidence also indicates that extensive, low latitute, continental glaciations occurred in the last Proterozoic between 0.9 and 0.6 Ga (Frakes, 1979). Stratigraphic evidence includes extensive mixtites and alternating glacio-marine deposits. Paleomagnetic evidence suggests that the glaciations may have extended well into the low latitudes (Embleton and Williams, 1986) and affected a very large portion of the globe.

Background: Late Proterozoic, land-based micro-fossils

Recent evidence (Kenny et al, 1990, Kenny, 1990; Horodyski and Knauth, 1994) suggests the presence of a land-based, microfloral community in the last Proterozoic. The data presented to date suggest that organic-walled microstructures are sporadically and poorly preserved in laste Proterozoic paleokarst material. Other, indirect evidence (for the presence of land-based, photosynthetic cyanobacteria) comes from significantly-depleted, stable carbon isotopes on carbonate precipitated in Precambrian paleokarst horizons. The significantly depleted carbon isotopes indicate that some type of photosynthetic existed on the land surface during

the late Proterozoic (Beeunas and Knauth, 1985; Kenny and Knauth, in prep).

The last Proterozoic, filamentous microstructures are preserved and encased in "secondary silica" that was precipitated during karst events which have been chronologically constrained to the last Proterozoic (Keey and Knauth, 1992). Using stable isotopic evidence, Kenny and Knauth (1992) also argued that the "secondary silica" was not precipitated under marine conditions, but under fresh water (terrestrial) conditions).

Studies of modern, terrestrial microfloral communities, have shown that: 1) light-colored, translucent rocks (at the land-air interface) provided ideal microenvironments for microfloral communities (Cameron, 1964); 2) numerous microflorate species are known to be primary colonizers (as determined from the studies of volcanic ash-devastated areas such as Katmai and Surtsey; Brock, 1973). And 3) modern microfloral communities occur in dense populations in microcaveties and voids just below the surface of all types of sedimentary rock materials (Bell et al., 1986). Hence, karsted horizons provide a viable habitate for microfloral communities.

During extensive weathering of carbonate (required to produce paleokarst features), precipitation of secondary silica occurs between surficial rubble and clasts (and in voids in the near-surface environment), if an adequate source of silica is available. In many cases, the sustained karsting and extensive weathering under warm-to-tropical paleoclimatic conditions may result in: 1) complete dissolution of the host carbonate rock; 2) an accumulation of surficial rubble of chemically resistant chert nodules; and 3) complete cementation by secondary silica (Robertson, 1967). The precipitation of secondary silica, therefore, entombs endolithic and cryptoendolithic algae or other primitive, microfloral or bacterial species. Hence, under ideal conditions, the optimum place for secondary silica precipitation during weathering of chert-rich carbonate rocks is also the optimum microhabitat for, land-based, microfloral communities.

Climate Discussion

Gray and Boucot (1978) speculated on the possibility that land-plant development may have begun during the late Proterozoic. Gray and Boucot (1978) argued that because of an absence of evidence from Cambrian samples that "land plant development failed during the Precambrian and was only followed in the later Ordovician by a second, successful attempt that ultimately gave rise to the modern terrestrial higher land plant vegetation." A reason for the "failure" has not been offered. In this discussion, we suggest that, if extensive continental glaciation occurred between 0.9 Ga and 0.6 Ga and was able to spread far into the low latitudes, then extensive glaciation may have dealt a devastating blow to the ability of an evolving land-based plant community to survive in numbers which were capable of being preserved in a terrestrial sedimentary record. Hence, the absence of microfloral evidence from Cambrian samples may actually reflect: 1) massive destruction of early land-based microfloral communities (stemming from extensive low-latitude glacial events and dramatic paleotemperature shifts); or 2) significant dimunition of land-based microfloral communities. The open questions before us now is why the land-based microflora are not well-preserved in the Cambrian. The answer may, in fact, lie in the stratigraphic record which indicates that extensive, low-latitude glaciations covered a large portion of the glove, and may have had a profound effect on the evolving land-based life forms.

Conclusions

The Proterozoic paleoenvironment (-0.9 Ga): 1) was presumably colonized by some sort of microfloral community; and 2) had paleotemperatures that were intermittently warm-to-tropical in low latitude, continental areas. There also appears to be a logical connection between stratigraphic evidence (after -0.9 Ga) for extensive glaciation, cold climates, and a scarcity of terrestrial microfossils. Because of this, we speculate that low latitude continental glaciations (perhaps triggered by relatively low solar luminosity, low greenhouse effects, or other perturbations or forcings), along with a dramatic shift in temperature, may have proved fatal (or near-fatal) to evolving, early land-based plant communities.

Acknowledgments

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Slaughter Canyon Cave, Carlsbad Caverns National Park, New Mexico

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Carlsbad, Caves & a Camera - by Robert Nymeyer, 1978, (Illus.) 318 p.

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