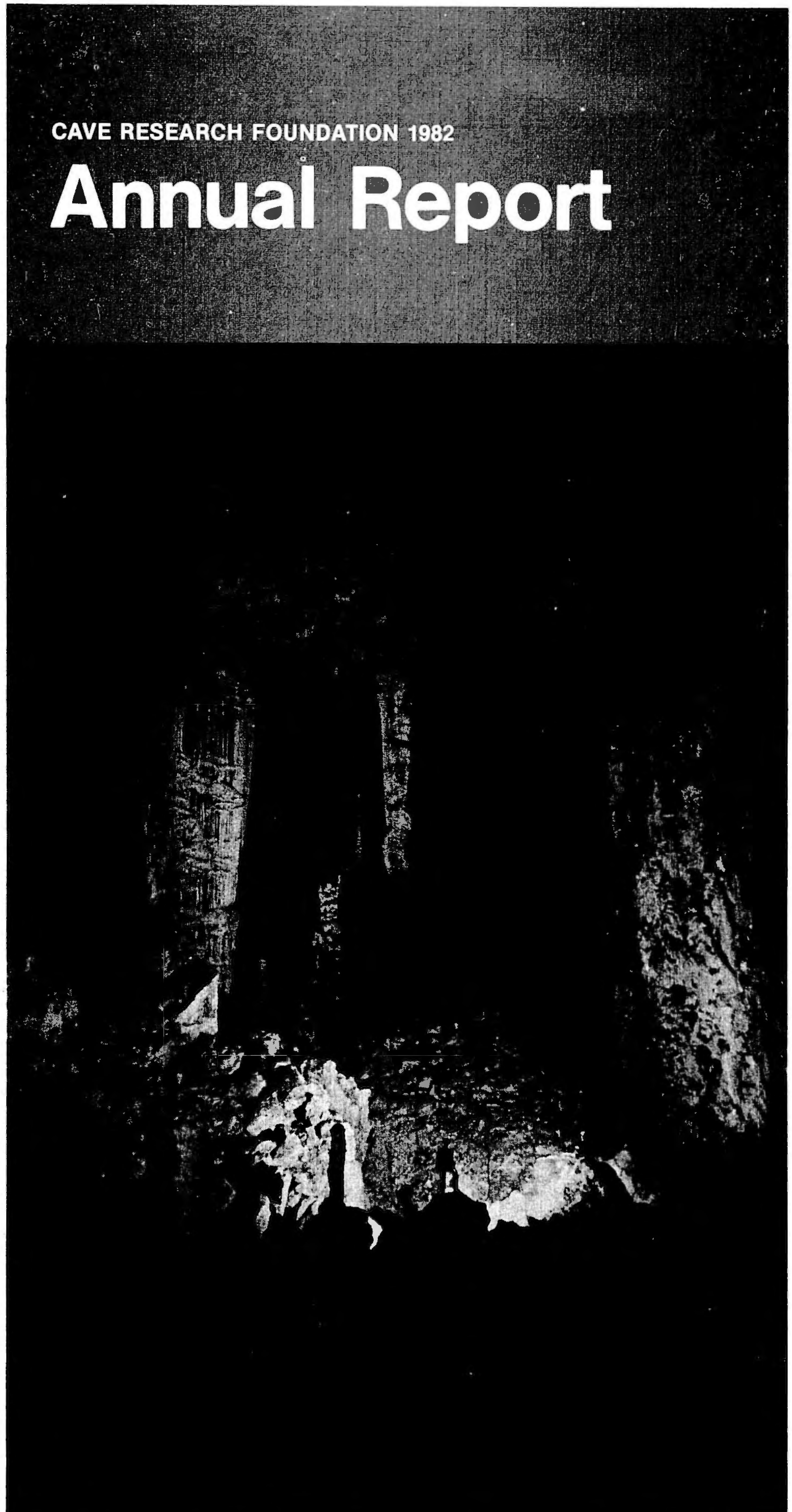
CAVE RESEARCH FOUNDATION 1982

Annual Report



CAVE RESEARCH FOUNDATION

CAVE RESEARCH FOUNDATION

4916 BUTTERWORTH PLACE, N.W.
WASHINGTON, D.C. 20016
202 - 244-6841

August, 1983

Dear Members, Joint Venturers, and Friends,

This volume of the Annual Report of the Cave Research Foundation marks a very special anniversary--we are 25 years old. A small, well planned venture begun in Floyd Collins Crystal Cave near Mammoth Cave, Kentucky has expanded to Mammoth Cave, Carlsbad Caverns, and Sequoia/Kings Canyon National Parks and to the Ozark-St. Francis Forest in Arkansas. And there have been numerous projects in other areas throughout the country and the world. Our exploration and mapping program produce superlative maps; we continue to encourage and support outstanding multidisciplinary research; our advice on resource management is sought by National Park Service and US Forest Service lands managers; our publications program is the financial flywheel that supports a large share of these activities. For most of us, the unifying force that brings us to these activities is the great adventure of exploring exciting caves with the companionship of very interesting people.

In previous years Annual Reports have been available to all at a cost of $5.00 each. Because this is our 25th anniversary report I wanted everyone in the Foundation to receive a copy without charge. However, I will be grateful if you are able to make a financial contribution to the Foundation to help support this publication. Contributions may be made to:

Cave Research Foundation
c/o Roger McClure, Treasurer
4700 Amberwood Dr.
Dayton, OH 45424

Additional copies of the Annual Report and other publications may be ordered from:

Cave Books
901 Buford Place
Nashville, TN 37204

I expect the next 25 years to be no less challenging and exciting than the first 25 years. I hope you will continue to share my commitment to the Foundation and that you will support its programs in any way you find rewarding.

Sincerely yours,

Sarah G. Bishop
President

Cave Research Foundation 1982 Annual Report

Cave Research Foundation
4916 Butterworth Place, NW
Washington, DC 20016

The Cave Research Foundation (CRF) is a nonprofit corporation formed in 1957 under the laws of the Commonwealth of Kentucky. Its purpose is to support scientific research related to caves and karst, to aid in the conservation of cave and karst wilderness features and to assist in the interpretation of caves through education.

Cover: Ogle Cave, New Mexico. Photo by A.N. Palmer

ISBN 0-939748-06-1

Published by
CAVE BOOKS
756 Harvard Avenue
St. Louis, MO 63130 USA

Printed by
ADOBE PRESS
Albuquerque, New Mexico
USA

CONTENTS

CAVE CONSERVATION

The caves in which we carry out our scientific work and our exploration are our "natural laboratory". Without it we could do little of what is described in the pages that follow. The Cave Research Foundation is committed to keeping that natural laboratory natural.

In all of our activities we take considerable care that we not destroy that which we study. Caves are fragile in many ways. Their features take hundreds of thousands of years to form. And many of the processes that formed the cave passages that we travel are no longer active in the same places. Cave animals, such as blind fish, live in precarious ecological balance in their isolated underground environment. That balance is easily disturbed. Unlike other natural laboratories, any damage that we do will not be repaired. Great and often irreparable damage is done by people who unthinkingly take or break stalactites and other flowstone formations. Disturbing animals, such as bats in winter hibernation, is as deadly as shooting them with a rifle.

Caves are wonderful places for research, recreation and adventure. But before you enter a cave, we urge you to first learn about careful caving by contacting the National Speleological Society, Cave Avenue, Huntsville, AL 35810 USA. They have excellent advice and guidance for novice and expert alike.

Acknowledgments

Many of the projects outlined in this report have been conducted within the boundaries of public lands. The support and encouragement of the Superintendents and staffs at Mammoth Cave National Park, Carlsbad Caverns National Park, Guadalupe Mountains National Park, Sequoia-Kings Canyon National Park, Grand Canyon National Park, Lincoln National Forest, Buffalo National River and the Bureau of Land Management responsible for Torgac and Ladron caves have contributed greatly to the success of these projects and their assistance is greatly appreciated.

Sarah G. Bishop was awarded a Certificate of Appreciation from the U.S. Dept. of the Interior and a Certificate of Merit from the National Speleological Society for her efforts in developing the successful nomination of Mammoth Cave to the World Heritage List.

Roger Brucker received a Certificate of Merit from the National Speleological Society, as did Robert K. Murray, for co-authoring *Trapped!*, the story of Floyd Collins. The book has been republished as a paperback by the University Press of Kentucky.

Art and Peggy Palmer were awarded Honorary Life Memberships in the National Speleological Society for their contributions to speleology over many years.

John Pickle has received the National Speleological Society Ralph Stone Award for science, to support his thesis research on the topic of underground stream sediment transport and stream profiles in the Turnhole Spring drainage basin near Mammoth Cave.

Ronald Wilson was awarded a Certificate of Merit from the National Speleological Society for his continuing contribution to the Society.

Highlights of 1982...

Throughout 1982 the Cave Research Foundation continued scientific research and management advisory activities in four field areas. The Foundation also supported speleological research in a number of other caves and karst areas throughout the country and in Puerto Rico.

Cartography

Mammoth Cave National Park—A recently discovered entrance to the cave system in Mammoth Cave NP provides access to the river area in the easternmost regions of the park. While trying to "clean up" areas in the system in order to produce complete maps, lots of new passages were discovered. The cave always seems to have the last word.

The CRF computer for eastern operations is finally up and running—storing, reducing, and plotting survey data. Area maps of the Mammoth Cave System will soon become a reality.

Our map making ability has already set a precedent for high level of achievement. The Poster Map of the Mammoth Cave System, published in 1981, won a prestigious design award from the Society of Typographic Artists.

Guadalupe Escarpment Area—Two significant discoveries this year in Carlsbad Caverns were a highly decorated little room over the Lake of the Clouds passage and a connection between New Section and Bat Cave. The survey of Glory Cave in Guadalupe Mountains NP was completed. Work in the Gypsum Karst on BLM land has supported the hydrological studies of Steve Sares. Three caves in the area have been surveyed in the process.

Lilburn Cave—The major CRF effort in this significant cave in Sequoia/Kings Canyon NP has been to develop the mapping expertise of the joint venturers working there. The resulting map is growing satisfactorily in level of detail.

Arkansas Area—CRF completed another contract with the US Forest Service to survey a dozen caves in the Sylamore District of the Ozark/St. Francis National Forest. The portfolio of maps, the final product of the contract, is of professional quality. A smaller project will continue through 1983. In December, the Foundation submitted a proposed management plan for Beauty Cave in the Buffalo National River. This proposal is further evidence of the CRF's continuing interest in Arkansas karst areas.

Scientific Studies

Studies in ecology, archeology, physical sciences, and history were conducted during the year in the three National Park areas. At MCNP, the Summer University in the Park sponsored by Western Kentucky University was staffed by and drew most of its curriculum support from CRF scientists and JVs. The Guadalupe Escarpment project area is supporting 15 publishing scientists. Research at Lilburn Cave continues to flourish. The 1982 CRF karst fellowship was awarded to Daniel W. Fong. The Foundation also awarded a research grant to Joseph W. Troester, and a special grant to Steven D. Emslie.

Education, Interpretation and Conservation

During the dedication of Mammoth Cave National Park as a World Heritage site, Russell Dickenson, Director of the National Park Service, recognized the unique contributions of the Cave Research Foundation to speleology in the park. This was the first time that the Foundation's capability and achievements were recognized publicly by a national leader.

Earlier in the year, in another first for the Fountation, the CRF Executive Director testified before a Congressional Committee and described the external threats to MCNP. Testimony received during this hearing led to the National Park System Protection Act which was overwhelmingly approved by the House of Representatives. Several CRF directors and others met with the Caveland Sanitation Authority to discuss the future of an ambitious sewage system for the Mammoth Cave Region that was being designed to alleviate these threats. After trying for a number of years to find a satisfactory way to eliminate the negative impact the Great Onyx Job Corps Center had on the cave system, the Park Service finally moved the Job Corps to a remote section of the park and returned the old site to its natural state. With the Job Corp gone, and a regional sewage system fast becoming a reality, the water borne pollution problems in MCNP whould be greatly reduced.

Finally, CRF helped establish the National Parks and Conservation Association's National Parks Action Project at MCNP. This several week project promoted interest among park visitors in protecting our natural and cultural heritage.

....

During the year, the Directors of the Foundation elected Dr. Sarah G. Bishop the eighth President of CRF. The major milestone the eighth President has the privilege to mark is the inauguration of the Cave Research Foundation's *second* 25 years as a volunteer organization dedicated to furthering research, interpretation, and conservation of caves and karst.

...and the First 25 Years

In 1957, the Cave Research Foundation was organized in the state of Kentucky as a non-profit corporation for the purpose of conducting research in the extensive cave systems of the world, encouraging cave preservation and conservation, and interpreting research information for educational and management purposes. In 25 years the Foundation has become the premier example of a volunteer organization supporting multidisciplinary research in this country's National Parks. What began in Kentucky has extended to many other states and several countries.

A significant factor in the success of the Foundation is the continuity we can promise to our investigators. The past 25 years of activities testify to our stability and commitment. We operate in the National Parks under a 20 year agreement with the National Park Service. We have field operations and permanent facilities to house those operations in four areas.

We signed our first memorandum of understanding at Mammoth Cave NP in 1959. Ten years later we signed the 20 year agreement that allows us to work in any park. Three years after that, CRF had established its first major research area outside of MCNP in Carlsbad Caverns NP when the Guadalupe Cave Survey, a group of southwestern cavers that had worked in the park since the mid-1960s, joined the Foundation. R. Pete Lindsley, the Director of the Survey, eventually became the President of the Foundation. In 1976 the Foundation began work at Lilburn cave in Sequoia/Kings Canyon NP. A fourth field area was established in 1977 when CRF volunteers negotiated a contract with the National Park Service to begin an inventory of caves on park lands in Arkansas. The success of that contract led to another one with the Park Service, and eventually to a series of mapping projects on National Forest lands. Contracts with the US Forest Service are still in effect.

Early in our history, 1962 to be exact, the Foundation started supporting speleological research outside of our field areas. We supported researchers who were part of CRF as well as other researchers. The CRF karst studies fellowship program, begun in 1967 with a $500 grant, now makes up to $2000 a year available for graduate level research. The interest from an endowment fund supports this program.

Until 1969, most of the CRF exploration efforts in MCNP were focused on the caves under Flint Ridge. That year two major events changed the pattern of exploration. During the Memorial Day expedition over a dozen mapping teams started the CRF survey of Mammoth Cave. Earlier that year, two survey teams had mapped a sizeable trunk passage under Joppa Ridge. With large amounts of known cave passages under all the major ridges in the park it was only a matter of time before major connections would expand the total system to a world record length. Indeed, the "Everest of speleology," the connection of the Flint Ridge System (the longest cave in the world) with the Mammoth Cave System (the third longest cave in the world) occurred during the early hours of a September 1972 morning. Major discoveries in Proctor Cave on Joppa Ridge eventually resulted in the 1979 discovery of the largest underground river in the region, and the link between the Joppa Ridge Cave System and the Mammoth Cave System was surveyed and added to the map. In 1979 the cave system measured 214 miles. Today it is at the 235 mark. Our knowledge about this magnificent cave grows at a rate of several miles per year.

Our research has proven valuable to the NPS, and our management reports and advice are widely sought. We provide these services for the public good without cost to the agencies or others who seek our council. In 1970 CRF scientists initiated training sessions for MCNP staff in geology, biology, and archeology. Several years later similar training sessions were offered to Carlsbad Caverns employees. The Cave Management Symposia begun in 1975 by CRF, the National Speleological Society, NPS, USFS, and BLM has proven to be a very valuable forum for discussing public and private cave management problems. Based on its years of study of the cave system, CRF recommended to the Park Service that Mammoth Cave National Park be considered for nomination to the World Heritage List, a compilation of the unique cultural and natural features of the world that have universal value. In 1981, MCNP became the eighth U.S. property to be added to the list.

A major effort since the beginning has been to be sure our research is published. A partial list of publications reveals the following:

- 200 professional papers (mostly in reputable refereed journals),
- 30 management reports,
- 20 maps or folios of maps
- 12 PhD theses,
- 12 masters theses,
- 12 books (scientific and adventure),
- 350 other publications or presented papers.

For the last seven years the Foundation has produced those publications at a rate of about fifteen per year. That would be a commendable rate for small departments in many universities or major government laboratories. In addition to the work of our own joint venturers, we have lent support to dozens, maybe hundreds of other articles, dissertations, and books. The following lists a few of the highpoints in 25 years:

- *The Mammoth Cave National Park Research Center*, 1963—a management report to the park;
- *The Flint Ridge Cave System Folio*, 1966—the first CRF map of 44 miles of caves in MCNP;
- *The Cave Research Foundation Personnel Manual*, first published in 1967, has been updated twice. It is the final word on expedition caving and well used beyond CRF as a guide to caving techniques;
- *Wilderness Resources in Mammoth Cave National Park: A Regional Approach*, 1971—a CRF publication that became a major guide to the development of the Master Plan for the park;
- *Genetic Relationship Between Caves and Landforms in the Mammoth Cave National Park Area*, 1971—by Dr. Franz-Dieter Miotke and Dr. Arthur N. Palmer is the first major attempt to understand the geomorphic history of the region;
- *Archeology in the Mammoth Cave Area*, 1974—the results of work done by Dr. Patty Jo Watson beginning in 1969 with a grant from the National Geographic Society;
- *Carlsbad Caverns*, 1979—the first detailed map;
- In 1979, the Foundation bought out Zephyrus Press and went into the cave book publishing business; and
- In anticipation of the International Speleological Congress held near Mammoth Cave in 1981, CRF published *Origins: The First Ten Years*, a reprinted version of the Kaemper map, a Mammoth Cave poster map, and Palmer's *Geological Guide to Mammoth Cave*.

Numerous special projects may be remembered. In 1973, 10 JVs completed a resource inventory of caves in the Barra Honda region of Costa Rica. CRF had been invited to collect this information for the Costa Rican government which was contemplating making the area into a National Park. A study of the old saltpetre works in Mammoth Cave became a multidisciplinanary project that traced the history of petre mining in the area and recreated the entire saltpetre manufacturing process from mining to leaching. The rediscovery of the unique Mammoth Cave blind shrimp in 1981 led to their consideration for endangered species status. A subsequent population study is ongoing. During that same year a new field station designed to blend well with its surroundings was completed at Lilburn Cave. The biggest event of 1981 was the convening of the International Speleological Congress in the United States for the first time. The Congress was held at Bowling Green, Kentucky, because "everyone wanted to see Mammoth Cave." CRF sponsored pre and post Congress camps at its Flint Ridge facilities and also at Carlsbad Caverns.

The financial investment in all of these accomplishments is small indeed. The early budgets of the Foundation were in the range of a few hundred dollars per year. They grew to about

$5000 in the late 1960's; they were about $30,000 at the end of the seventies; and they are about $50,000 today. If you inflate the early years to make them all equivalent to 1983 dollars, the Foundation has spent the equivalent of about $100,000 over the 25 years of its existence. Compare this financial assessment with normal research investments to calculate the length of our "lever." The Federal Government pays between $60,000 and $150,000 to "buy" the research behind a professional publication. It spends about $200,000 to support a PhD thesis. Other publications might cost $10,000 each. In total, the government would expect to spend more than $35 million to "buy" the same results that CRF has produced for just $700,000.

In 1973, Dr. William B. White, Chief Scientist of the Foundation made the following observations: "...cave science has come of age... [CRF] did it with next to nothing in the way of financial support. ...Well-funded efforts with strong organizational bases are springing up. If the Foundation hopes to even compete, let alone maintain a leadership role in the decade to come, it will have to devise sources of support and methods of management that will allow long range, highly competitive research. ...This challenge should make the latter half of the 1970's an exciting time." The 1970's were indeed "an exciting time." An endowment fund initiated in 1974 exceeded its $25,000 goal in 1982. A new goal of $50,000 has been set. The interest from its investment sponsors research fellowships and grants.

As we set our sights on the next 25 years we look to past accomplishments for guidance and to the future for new ideas. During our formative years, the Park Service's commitment to us in the form of a long term agreement gave us the opportunity to set and carry out our agenda for exploration and research. As we begin to define our goals and objectives for the next 25 years, we intend to seriously consider what we may be able to contribute to meeting specific research and management needs within the National Park System. The CRF Directors will invite National Park Serivce managers to participate in goal setting discussions that will begin in the fall of 1983. The Foundation is looking forward to a productive second quarter century.

Sarah Bishop
President
May, 1983

Cartography Program

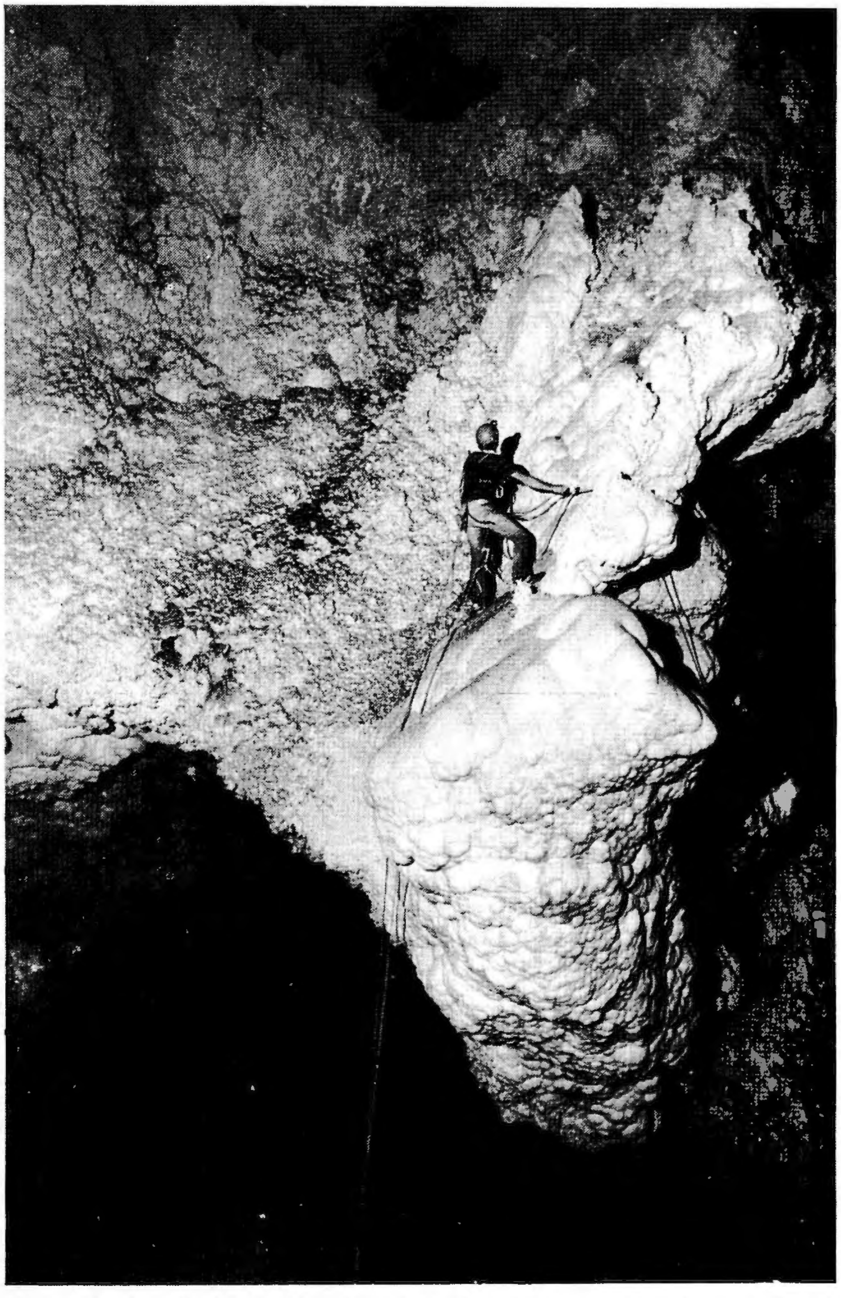


Figure 1. Ron Kerbo making the first ascent to a previously unexplored balcony overlooking Lake of the Clouds, Carlsbad Caverns. Photo by A.N. Palmer.

Cartography and Exploration in the Mammoth Cave Region

Richard B. Zopf
830 Xenia Ave., Yellow Springs, OH 45387

By November 1, 1982, the surveyed length of the Mammoth System was 379.4 km. This increase of 11.3 km in 1982 came for the most part from six areas of the system, four of which were in Mammoth Cave, two in Flint Ridge, and none in Joppa Ridge. Two thirds of the resurvey was in Mammoth Cave and the rest was in Flint Ridge. The total survey for the year, including some 0.6 km of surface survey, was 15.5 km.

Entrances had a significant effect on this year's work. The loss of the Turley Entrance lease slowed our work in The River area. The Echo River Spring survey of 1981 was tied into the system this year, and added to the length of the cave, also establishing another entrance. In conjunction with James Carter, a local caver, CRF discovered and opened a new entrance to the most eastern regions of Mammoth Cave. This entrance provides access to The River area and makes some areas of Mammoth Cave far easier to reach. Unfortunately, a large amount of survey was done in this area just before the Ferguson Entrance was open. We also supported James Quinlan, MCNP geologist, in his efforts to provide monitoring and entrance wells to The River area. On Flint Ridge the Woodson-Adair Entrance was reopened and as much new passage was surveyed as old passage was resurveyed.

The Woodson-Adair work is typical of numerous "clean up" operations throughout the system. We go back to areas that have been neglected for years in hopes of gathering the final data for a map, but often find the area is still not finished. In the Historic Section of Mammoth Cave new passage was found off Gorin's Dome. In the Robertson/Nickerson area a maze of new passages was found which includes a tie to the lower Bransford Avenue. The most significant work in the Bransford East area took surveyors further north under Strawberry Valley. Efforts in the Albert's Domes area yielded passage heading close to known Flint Ridge passages. Clean up in New Discovery and in the Emily's Avenue area was successful but less dramatic. Noteworthy passage was surveyed off Grand Avenue in Colossal Cave, but the bulk of new passage in Flint Ridge came from eastern Salts Cave where a maze of shafts and drains are beginning to be understood.

CRF's own computer system went into action this year with programs to store, reduce, and plot survey data. In addition, personal and business computers were used for the same purposes, and to modify the 1975 CRF data handling program for use with our new system. Also, we have shared part of this old data base with a computer programmer in Switzerland, Martin Heller, who has been able to present the survey plots three dimensionally. The flurry of computer activity did not entirely preclude map making. We produced a working map of the Nickerson/Robertson area and continued with the Historic Mammoth manuscript. Work is in progress updating the Salts manuscript. The poster map published last year won prestigious recognition for its design from the Society of Typographic Artists. The cartographic program was able to support scientific research extensively this year by providing maps, schematics, and verbal information.

Not only is the cartography program making an effort to support other scientific research, but we are also gradually putting more emphasis on producing survey and maps with greater detail, even at the expense of foregoing long, new surveys. This does not mean we will stop expanding the system, but we will make as much effort to expand the knowledge of the areas we already know. We may also focus more on some sections of the cave in order to develop the personel familiarity necessary to produce the greater interpretation we are seeking and to have enough data from an area to produce a fairly complete map.

Cartography Report: Guadalupe Area

Robert H. Buecher, RPE
2208 N. Sparkman, Tucson, AZ 85716

Carlsbad Caverns

This year we continued survey work in Carlsbad Caverns at the usual pace with a large increase in the amount of data reduced and plotted onto working maps. Most of this increase can be attributed to moving the survey files to Tucson and having two separate copies. The actual production rate for maps has tripled in the last year allowing us to catch up on some of the backlog of survey data. During the last year the survey in Carlsbad Caverns totaled:

7303.20 ft. underground
18,333.09 ft. surface

Primary areas of work were the New Mexico Room, New Section and the Bellcord Room and Lake of the Clouds

The preliminary Quadrangle maps at 1 inch = 50 ft. are now 70% complete. Three of the twelve quadrangles maps are now almost to the final map stage. Future work will concentrate on cross-sections of passages and profiles along the main passages.

Two significant discoveries in Carlsbad were made last year, each at opposite ends of the cave. First, a technical climb led to the discovery of a new room 60 ft. above the Bellcord Room. This room has been named the Bifrost Room and extends above the Lake of the Clouds passage. Unfortunately, no further leads have been found.

The second discovery was a connection between New Section and Bat Cave. This connection has been suspected for a long time from the pattern of air flow. The survey of the connection provides a second survey tie into the New Section. Many leads remain to be explored in this area. The potential exists to continue under Bat Cave on a level above and parallel to Left Hand Tunnel.

Archeological sites around the entrance area of the Caverns were tied into the surface survey network.

The survey of Glory Cave in Guadalupe Mountains National Park was completed. A map of this small cave will be finished next year.

Gypsum Karst

Large amounts of work were done in the Gypsum Karst. The majority of survey work this year has gone to support hydrology studies by Steve Sares. This has resulted in horizontal and vertical control of over 50 entrances and sinks. Vertical profiles along several canyons have been made. Three major caves were surveyed; Travertine (Spring) Cave, Resurgence and Skylight. The survey places siphons in Resurgence and Travertine only 70 ft. apart. Maps of these caves will be finished early next year. Survey totals were:

4552.50 ft. underground
126,167.82 ft. surface

The task of processing survey data has been speeded up by the use of several small computers. At present three different computers are being used to process data. 25% of the survey books for Carlsbad Caverns have been stored on the computer. This will allow for easy transfer of cartographic data between computers. A data base of survey data has also been started.

Lilburn Cave Cartography—1982

David J. DesMarais, PhD
Research Chemist
1015 Woodland Ave., Menlo Park, CA 94025

and

Peter Y. Bosted, PhD
Research Physicist
Slac Box 4349 Bin 57, Stanford, CA 94305

This past field season saw the resurvey effort intensify. The number and quality of survey personnel increased, and it is likely that by next season, a few of the key science investigatiors who were heavily involved in cartography in 1982 will be able to return to other research endeavors. The group at Lilburn now includes approximately eight Joint Venturers who can lead survey parties.

The 1982 surveys focussed upon the larger, more heavily used passageways for two reasons. First, the features within these larger passages are most poorly represented on the earlier map and, secondly, surveys of these passages created several new complete interlocking closed survey loops, which serve as a test for the accuracy of our mapping efforts. Areas of the cave which were surveyed include: the Klein Bottle area, East Stream (resurvey), the "Incredicrawl," Great Central Passage area, West Stream (lower section), Ant Lion Passage, the Hex Room, the passage parrallel to the main stream between the Rise and White Rapids, the Schreiber Complex and Impossible Dream, the Elevator, Corkscrew Way, Meyer Parallel Passage, the main stream at the bottom of River Pit and the main stream between the Z-Room and Thanksgiving Hall. This mapping created about 28 survey loops; the most important two dozen or so of these loops had excellent closures. The loops with unacceptable closures are those which have few stations and are located in areas where no new passages exist for further survey. Nonetheless, we will try to locate these errors.

As of December, 1982, 4272 meters (14,015 feet) of total re-survey are completed, which includes about 2500 meters (8300 feet) of 1982 survey.

The survey strategy for 1983 will be to concentrate upon the lower levels of the cave and to begin "filling in" the maze area in the Hex Room area, the Schreiber Complex and River Pit Avenue.

Scientific Programs

Figure 2. Prehistoric prints of slippered feet in Fisher Ridge Cave. Photo by W. McCuddy.

Ecology Program

Genetic Analysis of Regressive Evolution

Daniel W. Fong
Graduate Student
Department of Ecology and Evolutionary Biology, Northwestern University, Evanston, IL 60201

Regressive evolution is a common phenomenon in cave organisms. Reductions in eye size and pigmentation are found in at least some populations and species in all taxa with cave representatives. Elucidation of the mechanism for the phenomenon is a central theme in cave biology. Regressive evolution may be due either to selection or neutral mutation and genetic drift. This summary deals only with the role of selection in regressive evolution.

Selection directly against eye or pigment is improbable (Maguire, 1961; Sadaglu, 1967). Two hypotheses seem plausible to account for regressive evolution without direct selection. One is the energy economy hypothesis (see Poulson, 1963). Because many cave organisms are strongly food-limited and show adaptations to food scarcity, a mutation that reduces a useless structure will have a selective advantage if the energy saved can be used to increase the size of some useful structure or increase metabolic efficiency. The other hypothesis invokes pleiotropy. Pleiotropy is often used to explain the persistence of rudiments, but Prout (1964) and Barr (1968) observe that if there is positive selection for a trait which has a negative genetic correlation due to pleiotropic effects with a second character which is selectively neutral, this second character will become reduced. Although these two hypothesis have usually been portrayed as distinct competing hypotheses (Barr, 1968; Wilkins, 1971; Culver, 1982), they are in fact different aspects of the same hypothesis in that the pleiotropy hypothesis provides the genetic mechanism for the energy economy hypothesis.

Consider first the energy economy hypothesis. Ignoring environmental effects, assume there is an allele *a* that reduces eye size by some amount, α. Then the eye sizes of the genotypes are:

AA:x
Aa:x-α
aa:x-2α

where x is the "normal" eye size. According to the energy economy hypothesis, what affects fitness is not eye reduction *per se*, but that the energy saved from eye reduction allows an increase in some other structure or structures, for example, antennal length. Then the *A*-locus must be pleiotropic, affecting both eye size and antennal length. The following summarizes its effects.

Genotype	*Eye Size*	*Antennal Length*
AA	x	y
Aa	x - α	y + β
aa	x - 2α	y + 2β

where y is the "normal" antennal length, and β is the increase allowed by allele *a*. There may be selected structures besides antennal length that are affected, but there is no loss of generality by considering only antennal length. Note that the genetic correlation between eye size and antennal length is negative (-1 in fact). By the energy economy hypothesis, it is antennal length that may be a direct correlate of fitness.

Let us now consider the pleiotropy hypothesis. What is meant by the pleiotropy hypothesis is that selection for increased antennal length results, because of pleiotropic effects, in decreased eye size. This hypothesis can be stated more formally using the equation for correlated response of a character. If selection is acting only on character Y, the amount of change induced in character X is (Falconer, 1981);

$$C.R._X = i_y h_x h_y r_a \sigma_x$$

where i_y is the intensity of selection of Y, h_x and h_y are the square roots of the heritabilities of X and Y, r_a is the genetic correlation between X and Y, and σ_x is the phenotypic standard deviation of X. Since the correlated response must be negative (otherwise X would not by reduced), this requires that r_a be negative. But this is an equivalent to the pleiotropy required for energy economy hypothesis, which also requries a negative genetic correlation.

To summarize, the energy economy hypothesis offers an explanation of the way selection operates, and the pleiotropy hypothesis offers and explanation of its genetic basis. Both require a negative genetic correlation between characters. The most likely mode of selection is energy economy which requires pleiotropy to operate.

An experiment is in progress to test this model using the amphipod *Gammarus minus* population from Coffman's Cave, West Virginia, which shows extensive phenotypic variation. Specifically, the hypothesis being tested is that reduction in eye size results as a correlated response to selection acting on antennal length. The experiment is designed to measure the basic genetic parameters in (1). This experiment involves the following procedure, with notations following that of Falconer (1981) supplemented by Turner and Young (1969). A total of s males are mated with d females, producing at least k offspring per female. Measurements of eye size and antennal length from the parents and offspring are used to estimate the genetic parameters. The optimal values in terms of numbers of individuals utilized (see Robertson, 1959) are k = 2, d = 5 and s = 50 with a goal of 500 measured offspring.

Assuming that maternal effects, dominance effects and the like may be important, sib-analysis would give the best estimate of heritabilities (Falconer, 1981). An analysis of variance is performed to partition the phenotypic variance (σ_p^2) into components attributable to differneces among males (σ_w^2), differences among females mated to the same male (σ_d^2), and differences within progenies (σ_w^2):

	Variance Component	Mean Squares	Casual Components
(2)	σ_s^2	$\frac{1}{dk}(MS_s - MS_d)$	$\frac{1}{4}V_A$
	σ_d^2	$\frac{1}{k}(MS_d - MS_w)$	$\frac{1}{4}V_A + \frac{1}{4}V_D + V_{Ec}$
	σ_w^2	MS_w	$\frac{1}{2}V_A + \frac{3}{4}V_D + V_{Ew}$

where V_A is the additive genetic variance, V_D the variance due to dominance effects, V_{Ec} the variance due to common environment, and V_{Ew} the remainder of the environmental variance. Heritability in the narrow sense is

$$h^2 = \frac{4\sigma_s^2}{\sigma_p^2} \qquad (3)$$

The standard error of h^2 is given by Turner and Young (1969).

The estimation of genetic correlation (r_A) is obtained in a parallel manner to the heritability. Instead of analysis of variance, analysis of covariance is employed (Mode and Robertson, 1959), and

$$r_A = \frac{cov_{xy}}{\sqrt{var_x \, var_y}} \qquad (4)$$

where the covariance of characters x and y is based on the between sires component of cavariance which is ¼cov_{xy}, and var_x and var_y are the additive genetic variance of characters X and Y estimated from (2). Turner and Young (1969) give the very lengthy formula for the sampling variance of r_A.

Recalling the formula for correlated response,

$$C.R._x = i_y h_x h_y r_Z \sigma_x \qquad (1)$$

the techniques described above account for all parameters on the right hand side of the equation except i_y, the intensity of selection on character y, *i.e.*, antennal length in the present experiment. In fact, selection is not involved in the half-sib experiment. It is possible to get at least a rough estimate of the intensity of selection in the Coffman's Cave population by either (1) comparing the distribution of antennal lengths of adults that were born in the lab and not subject to selection with adults from the natural population, or (2) comparing newborn offspring in the above experiments with adults from the natural populations. Neither procedure is very satisfactory. In the first comparison the effect of laboratory conditions on antenna will be confounded with selection. In the second procedure, the non-constancy of antenna/head ratios through ontogeny requires an extrapolation from young to adults. However, little additional work is required and in the case of the first comparison, all necessary measurements will be made during the course of the half-sib analysis. Van Valen (1965, 1967) provides the rationale and graphs for estimating i_y for truncation selection from the observed changes in mean and variance. Finally, the apparent selective intensity on facet number can also be estimated in the same way, and then compared to the predicted correlated response in equation (1).

REFERENCES

Barr, T.C., 1968, Cave ecology and the evolution of troglobites: Evol. Biol., v. 2, p. 35-102.

Culver, D.C., 1982, Cave life: Cambridge, Harvard Univ. Press.

Falconer, D.S., 1981, Introduction to quantitative genetics (2nd ed.): New York, Longman.

Maguire, B., 1961, Regressive evolution in cave animals and its mechanisms: Tex. Jour. Sci., v. 13, p. 363-370.

Mode, C.J., and Robertson, H.F., 1959, Pleiotropism and the genetic variance and covariance: Biometrics, v. 15, p. 518-536.

Poulson, T.L., 1963, Cave adaptation in amblyopsid fishes: Amer. Midl. Natur., v. 70, p. 257-290.

Prout. T., 1964, Observations on structural reduction in evolution: Amer. Natur., v. 97, p. 239-249.

Robertson, A., 1959, Experimental design in the evaluation of genetic parameters: Biometrics, v. 15, p. 219-226.

Sadaglu, P., 1967, The selection value of eye and pigment loss in Mexican cave fish: Evolution, v. 21, p. 541-549.

Turner, H.N., and Young, S.S.Y., 1969, Quantitative genetics in sheep breeding: Ithaca, New York, Cornell Univ. Press.

Van Valen, L., 1965, Selection in natural populations, III. Measurements and Estimations: Evolution, v. 19, p. 514-528.

———, 1967, Selection in natural population. 6. Variation genetics and more graphs for estimation: Evolution, v. 21, p. 402-406.

Wilkins, H., 1971, Genetic interpretation of regressive evolutionary processes: studies on hybrid eyes of two *Astyanax* cave populations (Characidae, Pisces): Evolution, v. 25, p. 530-544.

Sex Ratios and Summer Roost Site Specificity of Bats on the White River Plateau, Colorado

M. Susanna Goad
Graduate Student
Department of Renewable Natural Resources, Univ., of Arizona, Tucson, AZ 85721

Introduction

Many bat species found on the western slope of the Rocky Mountains in Colorado are migratory (Barbour and Davis, 1969; Armstrong, 1972). They summer at high elevations in Colorado and likely winter at lower elevations in Colorado, Utah, and New Mexico. Banding bats at their summer areas of population concentration in Colorado, such as roost sites, can help to eventually reveal their winter hibernacula. On a short term basis, banding leads to information on roost site specificity, sex ratios, and species composition. This paper describes the short term information obtained from banding bats at roosting sites in western Colorado. Four caves and 1 hollow tree on the White River Plateau were selected as banding sites. A total of 114 bats were captured in 15 trapping nights.

Location and Habitat of Study Area

The White River Plateau of western Colorado, including the Flattops Wilderness Area, lies mainly within the White River and Routt National Forests (Figure 3). The rolling summit lands average about 3300 m. elevation and are dominated by Engleman spruce (*Picea englemanni*) and subalpine fir (*Abies lasiocarpa*) interspersed with meadows dominated by *Festuca therberi*, *Chrysopsis villosa*, and *Geranium* spp.

The caves selected for banding sites are within the Mississippian Leadville limestone formation (George, 1927). Two of the caves, Groaning and Fixin'-to-Die, are located on the rim of Deep Creek Canyon northwest of Dotsero, Colorado, in Garfield County. Groaning Cave is at an elevation of 2979 m and Fixin'-to-Die is at an elevation of 3002 m. Spring Cave is east of Meeker, Rio Blanco County, Colorado, near the South Fork of the White River at an elevation of 2438 m. Fulford Cave is

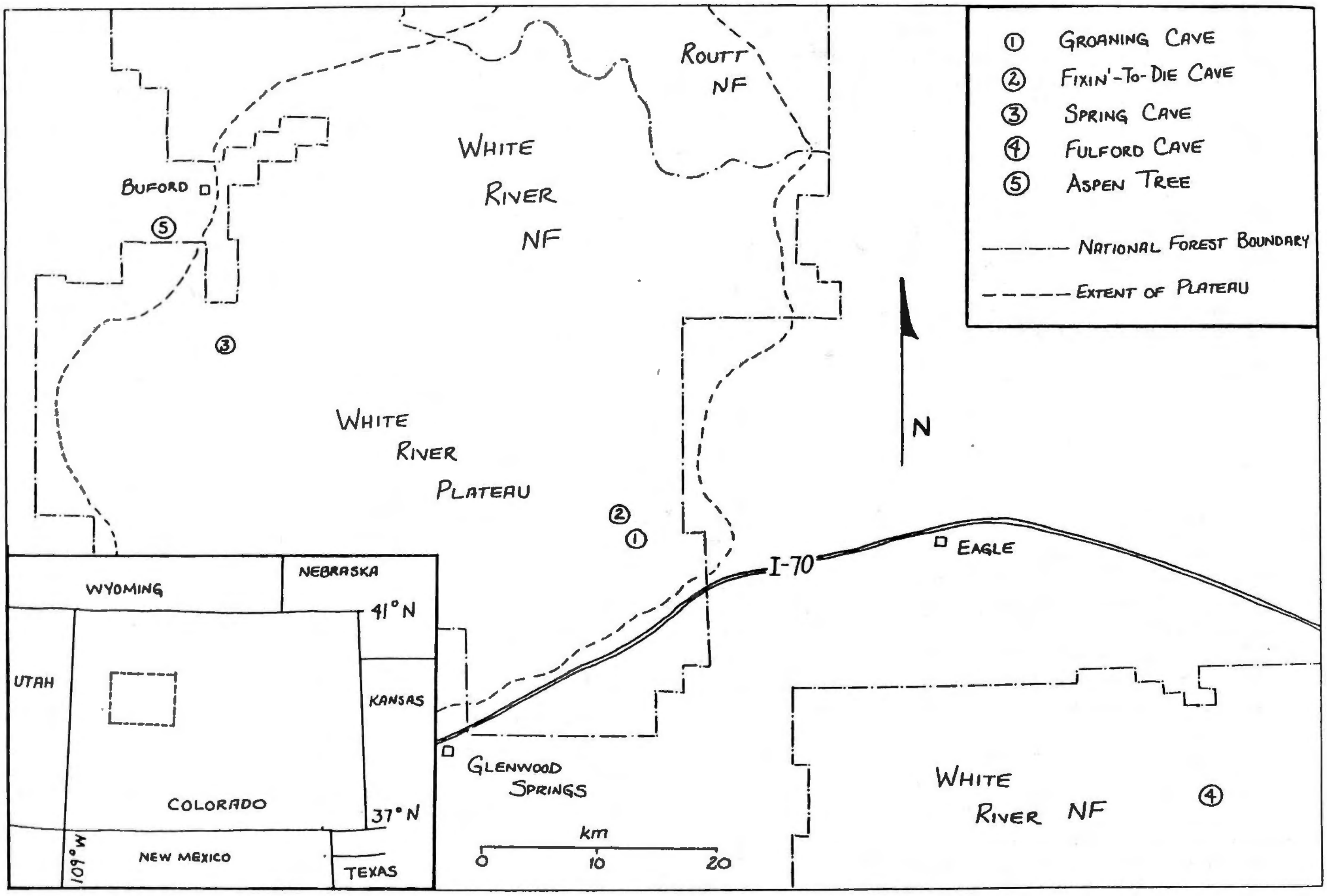


Figure 3. Location of bat banding sites, White River National Forest and vicinity, Colorado.

located south of the town of Eagle, Eagle County, Colorado, in the East Brush Creek drainage of the Sawatch Range, at an elevation of 3082 m. Although south of the White River Plateau, Fulford Cave was the capture site for Townsen's big-eared bat (*Plecotus townsendii*) which had previously eluded capture by the author on the plateau. A hollow aspen tree (*Populus tremuloides*) on Colorado Division of Wildlife State land southwest of Buford, Rio Blanco County, Colorado, was also a capture site. The tree is at an elevation of 2433 m within a stand of aspen and ponderosa pine (*Pinus ponderosa*).

Methods

Bats were captured with Japanese mist nets at the cave entrances, and a fish net on a pole at the hollow tree. United States National Museum of Natural History, Smithsonian Institution bat bands were used for banding. The European-style bands with flattened edges were used as opposed to small bird bands. The European design reduces the chances of injury to the bat and subsequent growth of flesh over the band making the number impossible to read (Hitchcock, 1957; Greenhall and Paradiso, 1968). Activity patterns, species composition, and roost site specificity were observed. Voucher specimens of each species were prepared and are now in the U.S. Fish and Wildlife Service, Division of Research Collection, 1300 Blue Spruce Drive, Fort Collins, Colorado.

Spelunkers visiting the caves were asked to report on the number of bats they observed during their visit. Messages to this effect were left in cave registers and conveyed verbally from June to August, 1981 and 1982. In addition, the author spent many days exploring the caves and looking for evidence of roosting bats.

Results and Discussion

A total of 114 bats were captured during the summers of 1981 and 1982 with six species represented (Table 1). The caves studied appear to be used almost exclusively as night roosts for periodic resting between feeding flights. During the first few hours after dusk, almost all of the bats captured were flying into the caves to roost. Later, bats were caught entering and exiting the caves. Of the spelunkers exploring the caves only a few reported seeing any bats during the daylight hours. While exploring the caves at night, however, bats were seen flying in the main corridors. At 0200 on 15 August, 1982, I saw several bats over 9.6 km from the entrance to Groaning Cave. Groaning Cave is the longest known cave in Colorado with over 19 km of passageways. Small guano deposits of varying ages throughout the cave suggest bat use of the entire cave over a long period of time.

The single, walk-in entrance and easy accessibility of Groaning Cave made mist-netting much easier than at multi-entranced and remote Fixin'-to-Die, Fulford, and Spring Caves. The nine banding nights spent at Groaning Cave provided evidence to suggest that it is predominantly a single-sex roost, with 92% of the captured bats male ($X^2 = 17.5$, $\alpha < 0.005$). The

TABLE 1
Captures of Bats at Five Roost Sites in Western Colorado

Location	Dates of Capture	Bat Species	No. ♂	No. ♀
Groaning Cave	2 July-8 August 1981	*Myotis lucifugus*	39	7
		M. evotis	8	
		M. leibii		5
		M. volans	23	**
	25 June-16 July 1982	*M. lucifugus*	18	2*
		M. evotis	3	1
Fixin'-to-Die Cave	3 July 1981	*M. evotis*	2	
Spring Cave	9 July 1981	*M. volans*	1	
Fulford Cave	20 September 1981	*Plecotus townsendii*		2
aspen tree Buford, Colorado	7 August 1982	*Eptesicus fuscus*		3**
		TOTAL	94	20

* 1 recapture, ♂, banded 4 July 1981 at Groaning Cave; ** 1 juvenile.

single-sex roosting may be within species since all of the small-footed myotis (*Myotis leibii*) captured were female. Disproportionate sex ratios in summer roosting and winter hibernating bats is well documented (Davis, 1959; Barbour and Davis, 1969; Fenton, 1969; Barrett et al., 1975; O'Farrell and Studier, 1975; Humprey and Kunz, 1976; Kurta and Matson, 1980). The dominant species at Groaning Cave appears to be the little brown bat (*M. lucifugus*), with numbers of long-legged myotis (*M. volans*) the secondary component of resident bats.

Numbers of bats captured in 4 banding nights in 1982 was 70% lower than the 5 banding nights in 1981. This decrease may indicate population fluctuations or that alternative caves are being used as night roosts. Also, the increasing number of people exploring Groaning Cave may have induced this change. People activity in caves can cause bats to abandon them as roosts (Mohr, 1972).

At Fixin'-to-Die and Fulford Caves, the bats captured were all 1 sex, 2 females and 2 males respectively, but the sample sizes are too low to statistically assure that these roosts are single-sex.

The little brown bat, long-legged myotis, long-eared myotis (*M. evotis*), and small-footed myotis are reported here for the first time from Garfield County, although the county has been in the suspected range of all these species. Capture of the long-legged myotis at Spring Cave in Rio Blanco County and of the Townsend's big-eared bat in Eagle County also confirm earlier suppositions (Armstrong, 1972; Bissell, 1978).

Big brown bats (*Estesicus fuscus*) are found throughout Colorado, but prefer roosting in trees, buildings, or bridges rather than caves (Barbour and Davis, 1969). They have been reported previously from Rio Blanco County (Armstrong, 1972). The hollow aspen tree near the town of Buford was used as a day roost by big brown bats. The cavity used by the bats is about 9 m off the ground and appears to have been originally excavated by a large woodpecker, possibly a northern three-toed woodpecker (*Picoides tridactyles*). Of the estimated 15 bats roosting inside, the 3 captured were all female. One was a juvenile.

One adult male little brown bat was recaptured at the entrance of Groaning Cave on 25 June 1982, almost a full year after banding the bat at that location on 4 July 1981. This was the only recapture, a recapture success of less than 1%. The bat appeared healthy and the band showed no signs of having caused any injury. The return of that bat suggests that at least a small portion of the bat population use the same roost sites, summer after summer. Banding on successive nights at the same cave did not result in any recaptures from the previous evenings. This low recapture success may indicate that individual bats are likely to use several different night roosts over a period of time. Sexual segregation breaks down briefly for the breeding season in late summer, but is usually re-established at hibernacula (Davis, 1959; Fenton, 1969; Barrett et al., 1975; Kurta and Matson, 1980).

REFERENCES

Armstrong, D.M., 1972, Distribution of mammals in Colorado: Monogr. Mus. Nat. Hist., No. 3. Univ. Kansas, Manhatten, 415 p.

Barbour, R.W., and W.H. Davis., 1969, Bats of America: Univ. Press Kentucky, Lexington, 286p.

Barrett, G.W., M.P. Farrell, R.S. Mills., 1975, Population dynamics of the big brown bat (*Eptesicus fuscus*) in southwestern Ohio: J. Mammal., v. 56, p. 591-604.

Bissell, S.J., ed., 1978, Colorado mammal distribution latilong study: Colo. Div. of Wildl., Denver, 20 p.

Davis, W.H., 1959, Disproportionate sex ratios in hibernating bats: J. Mammal., v. 40, p. 16-19.

Fenton, M.B., 1969, Summer activity of *Myotis lucifugus* at hibernacula in Ontario and Quebec: Canad. J. Zool., v. 47, p. 597-602.

George, R.D., 1927, Geology and natural resources of Colorado: Univ. Colorado, Boulder, 228 p.

Greenhall, A.M., and J.L. Paradiso., 1968, Bats and bat banding: U.S. Dept. Interior, Fish and Wildl. Serv. Bureau of Sport Fisher. and Wildl. Res. Publ., No. 72., 48 p.

Hitchcock, H.B., 1957. The use of bird bands on bats: J. Mammal., v. 38, p. 402-405.

Humprey, S.R., and T.H. Kunz., 1976, Ecology of a Pleistocene relict, the western big-eared bat (*Plecotus townsendii*), in the southern Great Plains: J. Mammal., v. 57, p, 470-494.

Kurta, A., and J.O. Matson, 1980, Disproportionate sex ratio in the big brown bat (*Eptesicus fuscus*): Amer. Midl. Nat., v. 104, p. 367-369.

Mohr, C.E., 1972, The status of threatened species of cave-dwelling bats: Natl. Speleo. Soc. Bull., v. 34, p. 33-47.

O'Farrell, M.J., and E.H. Studier., 1975, Population structure and emergence patterns in *Myotis thysanodes* and *M. lucifugus* in northeastern New Mexico: Amer. Midl. Nat., v. 93, p. 368-376.

Amphibians of Mammoth Cave National Park

Marilyn Hale
2804 Alice Ave., Louisville, KY 40220

The local distribution and relative abundance of amphibians at Mammoth Cave National Park have previously received little attention. Bailey (1933) devotes a chapter to amphibians of the cave region and Hibbard (1936) compiled a checklist of this area. Several more recent and broader distributional surveys have been conducted by Barbour (1971) and Conant (1975) but neither of these is specific to the park.

This research, therefore, investigates the distribution of amphibians to compile a current checklist of this specific locality.

Since May, 1982, 14 collecting trips have been conducted, identifying a total of 9 salamander species and 11 frog species.

Several areas have been focal points on these surveys: Sloans Crossing Pond, First Creek Lake, several springs including Three Springs, Collins Spring, and Cooper Spring, Mammoth Onyx Cave, and temporary ponds both north and south of the Green River. Several trips were specifically driving trips in which the roads were surveyed on foot and by car. (On rainy evenings, many amphibians may be found on warm road surfaces.) Some specimens were also collected on trails to and from specific ponds, lakes or springs.

The results of these trips are given in Tables 2 through 5.

This research corresponds closely with the checklist compiled by Hibbard (1936). The primary difference is that while Hibbard considered *Rana sylvatica* (wood frog) rare since he collected only one specimen, I have found nine adult specimens and numerous developing tadpoles identified as *Rana sylvatica*.

Several species which should be present in the park are most often encountered in the early spring before this research was started, and so have not been collected. These include *Ambystoma jeffersonianum* (Jefferson salamander), *Ambystoma texanum* (Small-mouth salamander), *Ambystoma tigrinum* (Tiger salamander), *Hemidactylium scutatum* (Four-toed salamander), *Eurycea bislineata* (Northern two-lined salamander), *Pseudacris triseriata* (Upland chorus frog), *Pseudacris brachyphona* (Mountain chorus frog), and *Gastrophryne carolinensis* (Narrow mouth toad). Two species of large salamanders, *Necturus maculosus* (Mudpuppy) and *Cryptobranchus alleganiensis* (Hellbender), should be found in the Green River.

This research will involve a survey of the trogloxenic or troglophilic amphibians of the cave system as well as the surface dwelling amphibians. In the upper levels, specifically shaft drains and terminal breakdown streams, as yet unidentified salamander larvae appear in early spring. These salamander larvae may be a major predator of the crustacean communities, since troglobitic fish and crayfish are found only in the lower levels.

Other amphibians occur regularly in river passages, cave streams, or cave entrances, and have not as yet been surveyed in this research.

TABLE 2
Preliminary Survey of the Distribution of the Frog Species *Rana* at Specific Localities in Mammoth Cave National Park

	Rana clamitans	*Rana palustris*	*Rana catesbiana*	*Rana sylvatica*	*Rana spenocephata*
Springs	x	x	x		x
Sloans Crossing Pond	x	x	x		
First Creek Lake					
Temporary ponds	x			x	
Great Onyx Cave					
Assorted trails (woods)				x	
Road trips	x	x	x	x	

TABLE 3
Preliminary Survey of the Distribution of Several Frog Species at Specific Localities in Mammoth Cave National Park

	Ambystoma maculatum	*Ambystoma opacum*	*Desmognathus fuscus*	*Eurycea longicauda*	*Eurycea lucifuga*
Springs			x	x	x
Sloans Crossing Pond					
First Creek Lake					
Temporary ponds					
Great Onyx Cave					x
Assorted trails		x			
Road trips	x	x			

TABLE 4
Preliminary survey of the Distribution of Several Salamander Species at Specific Localities in Mammoth Cave National Park

	Hyla crucifer	*Hyla chrysoscelis*	*Acris crepitans*	*Scaphiopus holbrookii*	*Bufo americanus*	*Bufo woodhousii*
Springs						
Sloans Crossing Pond	x		x			
First Creek Lake						x
Temporary ponds	x	x	x			
Great Onyx Cave						x
Assorted trails (woods)						x
Road trips	x	x		x	x	x

TABLE 5
Preliminary Survey of the Distribution of Several Salamander Species at Mammoth Cave National Park

	Plethodon dorsalis	*Plethodon glutinosus*	*Pseudotriton ruber*	*Notophthalmus viridescens*
Springs	x	x	x	
Sloans Crossing Pond				x
First Creek Lake				
Temporary ponds				
Great Onyx Cave		x		
Assorted trails (woods)	x	x	x	
Road trips	x		x	

REFERENCES

Bailey, Vernon, 1933, Cave life of Kentucky: Notre Dame, Ind., University Press, p. 212-217.

Barbour, R.W., 1971, Amphibians and reptiles of Kentucky: Lexington, Ky., University Press of Kentucky, 334 p.

Conant, Roger, 1975, A field guide to reptiles and amphibians of eastern and central North America: Boston, Mass., Houghton Mifflin Co., 429 p.

Hibbard, C.W., 1936, The amphibians and reptiles of Mammoth Cave National Park proposed: Trans. Kansas Acad. Sci., v. 39, p. 277-281.

A Biological Reconnaissance of a Polluted Cave Stream: The Hidden River Groundwater Basin

Julian J. Lewis, Teresa M. Lewis, and James Eckstein
Graduate Students
L.S. 330, Dept. Biology, Univ. of Louisville, Louisville, KY 40292

The Hidden River Groundwater Basin, lying to the east of Mammoth Cave National Park, contains a number of caves that allow entry into the underground Hidden River at various points along its course. Quinlan and Ray (1981) have delineated the subterranean drainage patterns of the area, infamous for its groundwater pollution. The best known cave in the basin, Hidden River (Horse) Cave, receives the effluents from both the Horse Cave and Cave City sewage treatment plants, through the south and east branches of the river, respectively. Quinlan and Rowe (1977) and the E.P.A. (1981) have provided information on the physical and chemical effects of the sewage (including the industrial metal plating the creamery wastes at Horse Cave) on Hidden River Cave and points downstream.

Almost nothing had been published on the effects of the sewage on the cave fauna of Hidden River. This degredation presents an excellent opportunity to study the recovery of a troglobitic fauna from the effects of groundwater pollution. To this end, we have initiated observations on the communities at four localities: (1) L&N Cave—located in Cave City. This cave is a tributary to the East Branch of Hidden River, adjacent to the part of the branch that receives the Cave City effluent. The easily entered part of L&N Cave consists of about the first 300 meters, which is typically walking height by 5 meters wide, with a brisk stream flowing over a gravel strewn bottom. (2) Hidden River Cave—located in downtown Horse Cave. It is entered through an immense sinkhole that allows immediate access to the South Branch of Hidden River. The effluent from the Horse Cave treatment plant enters the South Branch an unknown distance, perhaps a kilometer, upstream from the point encountered at the entrance. The East Branch of Hidden River joins the South Branch via an unenterable passage in the entrance breakdown. Immediately downstream the passage size increases at a large breakdown dome. A sizeable dam, no longer ponding the water, is found directly below the confluence of the two branches. Below the dam, deep wall to wall water is breached only by a long sandbar stretching into the river. Further travel requires a boat (or walking through the barely diluted effluent). (3) Hick Cave—located about 5-6 km north of Horse Cave. It is described briefly by Quinlan and Rowe (1977). Only a small part of the 23.5 km of mapped passages have been sampled. Here Hidden River is a network of distributary passages, deep and difficult to work in, flowing over deep mud and breakdown.

TABLE 6
Selected results of water analysis from L&N Cave, Hidden River Cave South Branch, Hidden River Cave East Branch, Hick Cave and Hick Spring.*

	L&N Cave	HRC South	HRC East	Hick Cave	Hick Spring
temperature (C°)	11.5	14.0	13.0	11.5	13.0
dissolved O_2 (mg/l)	9.6	1.5	9.4	8.4	8.0
alkalinity (mg/l)	237	262	224	217	212
conductivity (umhos/cm)	300	800	510	520	580
pH	7.9	7.6	7.4	7.4	7.5
NO_3—N (mg/l)	2.96	0.11	2.88	3.44	3.84
NO_2—N (ug/l)	0.00	11.45	0.00	0.00	0.00
Total P (mg/l)	4.6	8.2	5.0	5.9	5.4

*All taken and analyzed 13 November, 1982.

Flooding limits access, completely closing the cave at times. (4) Hick Spring—Quinlan and Rowe (1977) found this permanent spring to be one of several that carry the water from the sewage treatment plants, via Hidden River and Hick caves, to the Green River. The spring is only a few hundred meters from the area sampled upstream in Hick Cave.

Results

L&N Cave—The aquatic fauna of this cave is typical of those of the sinkhole plain, characterized by the presence of the cavefish *Typhylichthys subterraneus*, the crayfish *Orconectes pellucidus*, the isopod *Caecidotea whitei* and the amphipod *Stygobromus* sp. A casual count of fish and crayfish on 13 November, 1982, under moderate flow conditions in the first 300 meters of the cave, revealed 5 *Typhlichthys* and 38 *Orconectes*. Censusing will be necessary in the future to quantify the fauna more accurately.

Physicochemical data indicate a reasonable undisturbed environment except for nitrate levels reported by E.P.A. (1981) at the drinking water limit of 10 mg/l. Our sample was much lower, but an unidentified microbial growth that occurs on the underside of stones in the stream may still be attributable to high nitrate levels. This is probably the result of fertilizer breakdown from agricultural areas on the sinkhole plain. EMB agar plates innoculated with 1 ml samples revealed 2-5 coliform colonies/ml, indicative of minor fecal contamination from an unidentified source.

Hidden River Cave, South Branch—Accounts published before pollution problems began in 1944 (Quinlan and Rowe, 1977, give a brief historical account) show that Hidden River once had a troglobitic fauna equivalent to that now present in L&N Cave, containing *Typhlichthys* (Eigenmann, 1909), *Orconectes* (Bolivar and Jeannel, 1931) and *Caecidotea* (Lewis and Bowman, 1981). Under present conditions E.P.A. (1981) stated that Hidden River South Branch "will not support aquatic life." This statement is basically correct when applied to anything resembling a normal cave community, but a flourishing sewage fauna exists in the South Branch. Large numbers of red tubificid worms inhabit the edges of stream pools. "Sewage fungus," charactized by the bacterium *Sphaerotilus natans* (Hynes, 1963), covers the surfaces of stones and forms filaments in excess of a centimeter long. Nearly anaerobic conditions exist in the stream, with dissolved O_2 measured at 1.5 mg/l. Nitrate levels are low, due to reducing conditions, whereas nitrite levels are elevated. Where sewage fungus does not cover the substrate, it is blackened by iron sulfide.

Hidden River Cave, East Branch—Although evaluation is difficult because of infiltration from the South Branch (Quinlan and Rowe, 1977), the East Branch appears to have recovered much of its natural character by the time it reaches Hidden River Cave from the Cave City treatment plant. The water is nearly saturated with oxygen (9.4 mg/l) and probably supports troglobitic life.

REFERENCES

Bolivar, C., and Jeannel, R. 1931, Campagne Speleologique dans l'Amerique du Nord: Arch. Zool. Exp. Gen., v. 71, p. 293-499.

Eigenmann, C., 1909, Cave vertebrates of America: Carnegie Institute Wash., 241 p.

Environmental Protection Agency, 1981, Environmental impact statement, draft, Mammoth Cave area, Kentucky: U.S. E.P.A., Atlanta, unpublished report.

Hynes, H. 1963, The biology of polluted waters: Liverpool, Liverpool University Press, 202 p.

Lewis, J., and Bowman, T., 1981, The subterranean Asellids *Caecidotea*) of Illinois (Crustacea: Isopoda: Asellidae): Smith. Cont. Zool., v. 335, p. 1-66.

Quinlan, J. and Ray, J., 1981, Groundwater basins in the Mammoth Cave region, Kentucky: Friends of the Karst, Occas. Pub., no. 1 (map, 1 sheet).

——————, and Rowe, D., 1977, Hydrology and water quality in the Central Kentucky Karst: Phase I.: Univ. Ky. Water Res. Inst., Res. Rep. no. 101, p. 1-92.

The Life Cycle and Distribution of Two Troglobitic *Caecidotea* in Mammoth Cave National Park

Julian J. Lewis
Graduate Student
L.S. 330, Dept. Biology, Univ. of Louisville, Louisville, KY 40292

and

Teresa M. Lewis
Graduate Student
L.S. 330, Dept. Biology, Univ. of Louisville, Louisville, KY 40292

During 1982 the thrust of work in Mammoth Cave National Park has taken two directions. These were: (1) the continued census of invertibrates in Shaler's Brook, with the goal of gaining new insight into the life cycle and ecology of the troglobitic isopod *Caecidotea stygia*; and (2) the search for new collection localities for both *Caecidotea stygia* and *C. whitei*, in order to refine the distribution pattern previously established in Mammoth Cave for these species (Lewis and Lewis, 1980; Lewis, in press).

Life cycle—Shaler's Brook is a small shaft drain stream near the end of Gratz Avenue, in the Historic Section of Mammoth Cave. The stream begins at the plunge pool beneath the waterfall at Annette's Dome, then flows horizontally less then 30 meters (over sand, gravel and bedrock) before plunging into

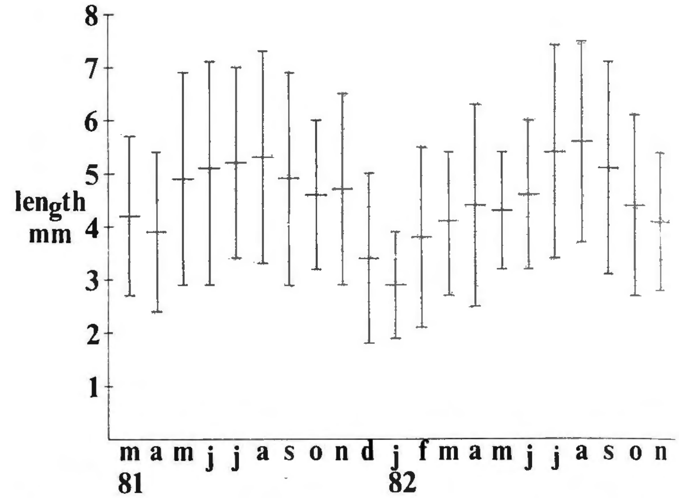


Figure 4. The monthly variation in the length of the troglobitic isopod *Caecidotea stygia* in Shalers Brook, Gratz Avenue, Mammoth Cave. (Center bars are mean length, outer bars are standard deviation.

another pit, Lee's Cistern. Six randomly placed 15 cm^2 survey stations have been examined since March 1981. Only three species are present during most of the year, the isopod *Caecidotea stygia*, the amphipod *Stygobromus vitreus*, and the flatworm *Sphalloplana percoeca*. Of these, the isopods are by far the most abundant, comprising at least 95% of the animals typically observed. During the later winter (February and March) as yet unidentified salamander larvae (*Eurycea lucifuga?*) appear in the stream. Of these four species, all are counted at each of the six stations and each of the isopods is placed in 1 mm size classes by visual estimation. Seasonal changes in size classes (Figure 4) now allows some observation on the life cycle of *Caecidotea stygia* in Shaler's Brook.

In October ovigerous 4-6 mm females begin to appear in Shaler's Brook. In December and January numbers of 2 mm individuals appear, found almost exclusively in the gravel habitats of the stream. This, taken with the approximate 1 mm size of immatures taken from the brood pouches of ovigerous females, suggests that the isopods molt immediately upon release from the females (which average 5 mm at this time). Magniez (1981) reported the intramarsupial development period of *Caecidotea recurvata* reared in captivity as about 70-80 days, a time interval similar to that seen in *C. stygia* in Shaler's Brook.

Through the winter the average size (Figure 5) of the population slowly increases. In February-March of 1982 salamander larvae (3 to 8 individuals) appeared in the pebble-sand habitat of the upstream part of the stream. These salamanders are probably the only active predators of *Caecidotea stygia* in Shaler's Brook, since neither fish nor crayfish are present.

In the period between May and July the average size of the population attains the size of the smallest ovigerous females in Shaler's Brook (about 4.5 mm), but few ovigerous females or juveniles are found at this time. A bimodal size distribution is apparent and is skewed toward higher size classes as the season progresses. In August of both 1981 and 1982, the average size reached its maximum at about 5.5 mm. This figure represents a relatively large number of the juveniles reaching reproductive size, plus their presumed parents in the 7 to 12 mm size classes. In both years the average size dropped during the autumn as the result of the disappearance of most of the larger size classes, with the combined gradual appearance of a new generation of juveniles.

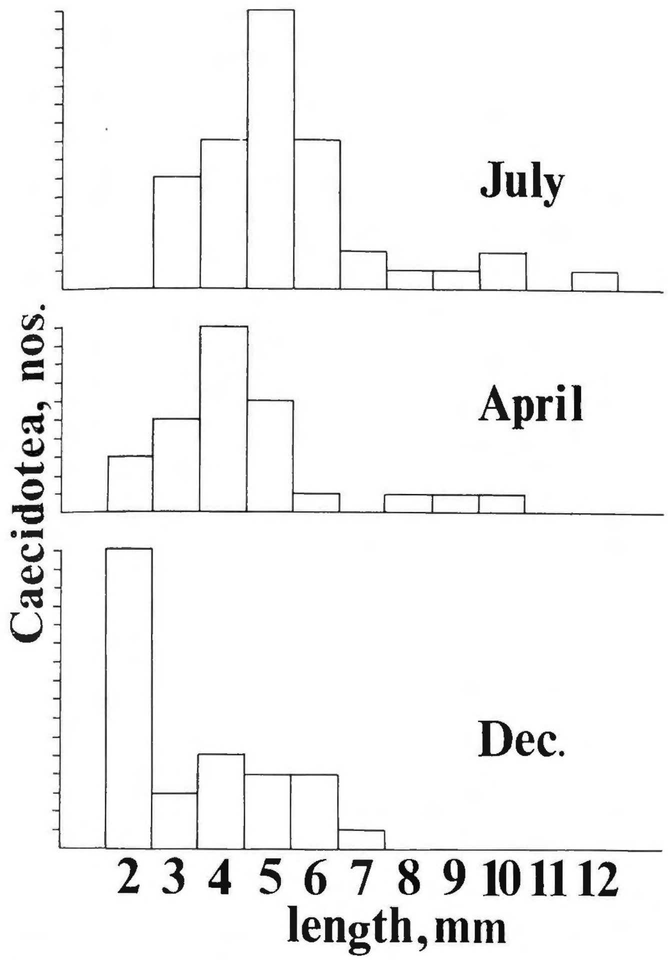


Figure 5. Size class distribution of *Caecidotea stygia* in Shaler's Brook, illustrating the bimodal distribution of the population and the overall increase in size with time from winter to summer.

Combining these data I can speculate on the life cycle of *Caecidotea stygia* in Shaler's Brook. A given individual begins its embryonic life in the autumn, then is released into the stream after about 2 months. If it escapes the pressures of predation and competition, the isopod will attain reproductive size that summer. About a year after their conception, a female isopod becomes ovigerous, releasing its 20-30 juveniles into the stream during December or January. The fate of these adults in the following months is unknown. At least some continue to live through the following summer, accounting for the larger size classes present. The decline of the presence of large individuals in late autumn suggests that they die after about 22-24 months of life.

Distribution—The distribution of *Caecidotea stygia* and *C. whitei* in Mammoth Cave has been discussed previously (Lewis and Lewis, 1980; Lewis, 1981; Lewis, in press). In brief, *C. stygia* occures only in relatively small upper level habitats, while *C. whitei* occurs in larger master shaft drains and the base-level cave rivers.

This year a concerted effort has been made to learn the distribution of these two isopods in one of the park's subterranean rivers from its headwaters to the spring. This task has been difficult because of limited accessibility (e.g., the River Styx flows only a short distance before siphoning in both directions) or logistics (e.g., the Hawkins River area takes several hours to reach). Thus, the best choice for study was the Echo-Roaring River complex. In the commercial part of the Styx and Echo Rivers, the only isopod species present is *Caecidotea stygia* (*C. whitei* is known from a single specimen taken from The River Styx). This is probably attributable to disturbance from the Green River, which flows into the cave through Styx Spring and exits at Echo Spring. Whether the presence of *C. stygia* at base-level (rather than *C. whitei*, as is the case everywhere else in the cave system) in the Styx-Echo area is natural or the product of increased disturbance due to the pools behind Green River Dam 6 is unknown. Isopods were not identified from the river areas until well after the dam was built, so it is impossible to say what was present prior to the 1906 creation of the navigation pool. However, it is entirely possible that the distribution seen today is a natural one, since the Green River undoubtedly affected the present commercial sections of the river long before the dam was present.

Upstream from Echo River, in its continuation called Roaring River, both *Caecidotea stygia* and *C. whitei* are present syntopically to the confluence of Mysticriver with Roaring River. There both species are still present, but upstream from that point several trips into Mystic River have revealed only *C. whitei*. Upstream Mystic River eventually heads in shaft drains; by following these drains upstream one should eventually find a population similar to the one in Flint Dome (Jessup Avenue), where both species are again present. Upstream from that area a Shaler's Brook type population containing a single isopod species, (*Caecidotea stygia*) probably exists.

Upstream in Roaring River, collections have been made in the far reaches of the river accessible through the New Discovery. Once again, only *Caecidotea whitei* was present there, similar to the situation found in Mystic River. On the way to Roaring River, in the New Discovery, a number of low level shaft drains are encountered that harbor *Caecidotea*, but all specimens collected thus far have been unidentifiable females. Future trips will show if these shaft drains contain the first upper level populations of *Caecidotea stygia* in that area of the cave.

REFERENCES

Lewis, J.J., 1981, The subterranean *Caecidotea of the interior low plateaus: International Congress of Speleology, 8th Proceedings, v. 1, p. 234-236.*

————, 1982, Aquatic ecosystems and management problems in the Mammoth Cave area, *in* Wilson, R.C., and Lewis, J.J., eds., National Cave Management Symposia, Carlsbad, New Mexico, 1978; Mammoth Cave National Park, Kentucky, 1980: Oregon City, Oregon, Pygmy Dwarf Press, p. 73-76.

————, in press, The systematics of the troglobitic *Caecidotea* of the southern interior low plateaus (Crustacea: Isopoda: Asellidae): Brimleyana, v. 8.

————, and Lewis, T.M., 1980, The distribution and ecology of two species of subterranean *Caecidotea* in Mammoth Cave National Park: Cave Research Foundation 1980 Annual Report, p. 23-27.

Magniez, Guy, 1981, Experimental breeding of the U.S. cavernicolous crustacean *Caecidotea recurvata* (Steeves, 1963): International Congress of Speleology, 8th Proceedings, v. 1, p. 241-242.

Cave Rat Feces: A Model for the Study of Communities

Thomas L. Poulson, PhD
Professor of Biology
Dept. of Biological Sciences, Univ. of Illinois at Chicago, P.O.B. 4348, Chicago, IL 60680

and *Kathleen H. Lavoie*, PhD
Assistant Professor of Biology
Dept. of Biology, The University of Michigan-Flint, Flint, MI 48503.

The recognition that caves provide simple enough model systems to make important contributions to evolutionary ecology should become more widespread with the publication of David C. Culver's important book (1982). Culver extends and elaborates the Poulson and White argument that caves are "natural laboratories" in which to study "general processes" (1969). Culver's treatment is rigorous and includes both current theoretical and quantitative approaches. One of the areas to which he gives greatest attention is that of "community ecology". It is based mainly on his own use of theory to suggest which are the most critical tests both using natural experiments in the field and manipulative experiments in the laboratory. He emphasizes that this approach feeds back on theory to tell whether it is adequate; if it will not work in the relatively simple communities in caves, then surely it will not work in complex communities. Given the encouraging results with simple cave stream communities, Culver suggests that we should forge ahead and use theory to focus our research more critically on the more complex terrestrial cave communities, particularly those in Mammoth Cave which are the best understood to date. In this report we summarize how we have studied these communities in the past and describe the nature of current efforts to incorporate a variety of approaches and theories used by ecologists in complex and non-cave systems so that we can meet Culver's challenge in the future. In particular we take the rat feces system as an illustration of our approaches. Our studies of this and other systems are summarized in past Annual Reports and the Proceedings of the 8th International Congress of Speleology (1981).

Communities are difficult to define and delimit. They encompass a wide range of biological levels of organization with a span of 6-8 orders of magnitude for organism mass. They are affected by the amount of the resources on which the organisms depend where increased area of sampling of the resource brings in more microclimates and substrates. This in turn affects the kinds of organisms that can utilize the resource. Nonetheless boundaries of communities in caves are easier to delimit than on the forest floor. Organisms that forage on the forest floor and live in caves provide the food base for many cave communities. Cave rat fecal communities are deposited in discrete latrine areas where the feces are not mixed with other kinds of organic import such as cricket feces. Unlike cricket feces, even single rat pellets are large enough and have enough energy concentration that they are always used by some organisms as long as they are in areas protected from the drying rigor of cold winter air flowing into entrances. The effects of increasing density of rat pellets are illustrated by Figure 6.

The most general definition of "community" is a set of species that co-occur in space and interact over time. One samples increasing areas until the number of species on rat feces stops increasing. Such a species-area curve is a composite of many effects. With increasing area: (1) trophic levels increase; (2) stages of successional decomposition increase; (3) size of island piles increases successional stages present at one spot and provides buffering against varying microclimate; and (4) sizes, ages and substrates of island piles in a local archipelago are increased. Figure 6 deals only with isolated piles of different size on a single substrate. The fecal amount at which each species first appears is a clue to its trophic position in a food chain. Bacteria and early successional Phycomycete fungi require less feces to support themselves than 1° consumers like the *Bradysia* fly and *Ptomaphagus* beetle whereas 2° consumers that eat the 1°, like the *Quedius* staphylinid beetle, require larger piles of feces. However, this mode of deduction works only for the smallest pile sizes and the initial stages of successional decomposition.

The only clear way to separate confounding effects of increasing pile size is to experimentally separate the effects. The first problem is succession. The larger piles have fruiting structures of all the fungi, not only the mycelia sterilia of the older and more fragmented pellets but also the Phycomycetes on the freshest pellets that are at the initial stage of successional decomposition. Natural experiments of unrenewed piles ≤15 g confirm this interpretation because the fungi appear in the sequence listed on Figure 6 (Lavoie, 1981a). For species that appear only on larger piles, manipulative experiments are needed to determine whether they are responding to succession, very high food needs, inability to "find" smaller piles, or subtly more stable microclimates associated with the largest renewed piles. Single rats in the cave do not produce piles of ≥150 g of the same age so we relied on the composite contribution of a lab colony (Lavoie, 1981a). With 150 g of fresh feces we found the same fungal and *Ptomaphagus-Bradysia-Quedius* succession as on smaller natural piles. The large sciarid fly and its black staphylinid beetle predator were not present so we presume that they require archipelagoes, of various ages and sizes of pile, or a single very large pile to locate the fecal resource. Experiments also eliminated the confounding effect of different substrates under large piles. Compared to the community composition of Figure 6, sandier substrates have more leaching of nutrients and/or a drier microclimate. Natural experiments suggest that this merely increases the frequency and abundance of species already rare in feces on sandy clay, such as the *Sinella* springtail and its major predator *Pseudanophthalmus*, a carabid beetle.

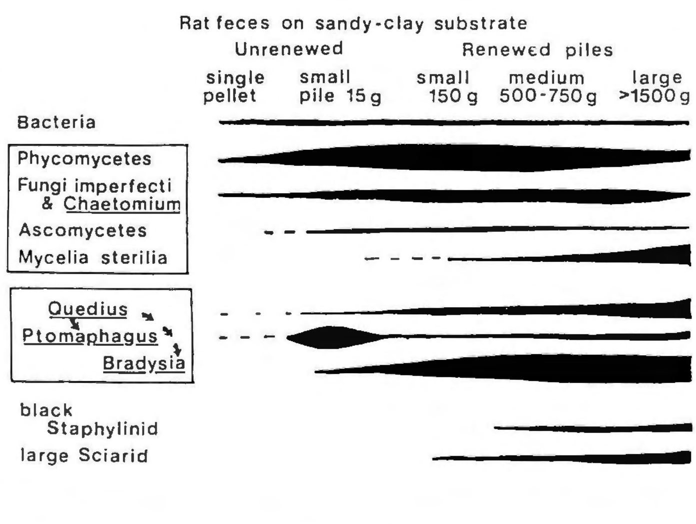


Figure 6. Importance values (see text) of organisms on rat feces.

Feces on a wet rock substrate have more differences since succession is greatly affected by development of a smelly anerobic bacterial slurry, at the fecal-rock interface, fed upon by an abundant and slow-moving "lumpy" mite. Having narrowed the long list of species to those that interact on sandy-clay, it still remains to determine which of the species has (have) greater effect(s).

It is obvious that a species with high impact is one that is not only numerous and large but also occurs frequently in space and time; such species are called aspect dominants and have a high overall Importance Value (IV) which is the sum of their density, biomass and frequency. Figure 6 is a plot of IVs and suggests that *Bradysia* might be expected to have a big effect on communities in large piles whereas *Ptomaphagus* is more important on small piles. It is not so obvious that species with large size but low overall IV can have a large impact; they are called functional dominants. Two sets of field observations suggested that *Quedius* is functionally dominant by modulating the relative IV of its two major prey, *Ptomaphagus* and *Bradysia*. Figure 6 shows that *Ptomaphagus* shows a high IV only on small piles where *Quedius* is not very abundant. Also, *Ptomaphagus* has a low IV for the rat feces community as a whole and its IV is highest overall on the low energy cricket guano community (Poulson and Kane, 1981). This is surprising since we know it to be an opportunist which is readily baited to high energy "bonanza" food items like a rotting mouse carcass in the cave and reproduces most on high energy foods like fresh rat feces in the laboratory (Poulson, 1976; Lavoie, 1981b). These natural and manipulative experiments led us to the hypothesis that *Ptomaphagus* is more vulnerable than *Bradysia* to predation by *Quedius*. We then observed that *Ptomaphagus* larvae use the outer parts of the fecal piles and pellets whereas *Bradysia* larvae are more inside the piles and pellets. This, and the fact that *Ptomaphagus* adults stay on the piles and cannot fly whereas *Bradysia* often fly off the piles and perch nearby, is consistent with our hypothesis. So is the observation that *Ptomaphagus* do well on fresh piles that we place away from natural piles until the piles are found by wandering *Quedius* (Lavoie, 1981a). It remains for us to do exclosure studies in the field and feeding preference experiments in the lab to quantify the dynamics of this trio's interactions to the point that current theory of competition and predation can be tested.

REFERENCES

Culver, D.C., 1982, Cave life: evolution and ecology: Cambridge and London, Harvard Univ. Press, 189 p.

Lavoie, K.H., 1981a, Abiotic effects on the successional decomposition of dung: International Congress of Speleology, 8th Proceedings, v. 1, p. 262-264.

——————, 1981b, Invertebrate interactions with microbes during the successional decomposition of dung: International Congress of Speleology, 8th Proceedings, v. 1, p. 265-266.

Poulson, T.L., 1976, Terrestrial ecology: the relation between species biology and community complexity: Cave Research Foundation 1976 Annual Report, p. 31-33.

——————, and Kane, T.C., 1981, How food type determines community structure in caves: International Congress of Speleology, 8th Proceedings, v. 1, p. 56-59.

Archaeology Program

CRF Archeological Project and Shellmound Archeological Project —1982

Patty Jo Watson, PhD
Professor of Anthropology and Department Chair
Dept. Anthropology Washington University in St. Louis, St. Louis, MO 63130

Fieldwork during 1982 included a wide variety of activities and locales. These are summarized under 3 headings: field research in and around Mammoth Cave National Park, consultant work at caves outside the Central Kentucky Karst, and the Shellmound Archeological Project.

I. Field Research in and Around Mammoth Cave National Park

Besides the Western Kentucky University course in Cave Archeology taught June 20-26 by Pat Watson with generous CRF support (especially from JVs Tammy Bennington, Jack Freeman, Ron Wilson and Alison Wylie), work in the Park consisted of 3 bouts of surface survey in advance of proposed surface modification along the Northtown Road (no sites found) and at a series of points where NPS research geologist James Quinlan needs to drill observation shafts from the surface to the cave system. The presence of archeological material (apparently a prehistoric camp or settlement) near Union City located by Ken Carstens several years ago will have to be assessed in greater detail when the drill point at this general location is precisely pinpointed. Examination of drill points near the west edge of Cedar Sink yielded no sites, although there are a few in the general vicinity as described in Carstens' dissertation.

Research outside the Park was carried out over several summer and fall weekends at 3 sites: Fisher Ridge Cave, Crystal Onyx Cave and Pit of the Skulls. Larry Bean and Leslie Putnam led a CRF archeological party (Tammy Bennington, Ellen Levy, Bill McCuddy, Pat Watson and Alison Wylie) to those parts of Fisher Ridge Cave that had been explored prehistorically. At least 2 aborigines had roamed parts of Fisher and Raccoon Avenues leaving a scattering of cane torch charcoal and a chunk of a small oak tree, materials we sampled for radiocarbon dating by the Smithsonian Laboratory. They also left several imprints of their slippered feet in one mud-floored piece of passage.

The Crystal Onyx Cave and Pit of the Skulls sites are both places where the prehistoric people disposed of their dead by throwing the bodies into vertical shafts. To judge from a single radiocarbon date (of 680 B.C. $\pm$95 obtained several years ago when Crystal Onyx was under the management of Cleon Turner) and the general characteristics of the human skeletal remains found so far, these pits were used by a prehistoric group contemporary with the first human explorers of Mammoth Cave

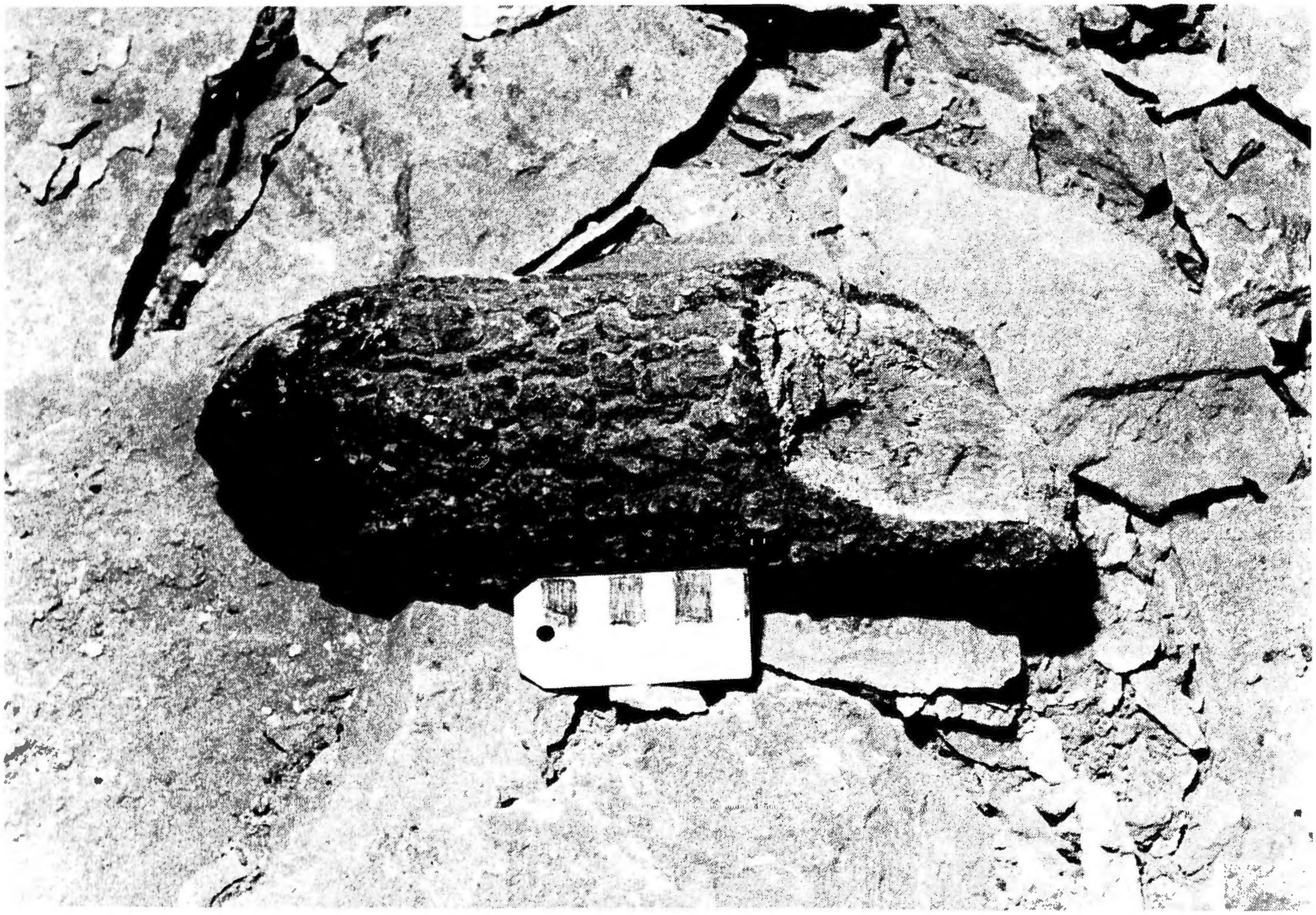


Figure 7. Fragment of small oak tree apparently brought into Fisher Ridge Cave by prehistoric explorers. (A portion of this large fragment has been submitted for radiocarbon dating). Photo by W. McCuddy.

and Salts Cave. Ron Wilson has identified the nonhuman fauna from Pit of the Skulls (see the Annual Report for 1981); Jeff McKee (Anthropology, Washington U.) is working on the human remains; and Robin Burgess (Anthropology, U. of Chicago) has examined the sediments and the depositional situation in that pit. Maps of both pits have been prepared: Crystal Onyx by Diana Daunt-Miller, Diane Blankenship, Diane Emerson, Ellen Levy, Roger Miller, Frank Reid and Ron Wilson; Pit of the Skulls by Don Coons, Sheri Engler, Roger Kline, Michael Hennion and Chris Gerace. Michael Hennion first told us about the human remains in this pit and has aided us in our subsequent work there as have a number of CRF JVs besides those already mentioned: Tammy Bennington, Mary Kennedy, Ellen Levy, Alison Wylie and Richard Zopf.

II. Consultant Work by R. Wilson and P. Watson at Caves Outside the Central Kentucky Karst, July 22-27, 1982

Our first stop was Knoxville, Tennessee, where—together with Louise Robbins—we met Univ. of Tennessee archeologist Charles Faulkner, photographer Bill Deane, and the crew of cavers and archeological students they have had working at Mud Glyph Cave in eastern Tennessee. This is an extraordinary site discovered by caver, Walter Merrill, where people of the Late Woodland/Mississippian period (a few hundred to a thousand years ago) decorated the mud-covered cave walls of a 100 m long passage with curvilinear, geometric and representational designs drawn with sticks and their fingers. With the aid of a grant from the NGS, Faulkner and Deane have documented the artwork in great detail by means of photos which will be studied and interpreted by Jon Muller (Southern Illinois Univ.-Carbondale), a specialist in art of the Mississippian period.

Next we were guided to a series of caves in the Tennessee-Alabama-Georgia area by NSS cavers, Joel and Carole Sneed and Larry Blair. We visited 4 caves, all of which contained archeological or paleontological remains discovered by this dedicated group of cavers. These are Lookout Mountain Cave and Big Bone Cave in Tennessee, Sequoyah Cave in Alabama, and Kingston Saltpeter Cave in Georgia. Lookout Mountain Cave has had heavy use in the 19th and 20th centuries, but also has a prehistoric human component (probably Late Woodland) represented by a few projectile points and small sherds, and several fragments of burned human bones and teeth. There are also some interesting paleontological remains here including scutes of the giant armadillo as well as skeletal fragments of long-nosed peccary and other non-human vertebrates, extinct and modern.

At Big Bone Cave remains of giant sloth were found during the 19th century (Mercer, 1897), and there was also intensive 19th century saltpeter mining here, but there is an impressive amount of material left by aboriginal humans as well. Items found by the Sneeds and Blair while mapping the cave include gourd and squash shell fragments, sunflower achenes, torch ties and fuel and textile remains. They presented their finds to State Archeologist, Samuel Smith, who is cataloging and curating them at the Dept. of Conservation, Nashville. Smith and Watson collected wood and twigs from a crawlway for dating (these are being identified by Fran King at the Illinois State Museum before submission to Dr. Robert Stuckenrath at the Smithsonian Radiocarbon Laboratory).

At Sequoyah Cave Blair and the Sneeds found several prints of bare feet and a scatter of charred pine-splint fragments they thought might be prehistoric. Wilson also identified raccoon claw marks in this cave off the tourist trail. Watson and Wilson thought the human prints and pine splints were from 19th or early 20th century exploration but have submitted a pine fragment to Stuckenrath at the Smithsonian for dating.

Kingston Saltpeter Cave, like the two Indiana caves noted below, has been and is being badly vandalized and disfigured by modern visitors. However, some very interesting paleontological remains have been found there including bone fragments from now extinct animals such as mastodon, giant armadillo, long-nosed peccary and jaguar.

On October 2 Wilson and Watson were taken by Indiana University archeologists, Patrick and Cheryl Munson, to see two southern Indiana caves that were probably explored prehistorically. Both caves (Coon's Cavern and Buckner's Cave) have suffered and are suffering heavy modern traffic but in each place there are scattered fragments of charred hickory bark probably indicating aboriginal human activity. The use of strips of shagbark hickory bark for prehistoric torches is well attested at Wyandotte Cave near Corydon, Indiana, which the Munsons have been investigating.

It now seems obvious that prehistoric cave use and exploration was widespread in the extensive midwest-midsouth karst region that stretches from southern Indiana to Georgia and Alabama.

III. Shellmound Archeological Project

The relationship of this Project—codirected by Bill Marquardt and Pat Watson— to the CRF Archeological Project is described in earlier Annual Reports (especially those for 1977-1981). In brief, we went to the prehistoric shellmound sites on Green River near Logansport (Butler Co., Ky.) to find the antecedents of the horticultural complex so well expressed in the archeological materials present at Salts Cave and Mammoth Cave. We began work at the shellmounds in 1972; a detailed report on the initial stages of research there is approaching completion. The major accomplishment of our 3-week 1982 season was refining the site map and putting in a test pit at the DeWeese site, one of the largest of the Green River shellmounds. The site has never been scientifically excavated but has been badly vandalized. Mr. DeWeese kindly gave us permission to carry one of the open vandals' pits down to sterile soil, so we dug a rectangle measuring approximately .70 x 1.25 m from 1 m below the surface (the bottom of the vandals' pit) to 2.5 m below the surface. Our major objective was to obtain a stratigraphic column of shell for Diana Patch (Univ. of Pennsylvania) to identify and Cheryl Claassen (Univ. of Cincinnati) to analyze for seasonality information. Julie Stein is also examining the

Figure 8. Measuring prehistoric footprints in Fisher Ridge Cave. Photo by W. McCuddy.

sediment from this same pit, having taken a stratigraphic series of samples from the profile. SMAP crew members for the 1982 season were: Cheryl Claassen, Elizabeth Coughlin, Janet Levy, Bill Marquardt, Alan May, Diana Patch, Julie Stein, Pat Watson and Alison Wylie.

Acknowledgements

Our work in MCNP is made possible and greatly facilitated by the support of Superintendent Robert Deskins and his staff, to whom we are deeply grateful. Outside the Park, we are thankful to Mr. Reynold for permission to work at the Pit of the Skulls and to Mr. Kline for aiding our access to the site. Mr. and Mrs. Wesley Odle kindly allowed us to examine the human skeletal material at Crystal Onyx Cave. Joel and Carole Sneed and Larry Blair were not only excellent cave guides to the TAG area but also gracious hosts, as were Patrick, Teddy and Cheryl Munson in southern Indiana. We are grateful to Larry Bean for contacting us about the archeological remains in Fisher Ridge Cave. We are deeply indebted to Fran King for identifying the radiocarbon samples from there and from Big Bone Cave and Sequoyah Cave, and to Dr. Robert Stuckenrath for the radiocarbon determinations on these and other cave sites.

In the shellmound area we are grateful to Mr. George DeWeese for enabling us to work at the mound on his property. As always, our research in the Logansport vicinity was supported in countless ways by Waldemar and Ethie Annis and by John L. Thomas, who have unstintingly aided and abetted us for the past 10 years. Indeed, the unfailing hospitality and cheerful generosity of the people of Logansport reduce the usual annoying and frustrating logistical problems of archeological fieldwork to a series of pleasant challenges.

REFERENCES

Mercer, Henry, 1897, The finding of the remains of the fossil sloth at Big Bone Cave, Tennessee, in 1896: Proceedings of the American Philosophical Society, v. XXXVI, No. 154, p. 5-39.

Physical Science Program

Investigation of the Hydrology of Redwood Canyon Karst

John W. Hess, PhD
Associate Research Professor
SR 89038 Box 53, Las Vegas, NV 89124

Introduction

The objectives of the research are to gain a better understanding of the physical and chemical hydrology of the Redwood Canyon Karst, Kings Canyon National Park. Hydrologic investigations to date have been limited to trying to understand the ebb and flow nature of the Big Spring discharge by recording water levels and water tracing experiments. Specific objectives are:

1) Investigate the isotope hydrology of the karst area,
2) Investigate the chemical hydrology of the karst area,
3) Analyze the Big Spring hydrographs,
4) Apply the results to a better conceptual model of the physical hydrology of the karst including the ebb and flow discharge behavior of Big Spring, and
5) Develop computer based physical models of the karst.

Approach

The research will be conducted in several phases:

Phase I—Preliminary Investigation.

Water samples have been collected at high and low runoff periods (spring and fall) for stable isotope analysis. The stable isotope ratios to be used are $^{18}O/^{16}O$ and D/H. At the time of collection, temperature and specific electrical conductance were measured. Sample sites included snowmelt in the upper reaches of the basin, surface streams, cave waters and Big Spring. Twenty-seven samples were collected at nineteen sites in May 1982. Thirteen samples were collected at thirteen sites sampled in October 1982. Six of the sites were dry in October.

Phase II—Intensive Investigation

Based on the results of Phase I, a suite of sample sites including precipitation will be selected for routine sampling. Samples will be collected as frequently as possible on a regular schedule. In addition to the stable isotope analysis, selected samples will be collected for chemical analysis. Temperature, pH and Spc will be measured at the time of collection. Alkalinity, Ca, Ca + Mg will be measured at the end of each day in the field. Selected samples will be taken to the laboratory for more complete chemical analysis. Laboratory analysis will include Ca, Mg, Na, K, HCO3, Cl, SO4, SiO2.

The isotope data will be used in two ways. First, it can be used as a tracer to track water through the hydrologic system. Second, it can be used to investigate mixing of different waters. These can be combined in a method of thinking of the system as a signal modifier. The input signals to be modified are chemistry and stable isotope ratios versus time of precipitation. The output signal to be compared is the chemistry and isotope ratios at some other point in the hydrologic system. These input/output signals are most efficiently analyzed by use of time series, regression and lag correlation analysis.

Phase III

Water level records of Big Spring will be analyzed. Selected sections of the records will be digitized for time series analysis on a computer.

Phase IV

Information derived from the first three phases will be combined into development of a better conceptual model of the physical hydrology of Redwood Canyon. This model then can be used by the National Park Service to aid their management and interpretation of the Park.

Phase V

If possible, a computer-based model of the Redwood Canyon hydrology will be developed. This phase will be dependent upon sufficient data and understanding being developed from the initial phases. A more detailed approach to this phase will be developed as the project develops.

The results of this work will be a better understanding of the physical and chemical hydrology of Redwood Canyon Karst including the nature of the ebb and flow discharge of Big Spring.

Ice Speleothems in the Eisriesenwelt Cave Near Salzburg, Austria

Carol A. Hill, MS
Box 5444 A, Route 5, Albuquerque, NM 87123

Eisriesenwelt (gigantic ice world) Cave is located about 30 km south of Salzburg, Austria. The cave exists high in the Tennengeburge mountains, and is developed in a low-grade marble limestone. The show part of the care exactly overlaps with the ice-filled part of the cave, about 0.5 km in extent. Ice speleothems noted along the tourist trail were: stalactites, stalagmites, columns, flowstone, draperies and microgours. The most common speleothem type observed were ice waterfalls, the H_2O counterpart to calcite frozen waterfalls.

Frozen-together, composite clumps of ice crystals compose the cave ice, some of which has a bluish or aquamarine tinge. Layering within the ice is evident in areas where trail building or melting has truncated the ice sheets. In one location, ice layers have assumed an arched shape due to preferential melting of one side of a frozen waterfall.

It is interesting to consider the similarities and differences of ice and carbonate speleothem morphology and the reasons for the differences. Initially, each mineralogical type forms similar dripstone and flowstone shapes: stalactites, stalagmites, draperies and the like. Yet, due to the extremely transient nature of ice, these initial shapes change over time into one type: flowstone. Ice stalactites tend to be small and short-lived forms; the stalactites drip into non-existance as warmer air moves ceiling-ward. Stalagmites may start out as normal totem-pole varieties, but by melting, they gradually assume stumpy, broad-based shapes. Finally, the stalagmites melt down completely into sheets of flowstone which cover cave floors, or which cascade over ledges as ice waterfalls.

In the Eisriesenwelt Cave, sheet ice is especially predominant at the very end of the ice-filled section, where the mean annual cave temperature rises above 0°C, the melting point of ice. The remainder of the cave (over 5 km in extent) is free of ice.

Mineralogy of Ladron Cave, Ladron Mountains, New Mexico

Carol A. Hill, MS
Box 5444A, Route 5, Albuquerque, NM 87123

Ladron Cave (also called Riley Cave) is located west of the Ladron Mountains near Socorro, New Mexico. The cave is developed in the San Andres Limestone of Permian age. Ladron Cave is very small—only a few hundred meters in extent—and has been badly vandalized over the years. However, some unusual mineralogy still remains, the most unique feature being limonite boxwork on cave ceilings, walls and floors. The boxwork is located primarily in the cave entrance room, but also occurs locally throughout the whole length of the cave. Boxwork fins (up to 2 cm deep) are composed of orange-brown limonite, weathered on the surface to a clinky, dark brown. The cave dissolved first; then the iron-bearing masses were emplaced; and lastly the iron was partially dissolved away by further solution, leaving the more resistant boxwork fins protruding. The iron masses in the cave probably formed contemporaneously with other, non-commercial manganese-iron deposits of the Ladron Mountain region. Many rocks found on the surface near Ladron Cave are iron-enriched.

Possibly related to the emplacement of the limonite masses are large (up to 12 cm long) crystals of euhedral, transparent selenite which fill small pockets in the limestone, especially on cave floors. The selenite crystals are derived subaqueously from sulfate-enriched solutions, comparable in origin to the selenite crystals of the Cave of the Swords, Mexico (Hill, 1976).

Secondary gypsum flowers formed by seeping water occur on the cave walls and ceilings; most of these have been severely vandalized. Tabular gypsum crusts (tabs 1-2 mm) coat the walls and ceilings everywhere and, in some places, cover limonite boxwork and the euhedral selenite crystals. The gypsum crusts are non-spectacular because they have been badly blackened by air-borne dust stirred up by cavers. The gypsum crusts and flowers are subaerial in origin, and were the last speleothems to form in the cave.

REFERENCE

Hill, C.A., 1976, Cave Minerals: Natl. Speleol. Soc., Huntsville, Alabama, 137 p.

Mineralogy of Torgac Cave

Carol A. Hill, MS
Box 5444A, Route 5, Albuquerque, NM 87123

Torgac Cave, on Bureau of Land Management land, is located approximately 100 km northeast of Capitan, New Mexico. The cave is developed in the San Andres Limestone, a silty, dolomitic limestone with interbedded gypsum and anhydrite. At the cave entrance, a 1 m thick selenite-gypsum bed overlies a 1.4 m thick limestone bed marbled with gypsum pods, overlying a thick unit of gray limestone. It is this sequence of bedded gypsum over limestone that accounts for the unusual sulfate mineralogy of Torgac Cave: soluble sulfates, derived from overlying gypsum bedrock, filter down through joints in the underlying limestone to produce the most outstanding display of gypsum dripstone speleothems in the world.

Figure 9. Gypsum "claw" stalactites in the Main Formation Room, Torgac Cave.

Sulfate Mineralogy

Gypsum

Stalactites: Profuse stands of sulfate dripstone occur in the Main Formation Room of the Northwest Passage, where stalactites extend to 3 m but are, more typically, 1-2 m in length. Some of the gypsum stalactites grow from water dripping through a hollow tube (remnant soda straw) in their centers; more usually, they enlarge from water flowing down over the outsides of the stalactites, the center holes having been plugged by crystal growth.

The gross morphology of gypsum stalactites differs startlingly from carbonate stalactites. Carbonate stalactites typically look like upside down carrots: gypsum stalactites resemble grotesque claws or tree roots hanging from the cave ceiling (Figure 9). Even gypsum soda straws exhibit undulating surfaces in comparison to straight-sided calcite soda straws.

Sometimes stalactites align along ceiling joints, the most notable occurrence being along the northeast wall of the Main Formation Room where a long curtain of stalactite-stalagmite-columns hangs. In other cases, stalactite orientation is random, without obvious alignment along ceiling joints. It is curious to note that all of the highly decorated passages trend N-NW (again, the prime example is the Main Formation Room), whereas those trending in other directions are almost devoid of dripstone formations except where they intersect a N-NW trending passage (e.g., the south end of the Main Formation Room). Another example is where the Northwest Passage jogs west on its northern end: here dripstone speleothems terminate abruptly. Profusely decorated areas probably correspond to where joint-controlled cave passages intersect with the dip of the limestone beds. Unfortunately, it is almost impossible to measure the actual dip of the beds, both on the surface and in the cave, because of the collapsed and jumbled nature of the San Andres Limestone unit in which the cave is developed. One exception: the Football Field, where a ceiling bedding plane strikes NE and dips 15° to the SE. It would appear that sulfate-bearing waters move down dip along NW-SE trending joints and into the cave.

Figure 10. Epsomite flower in the Flower Room pushing a piece of bedrock out from the wall.

Most of the stalactites in Torgac Cave grow without a preferred direction to their clawed lower tips. However, deflected stalactites do occur in certain areas of the Main Formation Room, where some of the "claws" point up-passage (NW), while other stalactites point at approximately right angles to NW (SW). Deflected stalactites are caused by uneven evaporation on sides of speleothems facing into and out of the cave relative to the cave entrance and air flow.

Stalagmites: Gypsum popcorn decorates the narrow, winding calcite stalagmites except they are more knobby, and many have drill holes down their centers from episodes of undersaturated drippage water. Crystal regrowth along the sides and tops of the drip-drill pits closes off the holes of the stalagmites' apices, a process observable in the stalagmites of the Hibernaculum.

Popcorn: Gypsum popcorn decorates the narrow, winding passage connecting the Main Entrance to the Football Field. Gypsum popcorn is a relatively rare speleothem compared to its very common carbonate counterpart. Tiny tabs of gypsum, arranged rosette fashion on the nodule, make up the popcorn coralloids.

Crust: Crustal mounds of crystalline gypsum occur on the ceiling of the Northwest Passage and, more conspicuously, in the Football Field, a passage trending NE, perpendicular to the highly decorated, dripstone-filled, NW trending passages. Gypsum does not flow or drip into the Football Field; rather, sulfate solutions exude from the updip wall (which strikes NE), depositing a seeping water type of crustal speleothem.

Epsomite

Flowers: Epsomite flowers decorate the Flower Room, the longest flower noted being approximately 15 cm in length. The flowers grow from the base, often transporting rock away from the wall with them (Figure 10). When the flowers reach a certain length, they break under their own weight and pile up on the cave floor. At the time of visitation (May 1982), the flowers appeared to be redissolved—not an unusual condition for epsomite, an extremely soluble mineral, highly susceptible to saturation and humidity changes. Taste of the epsomite flowers in the Flower Room is slightly bitter to pungent, relating to varying concentrations of epsomite and gypsum in the flowers' make-up.

Cotton: Tiny crystals of epsomite cotton sprout from the crumbled flower piles on the floor. The cotton tastes pungent and is probably pure epsomite selectively redissolved and regrown from the epsomite-gypsum flower material.

Crust: Thin (a few mm) layers of bitter-tasting epsomite crust exists on the cave wall just preceding the Flower Room. These layers possess the transparent sheen typical of epsomite.

Carbonate Mineralogy

Not a single carbonate speleothem was observed in Torgac Cave, a condition noteworthy in itself. Other caves known to contain gypsum dripstone deposits (Carlsbad Caverns, Crockett's Cave) are primarily decorated with carbonate speleothems, and less abundantly with sulfate speleothems. The reasons for the exclusive sulfate mineralogy of Torgac Cave are not known.

Mineralogy of Bida Cave, Grand Canyon National Park, Arizona

Carol A. Hill, MS
Box 5444A, Route 5, Albuquerque, NM 87123

A mineralogical reconnaissance was made of Bida Cave, Grand Canyon National Park, Arizona. Bida Cave is located in the upper one-fourth of the Mississippian Redwall Limestone, and has been exposed by backward erosion of the Redwall cliff face along a joint. A short passage leads immediately from the cave entrance to a large room. Speleothems noted in the Entrance Room include stalactites, stalagmites, popcorn and frostwork anthodites. Small gypsum flowers and crusts occur along the walls just beyond the Entrance Room.

The most impressive speleothem of Bida's upper passage are the mammillaries, "cloud"-like linings which coat cave wall projections (Hill, 1976). Four separate layers comprise the mammillaries, some of which are absent locally or are variable in thickness:

(1) A very fine, red silt layer which occurs irregularly on upper surfaces of bedrock projections;

(2) An approximately 3 cm thick, macrocrystalline, translucent calcite layer directly overlying the red silt layer which exhibits a blunt-faced, nailhead spar surface with the textural appearance of marbled linoleum;

(3) A powdery-white, opaque, finely crystalline layer which is usually thicker on upper surfaces than on undersides of bedrock projections;

(4) A subaerial crust of flowstone overlying the other three layers.

The mammillaries are confined to the upper level of the cave; as one descends from the Entrance Room to the large

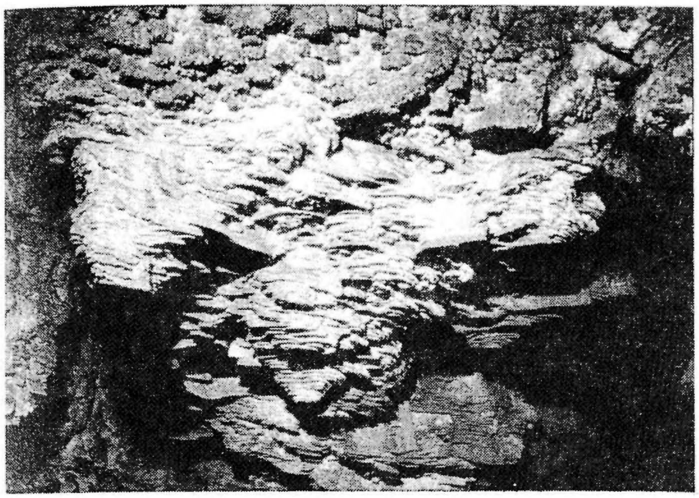


Figure 11. Folia ridges in the lower passage of Bida Cave, Grand Canyon National Park, Arizona. Ruler in lower right for scale.

Breakdown Room at the rear of the cave, well-developed mammillaries are present only at ceiling level. The relative absence of mammillaries at lower levels is most likely due to resolution rather than non-deposition, since—as one goes deeper into the cave—the nailhead spar crystals of layer (2) become progressively more eroded.

The mammillary crystal linings of Bida Cave attest to its past geological history. The red silt layer (1) exists only on upper bedrock projections, evidence that the silt settled out of suspension, perhaps contemporaneously with the dissolution of the cave. The crystalline spar linings (layer 2) were deposited next: subaqueously, under saturated conditions, in slow-moving water wherein large euhedral crystal faces could develop. The spar layer possibly crystallized while the Redwall Limestone still acted as the regional aquifer, before downcutting of the Redwall Limestone as a unit. The opaque, powdery layer (3) may be subaerial or subaqueous, but its powdery texture suggests it formed subaerially, perhaps from solutions oozing out of the cave wall at the time the cave was drained. Layer (4) is definitely subaerial; such speleothems as flowstone and gypsum flowers are often part of this overlying crust. This layer is still forming today, although most of the cave is "dead"; that is, it is dry and dusty with very few speleothems still actively growing.

Along the right wall, just before the Breakdown Room, is a pit by which a maze of passages at a lower level can be entered. In one of the lower changers is an exquisite gypsum flower, the length of which exceeds 0.3 m. Also, in the lower level of Bida exists the well known, classic occurrence of folia, a rare speleothem type consisting of "upside down rimstone dam" ridges (Figure 11). Folia ridges in Bida Cave slope down at angles (20°-60°) to the horizontal and usually (but not always) terminate in horizontal bottom edges. Cave rafts exist in close proximity with the folia, many of which lie stranded on ledges between individual folia ridges. The origin of folia still remains a mystery, but their development is believed to be related to fluctuating water levels which alternately form rafts and folia ridges.

REFERENCE

Hill, C.A., 1976, Cave Minerals: Natl. Speleol. Soc., Huntsville, Alabama, 137 p.

Mineralogy of the Newly Discovered Bifrost Room, Carlsbad Caverns

Carol A. Hill, MS
Box 5444A, Route 5, Albuquerque, NM 87123

In the Fall of 1982 a major new room was discovered in Carlsbad Caverns by Ron Kerbo and Michael Queen when they bolted up a vertical wall in the Bell Cord Room. Named the Bifrost Room, this discovery affords an unusual opportunity to study speleothems in an untrampled, pristine state.

The Bifrost Room contains most of the common speleothem types found elsewhere in Carlsbad Caverns: stalactites, stalagmites, columns, draperies, rimstone dams, moonmilk, flowstone, popcorn and grape coralloids, helictites, spar and calcite coatings. Of mineralogical noteworthiness is a 'forest' of aragonite 'Christmas trees'—a stalagmitic variety of frostwork anthodites. Aragonite trees in the Bifrost Room are exquisitely formed, very fragile and upwards of a meter and a half tall (Figure 12). Anthodites flashed with a strobe show typical green-colored carbonate phosphorescence. Interestingly, new carbonate growth on the tips of aragonite spicules displays the most vivid and long-lasting (about 2 seconds) phosphorescence.

Crinkle blisters, a rare speleothem type composed of high-magnesium carbonate minerals such as huntite and dolomite, also occur in the Bifrost Room, especially along the spar-covered back wall. Crinkle blisters are blistered in shape, but are crinkled along the edges, like cornflakes or Chinese fortune cookies.

Patches of dripstone and flowstone in the Bifrost Room are peculiarly colored a lemon to egg-yolk yellow, rather than being the more usual rust-brown shade of other, similar speleothems in Guadalupe caves. The limestone of the Bifrost Room contains a high proportion of clay (part of the back reef facies?), similar to the limestone of Spider Cave; perhaps clay impurities are responsible for the unusual yellow color. Clay impurities in the limestone are dark brown in color, falsely appearing to be manganese, both on cave walls and in weathered floor deposits.

As is typical of the Bell Cord Room and Lake of the Clouds area, the speleothems and limestone bedrock of the Bifrost Room are corroded on their surfaces (Figure 13). Corrosion features point towards the direction of the Bell Cord Room, and are most pronounced near the ascent into the Bifrost Room and

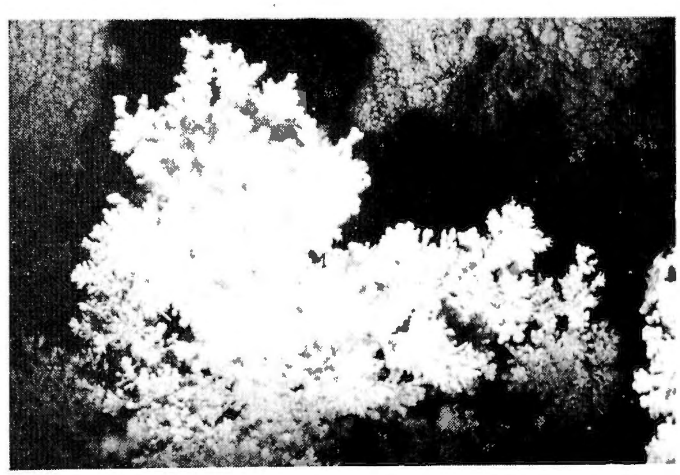


Figure 12. An aragonite "Christmas tree", in the Bifrost Room Carlsbad Caverns.

Figure 13. Caver's finger points to the corroded side of a column. Walls are corroded flush with flowstone in the upper right hand corner.

up into the high alcove along the right wall, while fading in intensity towards the back of the room.

All the minerals in the Bifrost Room were identified as carbonates with the exception of two small primary gypsum blocks located about 2 meters into the room from the ascent ledge. In a few locations secondary gypsum crusts are exposed directly beneath calcite coatings, but no other sulfate mineral occurrences were noted.

REFERENCE

Hill, C.A., 1973, Huntite Flowstone in Carlsbad Caverns, New Mexico: Science, v. 181, p. 158-159.

Deposition of Aerosols in Caves. A Controlled and Possibly Custodial Environment for Aerosol Deposition

Edwardine Nodzenski, MS
and Thomas J. Murphy, PhD
Professor of Chemistry, Department of Chemistry, DePaul Univ., 1036 West Belden Ave., Chicago, IL 60614

The deposition rate of aerosols (particles) from the atmosphere to surfaces is a very complex and not very well understood process. Two of the important factors are the nature of the collecting surface, and the ambient wind speed and turbulance. Because of the generally low air-flow rates, lack of appreciable turbulance, constant temperature and humidity, and an absence of most sources of aerosols, studies on the deposition of aerosols in caves could contribute to understanding their deposition in general.

In addition, there is little information on the sizes, composition and concentrations of particles in the atmosphere in mid-latitude continental areas in past centuries. It is possible that mineral surfaces in areas of caves now distant from entrances, but which were close to entrances in the past, could retain a record of the concentrations and compositions of ancient atmospheric aerosols. This is the report of a project to determine the feasibility of making these kinds of measurements in caves.

To determine if predictable patterns of aerosol deposition occurred in caves, artificial substrates (polycarbonate filters) were placed at varying distances from the entrance in Floyd Collins Crystal Cave and in Salts Cave in Mammoth Cave National Park. After several months, the filters were recovered and the number and sizes of particles on them determined using a scanning electron microscope (SEM). The lower limit of detection for the SEM is about 0.2-0.3 micrometers. As expected, the number of particles and the average size of the particles collected decreased with the distance from the entrance. The results from Crystal Cave are shown in Table 7. Separately collected aerosol air samples showed aerosol concentrations of less than 10 ug/m^3, a level typical of clean continental background air.

Table 7. Size Distribution of Particles (#/CM^2) in Crystal Cave.

Particle Size Range (micrometers)	*CRF Survey Station*		
	C-5	C-33	D-25
< 1	3000	2000	3000
1-5	17000	1700	1800
5-10	6600	710	150
10-25	4600	700	70
>25	600	200	0
Sum	32000	5300	5000
Distance From Entrance (meters)	220	536	490

In addition small pieces of different minerals from Great Onyx and Crystal Caves were collected and examined with the SEM. Unfortunately, the broken, rough surface of the limestone made it difficult to see particles, and it was not possible to determine numbers and size distributions on it. However, the flat, smooth surfaces of gypsum crystals generally permitted particles to be easily seen, measured and counted, and also to have their composition determined.

Thus it seems possible that exposed mineral surfaces in dry, remote caves, such as the east end of Marshall Avenue in Lee Cave (Joppa Ridge), might still retain air particulates from the time the entrance was open in that area, ∿2250 B.C., and these particles may still be able to be identified and recovered. It would be particularly useful if gypsum or other minerals could be found which had been growing since the entrance was open. If the growth rate of the crystals could be determined, a profile of the deposition since the crystal first emerged should be preserved along its length.

Cave Radio Locates New Entrances, Goes Underwater

Frank S. Reid
P.O. Box 5283, Bloomington, IN 47402

A busy year of cave-radio operations in and near MCNP brought several innovations in technique and improvements in equipment. The transmitter now has an underwater housing and antenna. A new receiving antenna improved maximum range by 40%, making easy work of 135-meter-deep locations at Hawkins River, in the deepest part of the system.

Jim Quinlan commissioned me and cave divers, Stephen Maegerlein and Jeff Forbes, to make underwater radio-locations for hydrological instrumentation wells at Mill Hole and Owl Cave. Steve had built an underwater housing for the radio equipment several years ago, but 1982 was its first use. We don't know if others have used an underwater cave radio previously. The summer's activity has generated much interest among cave divers. The underwater antenna's small size limits useful range to about 60 m.

Underwater explorations of Mill Hole and Owl Cave were extended during the radio work. Poor visibility was a problem. The Owl Cave location was successful, but Mill Hole is still pending. The first location there was inside the sink, an unsuitable drilling site. On the next attempt, the transmitter came untied from the safety line and was lost. The divers recovered it intact, three weeks later. Future operations will include a flashing strobe light in the transmitter case. The underwater passage at Mill Hole seems to trend along the long axis of the sink. A long dive may be needed to get the transmitter under flat ground where a drilling rig can be positioned.

Quinlan employees and CRF personnel did the underground work for radio locations in Whigpistle and Proctor Caves. In addition to instrumentation wells in Mill Hole, Owl Cave and Hawkins River, new vertical entrances may be made in Whigpistle and Proctor, using a large-diameter drill bit. These will provide easy and safe access in any weather. We may even be able to go kayaking on Hawkins River!

Pat Watson's people have inspected the proposed drilling sites, finding no archaeological remains which might be disturbed by the project.

Accuracy of radio locations for drilling sites is checked by making two transmitter setups at each site, 15 to 30 m apart. Bearings and distances between transmitter positions and their corresponding surface locations are compared. Horizontal accuracy is typically within 1% of depth, and true depths tend to be 4-5% greater than depths calculated from radio measurement.

The underground equipment can simultaneously transmit and receive. The cavers transmit for a predetermined period, or until signalled from the surface that all measurements are complete. Two-way communication saves much time, but success of the trip does not depend on it.

We were able to transmit weather information directly to cavers, who were at the Whigpistle location in a floodprone cave far from the entrance, via a VHF receiver tuned to Bowling Green's continuous weather broadcast, connected to the surface-to-cave transmitter.

Surface-to-cave voice transmission was unintelligible at the deep locations, but prearranged coded signals penetrated successfully. We learned that people untrained in Morse Code can understand messages sent very slowly, writing the dots and dashes and decoding with a list.

An article entitled "Cave Radio below 10 kHz" will appear in *73 Magazine*, an amateur-radio publication, sometime in 1983.

For more information see the third edition of the CRF Personnel Manual, p. 102.

Mineralogy of Lilburn Cave, Kings Canyon National Park, California

Bruce W. Rogers and Kathleen M. Williams
889 Colorado Ave., Palo Alto, CA 94303

Lilburn Cave contains a noteworthy assemblage of at least eleven speleothem minerals and eleven petromorph minerals, an unusually varied mineralogy that reflects the geologic setting. Lilburn Cave lies at an elevation of 1585 m on the western slope of the Sierra Nevada, in a pre-Cretaceous roof-pendant of calcitic to dolomitic marble in the Sierra Nevada batholith. Sulfide-bearing boudins and partings of schist, hornfels and quartzite exposed in the cave, a metaliferous tactite zone at a nearby granite-marble contact and sulfide mineral aggregates disseminated in the marble apparently account for the diverse mineral assemblage in the cave. Speleothem minerals include aragonite, azurite, birnessite, calcite, goethite, gypsum, hematite, hydromagnesite, malachite, "wad" and witherite. Petromorph minerals include axinite, azurite, bornite, chalcopyrite, diopside, goethite, hornblende, pyrite, sepiolite, sphalerite and tremolite.

REFERENCE

Rogers, B.W., and Williams, K.M., 1982, Mineralogy of Lilburn Cave, Kings Canyon National Park, California: Natl. Speleol. Soc. Bul., v. 44, p. 23-31.

Gravity Survey of Sediment Thickness in the Main Level of the Historic Route, Mammoth Cave

Arthur N. Palmer, PhD
Professor of Hydrology, Geology and Geophysics
Dept. Earth Science, State University College, Oneonta, NY 13820

Introduction

Many clues to the evolutionary history of the upper levels of Mammoth Cave lie hidden beneath several tens of meters of alluvial sediment in such major passages as Audubon Avenue and Houchins' Narrows. Excavation or augering would determine the depth of this sediment fill most directly but with awkward physical and logistical problems. Geophysical methods are far easier and less disruptive, though less precise.

To obtain at least a crude approximation of fill depths in these major passages, as well as to test the feasibility of further work of this nature, gravity traverses were made in Broadway-Audubon Avenue in the vicinity of the Rotunda by A.N. and M.V. Palmer in April 1982. The sediment has a lower density than the surrounding limestone, so the gravity readings in the cave are smaller than if no sediment were present. Ideally, gravity readings in this passage could be compared with readings

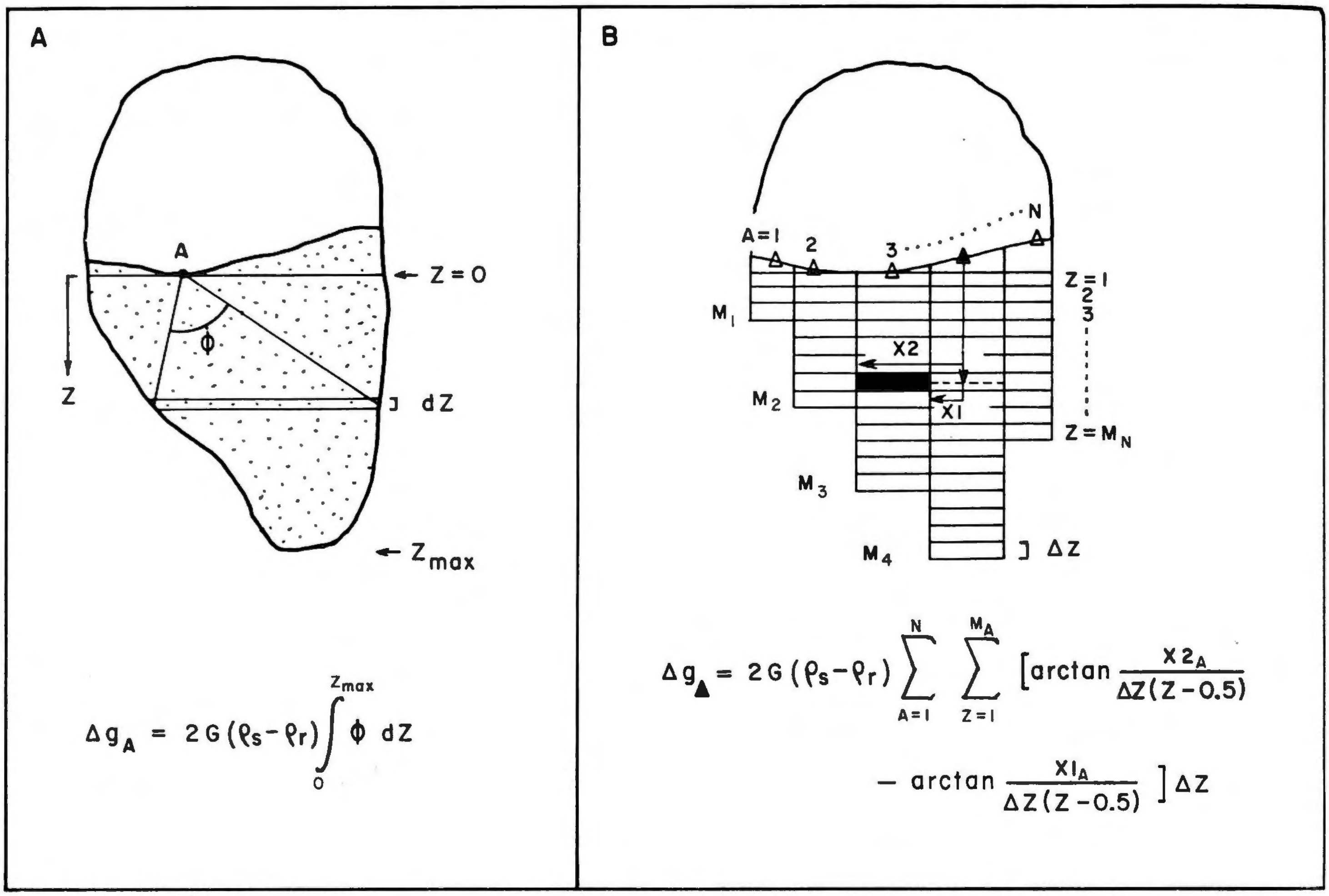


Figure 14. Gravitational effect of sediment fill in a uniform segment of cave passage. (a) Analytical solution) (b) Finite-difference solution for computer analysis. Δg = gravitational anomaly at the specified station caused by the entire sediment profile (gals): G = gravitational constant (6.67×10^{-8} dyne-cm^2/g^2); Ps-Pr = sediment and bedrock densities (g/cm^3); all length measurements in centimeters, Φ in radians.

elsewhere where the geologic setting is known precisely, using the difference in gravitational field strength to calculate the depth of fill. However, the correction factors required by this technique involve so many uncertainties that it would be hopelessly unreliable.

Field Technique

Fortunately, it is possible in such large passages to make two or more readings within any given passage cross section that are far enough apart that a kind of stereo view can be obtained, allowing us to resolve the depth of fill without requiring an outside base station. The best resolution would be obtained by making one gravity reading at floor level and another near the ceiling. But the gravity meter requires extraordinary stability and leveling, and the thought of reading the instrument atop a 6-meter stepladder lacked appeal. Instead, traverses of five stations each were made at floor level across the width of the passage at three locations: in Broadway 50 m. southeast of the Rotunda, and in Audubon Avenue 50 and 25 m. northwest of Little Bat Avenue.

A Worden gravimeter was used, which gives repeatable measurements to within 0.02 milligals (i.e., roughly 1/50 millionth of the earth's field). Measurements were made at the five stations in each traverse, alternating with repeated measurements at the first station to determine drift in the instrument. Relative elevations of stations were made with an engineer's level to within one millimeter. Cross sections of the air-filled part of the passage were made by direct measurement of ceiling heights at various points across the passage width.

Theory, Calculations and Corrections

It is not possible to obtain a unique solution to the configuration of sediment fill within a passage with a gravity traverse alone. Uncertainties in the values of density for the limestone and sediment fill add to the difficulties. However, it is quite feasible to construct a profile showing variations in fill thickness across the width of the passage. With some simplifications, approximate fill depths can be calculated, but they should be considered only first approximations.

Because this kind of survey seems not to have been done before, it is appropriate that the procedure be described in some detail. Standard corrections were made for differences in elevation and latitude (although the latter was almost insignificant). Corrections for the gravitational effect of the air-filled parts of the passage and for the sediment fill above the lowest station in each traverse were made using a variety of probable densities (2.5-2.7 g/cm^3 for the bedrock, 1.5-1.8 g/cm^3 for the sediment and zero for air). Over the 16-25 meter passage

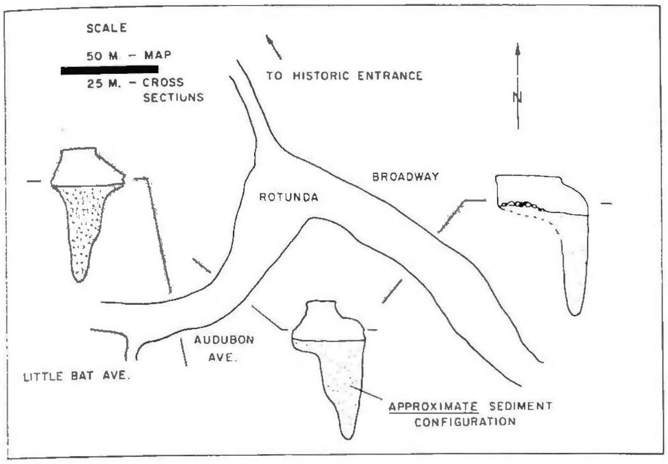


Figure 15. Sediment configuration in Broadway and Audubon Avenue interpreted from gravity profiles. Sediment depths are only crude estimates, but the position of the narrow, filled canyon is probably correct.

widths the gravity variations caused by nearby passages and overlying topography were assumed to be smooth and of minor importance.

The calculations were simplified enormously by choosing locations in passage segments that could be considered two-dimensional—in other words, uniform enough in direction and cross section that any variations perpendicular to the traverses could be ignored. With this assumption, at any station the gravitational effect of the entire body of sediment fill is shown in Figure 14a.

To make the calculations more digestible to computer processing, the sediment cross section was simplified to columns of small rectangular blocks, arranged vertically below each station, as shown in Figure 14b. The incremental thicknesses (Δ Z) were assigned values of 10 cm. (Corrections for the shape of the air-filled part of the passage were made in a similar way.) Successive approximations were made until the sediment configuration was found that gave the best fit to the gravity data.

Results

The sediment depths producing the best fit are shown in Figure 15. It appears that there is a deep canyon buried by the fill, having a width 20%to 50% that of the widest part of the air-filled sections and meandering from one side of the passage to the other. Its depth is probably between 10 and 30 meters. Several geomorphic interpretations and questions immediately arise, but these should be addressed only after the measurements are refined.

A word of caution: we experienced a greater amount of drift in the instrument than usual, so the magnitude of the drift correction exceeded that of the gravity anomaly produced by the sediment. (This is probably due mainly to our changing the calibration of the meter shortly before making the survey. Because the temperature and humidity in the cave were almost identical to those of the outside air at that time, the meter probably was not affected greatly in adjusting to the cave atmosphere.) Further measurements need to be made before the results in Figure 15 can be considered reliable. One of the first steps should be to run similar gravity surveys across large passages having no sediment fill, so that calculations similar to those used here can provide a closer estimate of the bedrock density.

The Geochemistry and Hydrogeology of the Rio Camuy, Puerto Rico

Joseph W. Troester
Instructor in Geology
Dept. of Geology, Univ. of Puerto Rico, Mayaguez, Puerto Rico 00708

This fall I began my geochemical research in the northern karst belt of Puerto Rico with some reconnaissance work in my field area. A number of caves were investigated, and a total distance of 11.9 km has been mapped in ten caves, including an additional 2.7 km in the Rio Camuy Cave System. Rio Encantado was explored and mapped to a length of 6.6 km plus some sketched passages.

Following the arrival of my laboratory equipment, I began phase two of my study of the geochemistry of the Rio Camuy. The results of phase one were published in Troester and White (1981). It is too early to draw any conclusions yet from phase two data. Work will continue throughout 1983 and I will summarize my results in next year's CRF annual report.

This work has been funded by a Cave Research Foundation Fellowship, the Geological Society of America, the National Speleological Society and the Pennsylvania State University, and would have been impossible without the aid of fellow cavers from the Sociedad Espeleológica de Puerto Rico, Inc., the McMaster University Caving Club, the Sheffield University Speleological Society and the Norwegian Speleological Society.

Tephrochronology of Sinkhole Deposits in the Redwood Canyon Karst, Sequoia and Kings Canyon National Parks, California

John C. Tinsley, PhD
Research Geologist
1040 Oakland Ave., Menlo Park, CA 94025

Virtually identical trace-element chemistries are the basis for correlating a tephra (volcanic ash) deposited in a sinkhole in Redwood Canyon and a tephra erupted about 720 14C years ago from the Deadman Creek Domes area near the south end of the Inyo Craters volcanic field, California. These trace-element "fingerprints" confirm the correlation that Tinsley (1981) proposed based on similar mineralogies and on the geographic distribution of late Holocene tephra plumes emanating from the Mono Basin and Long Valley caldera areas described by Wood (1975, 1977). The correlation establishes a 700-year isochron within the Redwood Canyon karst; the horizon will constitute a datum for comparison of sediment yields and rates of soil profile development in the Lilburn Cave area.

The chemical analyses reported here were performed at the U.S. Geological Survey's Western Regional Tephrochronology Laboratory by Janet Slate under the direction of Dr. A.M. Sarna-Wojcicki. The analytical procedure is relatively simple but exacting. From a bulk sample of the tephra, a pure separate containing solely volcanic glass is obtained using standard techniques for gravitational and magnetic separation of minerals. The trace-element content of the glass fraction is analyzed using energy-dispersive X-ray fluorescence techniques.

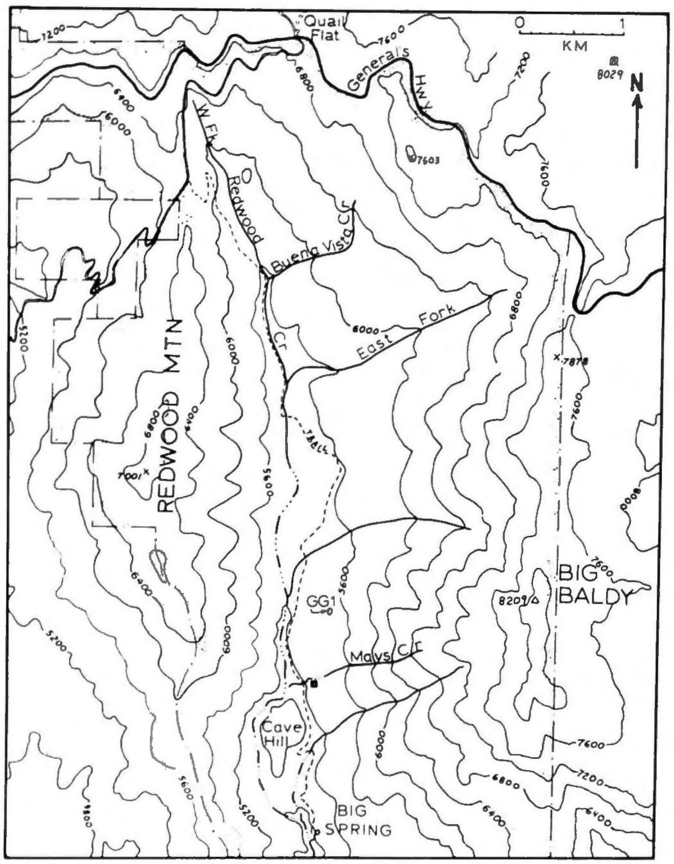


Figure 16. Geography of the Redwood Canyon area, Kings Canyon National Park, California. Topography generalized from the USGS Giant Forest 15 minute topographic map, scale 1:62500.

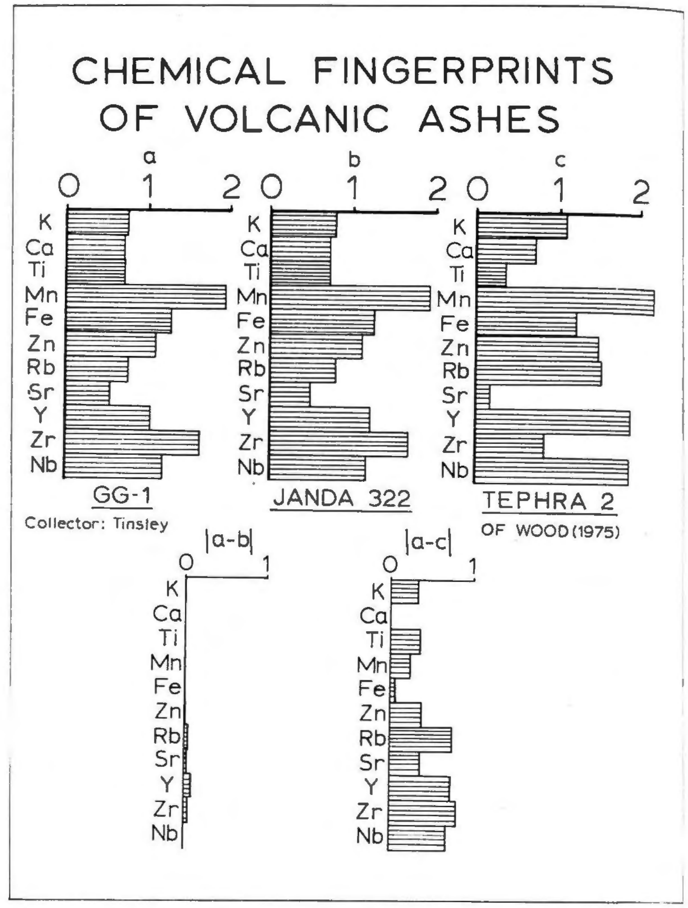


Figure 17. Trace-element contents and comparisons among tephra from the eastern Sierra Nevada, California. Tephra (a) and tephra (b) are identical within limits of analytical error and are correlative. Tephra (c) matches neither tephra (a) nor tephra (b); it was erupted about 500 years earlier from another eruptive center in the eastern Sierra Nevada.

The relative abundances of the trace-elements comprising the glass fraction is determined relative to a standard. Abundances are relative and not absolute because certain elements are inherently more fluorescent than others and no corrections for this effect have been applied. Direct comparisons among the trace-element profiles or "fingerprints" quickly lead to identifications, provided the tephra in question is contained in the data-base. The principal advantages of this technique for correlation among tephra deposits are that it is inexpensive, reliable, and requires but small samples compared to direct radiometric age determinations which are costly, seldom are reliable in such young deposits, and require rather large amounts of sample.

Figure 16 depicts the topography and principal geographic relations of the Redwood Canyon area. The Redwood Canyon karst extends south in a belt less than 0.5 km wide from the confluence of the East Fork and the West Fork of Redwood Creek to Big Spring. Lilburn Cave proper extends from 0.5 km north of Mays Creek to the south end of Cave Hill. The Lilburn Field Station is depicted by the black square immediately south of Mays Creek. The National Park boundary is stippled. The tephra locality, designated GG-1, is depicted in a sinkhole shown about 2 km west of Big Baldy.

In the top half of Figure 17 are compared the relative abundances of trace elements for (a) the Redwood Canyon tephra sample (GG-1), (b) a tephra collected from the Deadman Creek Domes area Tephra 1 of Wood (1975, 1977), and (c) a tephra erupted from the Panum Crater area within the Mono Craters volcanic field (tephra 2 of Wood, 1975, 1977). Tephra (b) and tephra (c) were erupted respectively about 720 and 1210 14C years ago (Wood, 1977). These tephra deposits are found in alpine meadow deposits in parts of the Sierra Nevada and are the most likely potential correlatives with tephra (a) because they are the most recent eruptives distributed beyond the volcanic fields to points west of the Sierran crest (Wood, 1977).

In the lower half of Figure 17, the absolute value of the difference in the relative abundance is depicted for each of 11 elements. At a glance, the trace-element profile for tephra (a) is virtually identical to tephra (b) but is substantially different from tephra (c). Similarity coefficients for these date computed according to the method of Borchardt, Aruscavage and Millard (1972) are 0.98 for tephra (a) and tephra (b) and 0.67 for tephra (a) and tephra (c), where a coefficient of 1.0 would indicate a perfect match. In practice, similarity coefficients of 0.97 to 1.0 may reflect analytical uncertainty inherent in the technique.

Through this correlation based on trace element composition, tephrochronology has established a datum, a 700-year isochron or marker horizon, that will be of inestimable value to researchers who are studying latest Holocene erosion and sedimentation, rates of soil genesis and correlations among sediment in the Redwood Canyon karst and elsewhere. As this investigation proceeds, we will systematically search for the GG-1 tephra elsewhere in the Redwood Canyon karst and also seek deposits of other, older tephra which may be preserved in broad, alluviated sinkholes in the Redwood Canyon area.

REFERENCES

Borchardt, G.A., Aruscavage, P.J. and Millard, H.T., 1972, Correlation of the Bishop Ash, a Pleistocene marker bed, using instrumental neutron activation analysis: Jour. Sed. Pet., v. 42, p. 301-306.

Tinsley, J.C., 1981, Seismic stratigraphy of alluvial deposits and tephrochronology of sinkhole deposits in Redwood Canyon, Kings Canyon National Park, California: Cave Research Foundation 1981 Annual Report (in press).

——— and DesMarais, D.J., 1982, Recent discoveries at Lilburn Cave and in the Redwood Canyon karst, Kings Canyon National Park, California: Abstracts of Presented Posters and Papers, First Biennial Conference of Research in California's National Parks, University of California, Davis, CA., September 9-10, 1982

Wood, Spencer H., 1975, Holocene stratigraphy and chronology of mountain meadows, Sierra Nevada, California: Earth Resources Monograph 4, U.S. Forest Service, Region 5. Note: This document may be procured from Western Forest Information System, Berkeley Service Center, P.O. Box 245, Berkeley, CA 94201.

———, 1977, Distribution, correlation and radio-carbon dating of late Holocene tephra, Mono and Inyo craters, eastern California: Geol. Soc. Am. Bul., v. 88, p. 89-95.

Provenance of Coarse Clastic Deposits in Lilburn Cave, Kings Canyon National Park, California

John C. Tinsley, PhD
Research Geologist
1040 Oakland Ave., Menlo Park, CA 94025

Pebble counts obtained from streams in the Redwood Canyon area indicate that the compositional variations among clast populations apparently stem chiefly from differences in the proportions of granitic and metasedimentary lithologies which characterize various drainage basins surrounding the karst. To the degree that different drainage basins have contributed distinctive sediment to the deposits preserved in Lilburn Cave, it is possible to determine if sediment was derived from Redwood Creek (transported from north to south through the cave) or from tributaries that debouche into the sinkholes above the cave (transported vertically downward via sinkholes and shafts). For example, the ratio of granitic-to-metamorphic clasts is 2 : 3 in the modern channel of Redwood Creek. However, in the Hexadendron Room about 80 meters subsurface in the central part of Lilburn Cave, the ratio of granitic-to-metamorphic clasts is 2.3 : 1. Clast populations in the Hexadendron Room were not derived solely from Redwood Creek. Meyer Creek, a tributary which drains a terrane underlain chiefly by granitic rocks and which has deposited an alluvial fan above the Hexadendron Room, seems to be a most likely source for the granitic clasts that dominate the clast population.

Additional clast counts will be required to test and to refine these preliminary trends and to further distinguish provenance relations among clastic deposits in Lilburn Cave and the principal sources of the sediment. It will also be interesting to compare the composition of the less-than-2 mm (sand) fraction with the composition of the coarser sediment fraction. We may find that boulders or cobbles chiefly fall into the cave via sinkholes and shafts, whereas sands and silts tend to be transported throughout the system. In any event, the sedimentology of the clastic deposits should provide an elegant means to identify the probable source(s) of sediment in Lilburn Cave, and to determine how Lilburn Cave has evolved as a conduit for sediment.

History Program

The Transporation of Kentucky Cave Saltpetre

Duane DePaepe
744 Upland Drive, Richfield, Utah 84701

Before and during the War of 1812 Kentucky was the nation's main source of cave saltpetre for munitions. The mining operation can be referenced into two distinct production levels: cottage production to serve family and local community needs and, large scale industrial production to meet military requirements. The crude nitrate was shipped in bags or barrels. Ox carts or pack animals transported the product for refining and subsequent manufacturing into gunpowder. Often, many small quantities of saltpetre were collected from caves over a wide area, and then collectively sent to distant powdermills.

Lexington was the most important regional processing and marketing center in the state. An array of regional caves supported six powdermills located there. Probably some of the larger saltpetre mining operations near the Ohio River in southern Indiana also sent their nitrate to Lexington. In many other instances, however, isolated pioneer settlements supported their own powdermill with locally mined saltpetre.

To ship saltpetre to the large industrial powdermills along the Eastern seaboard, the Appalachian Mountains had to be crossed. Two major transmontane routes existed at the time: the Forks of the Ohio and Cumberland Gap. By 1800 the Forks of the Ohio passage had become the National Road; an important saltpetre collection route. Other saltpetre traders benefited from the Wilderness Road through Cumberland Gap because it provided direct access to south-central Kentucky as well as Tennessee's Nashville Basin and Cumberland Plateau (Brown, 1948).

Mammoth Cave saltpetre was shipped to the du Pont powdermills at Philadelphia. There is no evidence that Mammoth Cave saltpetre supplied powdermills within the state, although this was probably true before the War of 1812 production years. Since Dixon Cave and Short Cave were mined under the Mammoth Cave management, it is inferred that this nitrate was also sent to the du Pont works.

Mammoth Cave saltpetre was apparently shipped up the Ohio River, above Louisville, to the National Road at Pittsburg; then overland to Philadelphia. During the late winter months, when ice on the upper Ohio River became a problem, saltpetre was sent downstream to New Orleans, there to be shipped to Philadelphia.

The benefits of water transportation were recognized at an early date. Imlay (1797) recorded that "From New Orleans to the Falls of the Ohio (Louisville), batteaux, carrying about 40 tons, have been rowed by 18 or 20 men in 8 or 10 weeks, which at the extent, will not amount to more than 500 pounds expence, which experience has proved to be about one-third of that from Philadelphia." However, during the War of 1812 production years, an easterly, more overland trip took approximately one month from Mammoth Cave to Philadelphia.

A particularly interesting account of saltpetre transportation can be found in Chisholm's (1892) guidebook to Grand Avenue Cave (now known as Long Cave in Mammoth Cave National Park): "On Green River near by was a powder mill erected on a flat boat, and to this mill the saltpetre was carried, where it was manufactured into gunpowder. This was in turn sent down Green River into the Ohio, and on down the Mississippi to New Orleans, and largely to the home-made gunpowder of the Wright Brothers at Grand Avenue Cave was due the memorable victory of General Jackson over Sir Edward Packenham and the British."

REFERENCES

Brown, R.H., 1948, Historical Geography of the United States: New York, Harcourt, Brace and World, Inc., p. 184-186.

Chisholm, T.O., 1892, Grand Avenue Cave: Nashville, Brandon Publishing Co', p. 5.

Imlay, Gilbert, 1797, Topographical description of the western territory of North America: Printed for Debrett, London, p. 333.

Interpretation and Education Program

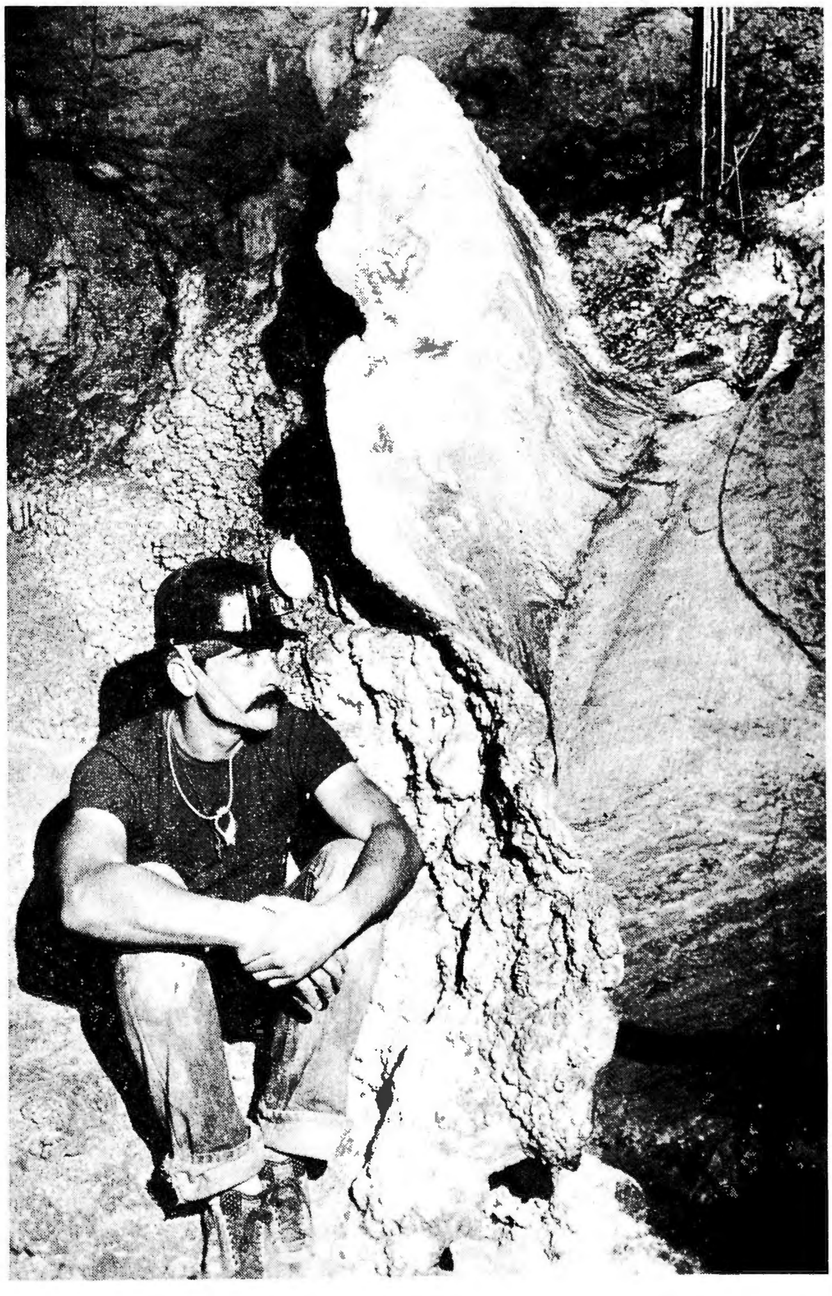


Figure 18. One of the "creeping ears" above the Lake of the Clouds, Carlsbad Caverns. Moisture in rising air apparently condenses on the windward side and evaporates on the downwind side, resulting in simultaneous solution and precipitation on the two opposite sides. Photo by A.N. Palmer. See related abstract by Donald Davis in the following section.

Conservation Committee Report

Sarah G. Bishop, PhD
4916 Butterworth Place, N.W., Washington, D.C. 20016

The role of CRF's Conservation Committee is to identify real and potential conservation issues in CRF project areas. The Foundation maintains liaison with various conservation organizations and assists their efforts by providing factual information as requested. The Foundation has a legitimate concern in the conservation of cave and karst resources. Without the adequate protection of these resources, research opportunities might be reduced if not eliminated.

Committee activities during 1982 included satisfactory conclusions to long term efforts along with assistance to ongoing projects. No new efforts were initiated. The high point of the year was the dedication of Mammoth Cave National Park as a World Heritage site. Members of the Committee worked with several organizations during the year, including the Caveland Sanitation Authority, the Washington Committee on Mammoth Cave, the National Parks and Conservation Association, and the National Speleological Society.

World Heritage Celebration

In April 1980 the Cave Research Foundation recommended that Mammoth Cave National Park be one of the U.S. 1981 nominations to the World Heritage list. Our recommendation was accepted, and the U.S. nominating document, based in large part on the CRF recommendation, was accepted by the World Heritage Convention in October 1981. On April 24, 1982 Mammoth Cave National Park was dedicated as the eighth U.S. property on the World Heritage list. Congressman William Natcher and National Park Service Director, Russell Dickenson, were the featured speakers during the ceremony. Director Dickenson recognized the importance of research at MCNP, and some of the contributions of CRF. He pointed out the major role that Science plays in the Park, noting that . . . "we learn new and amazing facts about [the cave] virtually every time that scientists and other cave explorers complete one of their missions." He also noted that it was ten years ago that Cave Research Foundation explorers stood on the brink of a discovery that made the Mammoth Cave System the longest known cave in the world. At the end of the ceremony, Superintendent Deskins and Director Dickerson presented a Certificate of Appreciation to Sarah G. Bishop, Executive Director of the Cave Research Foundatin for her assistance in causing the Park to be added to the World Heritage list.

Caveland Sanitation Authority

Conservation Committee members, CRF Directors and a representative of the National Parks and Conservation Association met with the Caveland Sanitation Authority, chaired by William Austin, a member of the Foundation, to discuss plans for a sewage system for the Mammoth Cave Region. At present, the Authority has a planning grant to design a sewage system for the Cave City/Horse Cave area. When the design is finished and approved, federal funds will be requested to build the system. One of the major concerns of this planning group is how to include Park City and the Route 70 corridor in the regional system. CRF, which has expressed concern about water pollution problems in the Mammoth Cave Region for a number of years, is pleased that federal funds have been made available to help alleviate these problems. However, an unresolved problem of continuing concern is potential pollution of the cave resources caused by storm runoff. The Foundation will continue to provide assistance as requested by the Park Service or the Caveland Sanitation Authority to help find solutions to the real and potential water pollution problems in the Mammoth Cave Region.

The Washington Committee on Mammoth Cave

In June 1979 members of the Washington Committee filed suit in U.S. District Court claiming that the Department of the Interior had acted arbitrarily and capriciously in allowing the continued pollution of Mammoth Cave from a sewage lagoon at the Great Onyx Job Corps Center. After three years of negotiation between the plaintiffs and the defendant, and numerous depositions from several CRF joint venturers concerning the unsuitability of a karst plateau for the location of a sewage lagoon, the judge ordered the Job Corps Center closed and the site returned to its natural state. The Center was closed in November and site restoration begun at that time.

Another interest of the Washington Committee has been the potential endangered status of *P. ganteri*, the Mammoth Cave blind shrimp. After preliminary hearings concerning the shrimp, the National Park Service awarded a grant to Terry Leitheuser to study the species and try to determine its range of habitation as well as its population size. CRF volunteers and scientists have provided him with field assistance as well as expert advice.

The National Parks Action Project (NPAP)

For the first time in its 25-year history, a Director of the Foundation testified before a congressional committee. Sarah Bishop, CRF's representative to NPAP (a project established by the National Parks and Conservation Association), testified about external threats to Mammoth Cave National Park before Representative Seiberling's Subcommittee on Public Lands and National Parks. She described the external threats to the park as being primarily those of water-borne pollution. The two major sources of this pollution are water that flows into the depressions on the sinkhole plain and carries harmful effluents through the cave passages and the backflooding of the Green River into the lower levels of the cave. This constant backflooding is caused by an unused navigational lock and dam downstream, just outside the Park. As a result of the hearing, Representative Seiberling introduced a bill entitled the National Park System Protection Act which provides authority for reporting on impacts on the resources of the parks and provides for grant assistance to local governments to promote planning that will emphasize park protection for areas adjacent to parks among other provisions. The House of Representatives passed the bill by an overwhelming margin in September.

Toward the end of the summer, CRF and the National Speleological Society helped establish an NPAP education project at MCNP. NSS members of the Green River Grotto were recruited to distribute information at Mammoth Cave about threats to National Parks and to offer visitors the opportunity to sign petitions urging the National Park Service to take effective measures to preserve our natural and cultural heritage. Over 6000 signatures were recorded during a two-month period. Several CRF JVs assisted with the project.

The National Speleological Society

During the past year the NSS has been negotiating a permit system with MCNP to allow wild caving within the park. CRF has assisted the NSS and MCNP personnel in determining the suitability of Running Branch Cave as a cave to be opened to wild caving. To date a casual inventory shows items of historical, geological and biological interest that will need further investigation before a recommendation on unsupervised visits to the cave can be made.

Other Activities

A major threat to the Guadalupe Area has been proposed leasing in the wilderness study areas for oil and gas exploration. The effect that drilling might have on caves is not thoroughly understood, though potential pollution from several sources is clearly a threat. Our concern about drilling was relieved somewhat by the House of Representatives passage of a bill that bans oil and gas leasing in proposed wilderness areas.

Roger Brucker, former President of the Foundation, participated in a planning meeting with National Park Service Regional managers to discuss ways to avoid environmental degradation in National Parks. He also gave a presentation at the Cave Management Symposium on cave conservation and management.

Conservation Committee activities for 1983 will continue to include monitoring CRF project areas for conservation issues of concern to the Foundation as well as working closely with conservation organizations.

CRF Fellowship and Grant Support

Each year, the Foundation may award up to $3000.00 as a fellowship or as one or more grants for research in karst-related fields. The truly exceptional proposal may receive a Karst Research Fellowship (limit $2000); meritorious proposals may receive one or more Karst Research Grants (limit $500 each), awarded to qualified students in graduate programs of the natural or social sciences. Applications are screened and evaluated by a committee of scientists. The judges seek promising or innovative topics, supported by evidence that the student has command of the literature and the methodology. A detailed announcement is mailed in mid-December, and the deadline for the receipt of the detailed proposal, supporting documents, and letters of reference is 15 February. Awards are announced by 15 April. Send proposals in triplicate to:

Dr. John C. Tinsley,
U.S. Geological Survey
345 Middlefield Road, m/s 75
Menlo Park, CA 94025.

In 1982, the competition for the fellowship was especially keen as six fine proposals were received. The following awards were given:

1. A CRF Karst Research Fellowship ($2000) awarded to Daniel W. Fong, Department of Ecology and Evolutionary Biology, Northwestern University, Evanston, IL, for his proposal entitled "Genetic Analysis of Retrogressive Evolution in an Amphipod Crustacean *Gammarus minus*".
2. A CRF Karst Research Grant ($500) awarded to Joseph W. Troester, Department of Earth Sciences, Pennsylvania State University, University Park, PA, for his proposal entitled "Geochemistry and Hydrology of the Northern Karst Belt of Puerto Rico: A Humid Tropical Karst".
3. The Foundation awarded a special grant ($300) to Steven D. Emslie, Los Angeles County Museum, Los Angeles, CA, for salvage archeology in Labor-of-Love Cave, Nevada.

Summaries of the first two investigations appear elsewhere in this Annual Report.

The CRF Fellowship and Grants Program is supported by the CRF Endowment Fund.

Abstracts of Papers in Press

Donald G. Davis
441 S. Kearney St., Denver, CO 80224

Rims, Rills and Rafts: Shaping of Cave Features by Water Condensation From Air

Certain poorly-understood cave features have relationships suggesting that caves can be significantly modified by corrosion and redeposition based on attack on rock by water condensing from air currents. "Cave rims," a rare, composite speleogen/speleothem form, are believed to arise in this way at intersections where airflows of consistently different temperature/humidity interact.

Larger scale condensation in areas of steep temperature gradient above former bodies of warm water is believed to have caused solution rill-fields seen in Carlsbad Cavern and two other caves. This solution may be coupled with deposition of calcite rafts and subaqueous deposits in the water body below.

Rims and rill-fields are extreme and unusual products of condensation, but more subtle, generalized effects may be widespread, and cave histories may be misinterpreted if these are not understood. Re-solution which has been thought to result from refloodings of Carlsbad Cavern and Jewel Cave may instead be caused by condensation corrosion. Condensation features are neither phreatic nor vadose in the conventional sense. I suggest that they be separately classified as *atmospheric* speleofacts.

Eugene H. Studier, Kathleen H. Lavoie and Sandra L. Drake
Dept. Biology. The Univ. of Michigan-Flint, Flint, MI 48503

Microbial Involvement in Bat Scent Production

Noctilionid bats possess inguinal pits which emit an odor characteristic of this species. Histological examination of these specialized pits in both noctilionids show no specialized glandular structures. Under high magnification, objects resembling bacteria appear to be embedded in the stratum corneum. Cultures of swabs from the pits of *Noctilio leporinus* yielded a mixed flora of predominantly gram positive cocci and gram negative rods. Certain pure cultures, which were grown anaerobically on a fat-containing medium produce odors similar to those characteristic of the species. These findings suggest that certain bat species may be symbiotically associated with specific microbes which produce or modify fatty glandular secretions into volatile compounds responsible for characteristic bat odors. Cultures will be available for smelling and comments.

Publications and Management

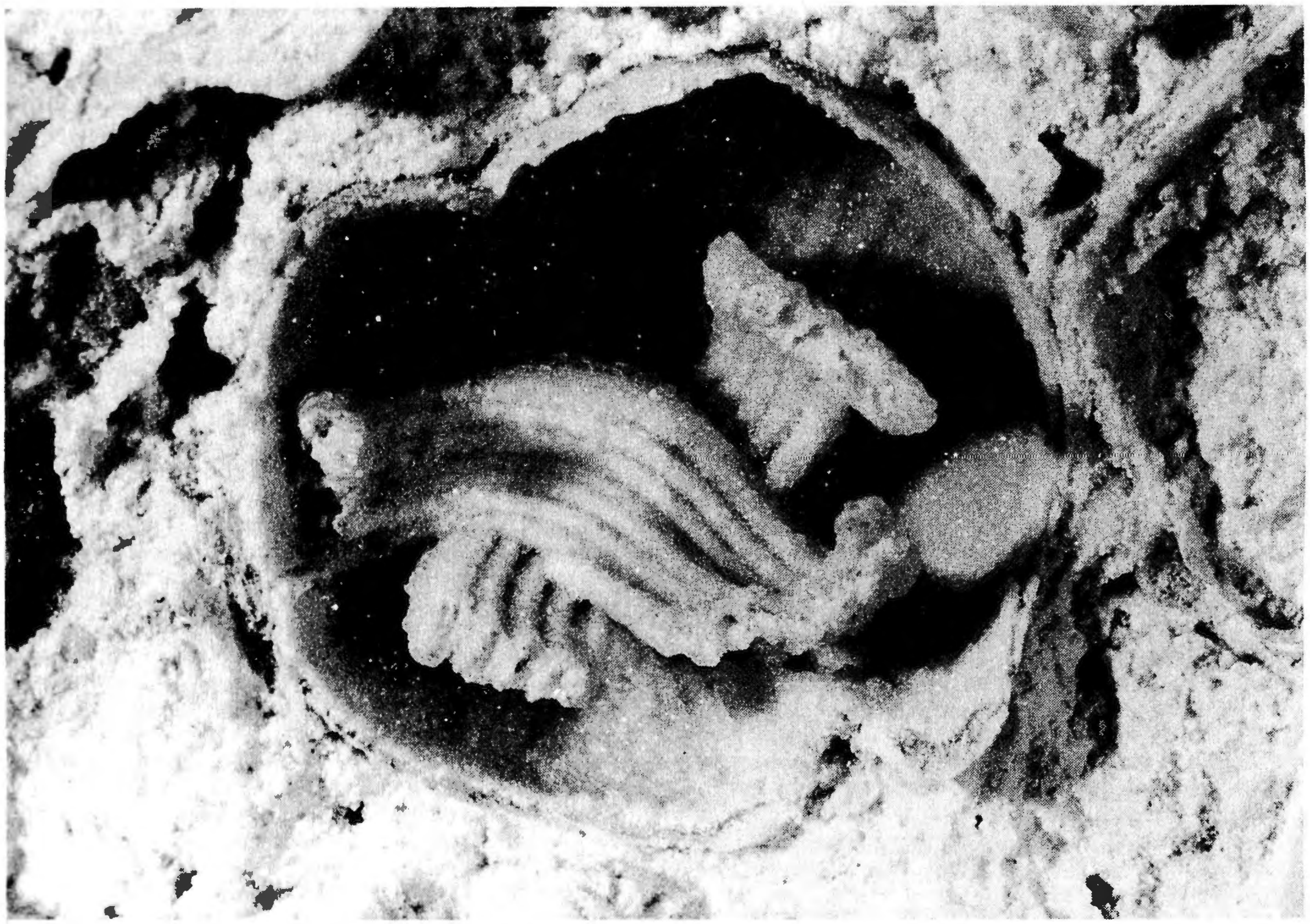


Figure 19. Fossil spirifer brachiopod in a passage near Mabel's Room, Carlsbad Caverns. The delicate spiralia, which provided support for internal organs, are unusually well preserved in this specimem. Photo by A.N. Palmer.

THESES

McCoy, Gail, 1982, Analysis of fractures and speleogenesis at Lilburn Cave, Tulare County, California (unpublished M.A. thesis): San Jose, San Jose State University, 84 p.

ARTICLES

Crawford, Gary, 1982, Late Archaic plant remains from west-central Kentucky: a summary: Midcontinental Jour. Archaeology, v. 7, p. 205-224.

Davis, N.W. and Hess, J.W., 1982, Hydrogeology of the drainage system, Burnsville Cove; Virginia: Natl. Speleo. Soc. Bull., v. 44, p. 78-83.

Harmon, R.S. and Hess, J.W., 1982, Groundwater geochemistry of the Burnsville Cove area, Virginia: Natl. Speleo. Soc. Bull., v. 44, p. 84-89.

Lewis, J.U. and Bowman, T.E., 1981, The subterranean Asellids (*Caecidotea*) of Illinois (Crustacea: Isopoda: Asellidae): Smithsonian Contributions to Zoology, v. 335, p. 1-66.

————, 1982, A diagnosis of the Hobbsi Group, with descriptions of *Caecidotea teresae*, n. sp., and *C. macropropoda* Chase and Blair (Crustacea: Isopoda: Asellidae): Proc. Biological Soc. of Washington, v. 95, no. 2, p. 338-346.

————, 1982, Aquatic ecosystems and management problems in the Mammoth Cave area: *in* Wilson, R.C., and Lewis, J.J. (eds.), National Cave Management Symposia Proc., Carlsbad, New Mexico, 1978; Mammoth Cave National Park, Kentucky, 1980; Oregon City, Oregon, Pygmy Dwarf Press, p. 73-76.

Rogers, B.W. and Williams, K.M., 1982, Mineralogy of Lilburn Cave, Kings Canyon National Park, California: Natl. Speleo. So. Bull., v. 44, p. 23-31.

Wagner, Gail, 1982, Testing flotation recovery rates: American Antiquity, v. 47, p. 127-132.

Watson, R.A., 1982, The philosophy of the cave: to be is to be perceived: Natl. Speleo. Soc. News, v. 40, p. 317.

White, W.B. and Hess, J.W., 1982, Geomorphology of Burnsville Cove and the Geology of the Butler Cave-Sinking Creek System: Natl. Speleo. Soc. Bull., v. 44, p. 67-77.

————, 1982, The caves and karst of Burnsville Cove, Virginia: Natl. Speleo. Soc. Bull., v. 44, p. 47.

Wilson, R.C. and Lewis, J.J., 1982, National Cave Management Symposia Proc., Carlsbad, New Mexico, 1978; Mammoth Cave National Park, Kentucky, 1980: Oregon City, Oregon, Pygmy Dwarf Press, 234 p.

MEETING PRESENTATIONS AND ABSTRACTS

Cohen, Julie and Poulson, T.L., 1982, Competition between fungi and *Ptomaphagus* beetles: Midwest Ecology Meetings, Michigan State Univ., East Lansing, Michigan, February.

Crawford, N.C., Dilamarter, R.R. and Palmer, A.N., 1982, Karst hydrogeology workshop: sponsored by the U.S. Environmental Protection Agency, coordinated by the Center for Cave and Karst Studies, Western Kentucky Univ., Nashville, Tennessee, September.

Hess, J.W., Harmon, R.S., Lawson, T.J., Atkinson, T.C. and Smart, P.L., 1982, U-series dating of speleothems from NW Scotland (abs.): Natl. Speleo. Soc. Convention, Bend, Oregon, June.

Lavoie, K.H., and McCrossnoe, 1982, Distribution of psychrophilic bacteria in a constantly cool environment (caves) vs. forest soil: Joint meeting of the Michigan Branch of the American Soc. for Microbiology with the Ontario Soc. of Microbiologists, Windsor, Ontario, November.

Lewis, J.J., 1982, Groundwater management in the Mammoth Cave region: Seminar presented to the Depart. Biology, Univ. of Louisville, Louisville, Kentucky, October.

Palmer, A.N., 1982, Geomorphic interpretation of karst features: Geomorphology Symposium, Rensselaer Polytechnic Institute, Troy, New York, September.

Studier, E.H, Lavoie, K.H. and Drake, S.L., 1982, Microbial involvement in bat scent production (abs.): 13th annual North American Symposium on Bat Research, Louisville, Kentucky, October.

Tinsley, J.C. and DesMarais, D.J., 1982, Recent discoveries at Lilburn Cave and in the Redwood Canyon karst, Kings Canyon National Park, California: Abstracts of Presented Posters and Papers, First Biennial Conference of Research in California's National Parks, University of California, Davis, California, September, p. 2.

Troester, J.W. and White, W.B., 1981, Chemical balance and groundwater flow in the Rio Camuy drainage basin, Puerto Rico: A humid tropical karst (abs.): Geol. Soc. Amer. Abstracts and Programs, Annual Meeting, v. 13, p. 569.

White, W.B., Scheetz, B.E. and Chess, C.A., 1982, The mineralogy of black manganese deposits from caves (abs.): Natl. Speleo. Soc. Convention, Bend, Oregon, June.

TALKS

Lewis, J.J., 1982, Caves and cave animals of the United States: talk given to Speleology class, Dept. Geology, Univ. Louisville, Louisville, Kentucky, January.

————, 1982, Life in Mammoth Cave: evening interpretive presentation given in the Park ampitheater, Mammoth Cave National Park, Kentucky, August.

Poulson, T.L., 1982, Cave ecology: Chicago Academy of Sciences, Chicago, Illinois, December.

Watson, Patty Jo, 1982, Prehistoric exploration of the world's longest cave: talk given at Stanford Univ. in the New Research in Archaeology Lecture Series, Departments of Classics and Anthropology, January.

————, 1982, Archeology of the Mammoth Cave area: talk given to the Institute of Archaeology, the Archaeology Program, the Friends of Archaeology and the Honors Collegium, Univ. California, Los Angeles, California, April.

————, 1982, Origins of plant cultivation in the eastern woodlands: talk given to the Depart. Anthropology, Stanford Univ., California, May.

————, 1982, Prehistoric exploration of the world's longest cave: talk given at the Illinois State Museum, Springfield, Illinois, November.

SERVICE

Watson, Patty Jo, 1982, Editorial Board (Anthropology): Natl. Speleo. Soc. Bulletin.
Watson, R.A., 1982, Member of the Natl. Speleo. Soc. Bulletin Advisory Board.
White, W.B., 1981, Editorial Board (Earth Sciences): Natl. Speleo. Soc. Bulletin.

WESTERN KENTUCKY UNIVERSITY KARST FIELD STUDIES AT MAMMOTH CAVE NATIONAL PARK—1982

This series of courses is directed by Dr. Nicholas Crawford, Center for Cave and Karst Studies, Depart. of Geography and Geology, Western Kentucky Univ., Bowling Green, KY 42101

Speleology—An introductory course which examines the basic processes in speleology. Roger W. Brucker, May 30-June 5.

Karst Geology—A study of the origin, hydrology and morphology of caves and other karst features. Arthur N. Palmer, June 6-12.

Cave Ecology—An introduction to the dynamics of the cave environment. Thomas C. Barr, Jr., June 6-12.

Karst Geomorphology—A course describing the landforms of karst regions with an introduction to the chemistry of carbonate rock solution. William B. White, June 13-19.

Cave Archaeology—An introduction to the study of archaeological remains in caves and rock shelters and of prehistoric subsistence patterns. Patty Jo Watson, June 20-26.

Karst Hydrology—A review of the hydrology of karst terrains. Timothy C. Atkinson, June 20-26.

Management Structure

DIRECTORS

R. Pete Lindsley, President
Sarah G. Bishop, Executive Director
Roger E. McClure, Treasurer
Rondal R. Bridgemon, Secretary
Kip K. Duchon
Charles F. Hildebolt
John C. Tinsley
W. Calvin Welbourn
Ronald C. Wilson

OFFICERS AND MANAGEMENT PERSONNEL

General:

Chief Scientist	Thomas L. Poulson
Newsletter	Lynn M. Brucker
Personnel Records	Kathleen Womack
Computer Records	William F. Mann
Cave Books	Claire B. Weedman

Kentucky Area:

Manager	Ronald C. Wilson
Personnel	Walter A. Lipton
Cartography	Richard B. Zopf
Medical	Stanley D. Sides
Safety	Kenneth E. Sumner
Supplies	John A. Branstetter
Vertical Supplies	Lynn M. Brucker
Log Keeper	Kathleen Womack
Field Station Maintenance	Robert O. Eggers

Operating Committees

Guadalupe Escarpment Area:

Manager	Rondal R. Bridgemon
Personnel	Ron Lipinski
Cartography	Robert H. Buecher
Safety	Don P. Morris
Finance and Supply Coordinator	Linda Starr
Field Station	J. Buzz Hummel
Log Keeper	Irene Flores
Survey Book Coordinator	Rondal R. Bridgemon

California Area:

Manager	David J. DesMarais
Personnel	Luther B. Perry
Cartography	David J. DesMarais, Peter Bosted, Lee S. Blackburn
Safety	Haward A. Hurtt
Science	John C. Tinsley
Field Station	Thomas Mathey, Stanley R. Ulfeldt

Arkansas Area:

Project Director	W. Calvin Welbourn
Buffalo River Coordinator	Paul Blore
Sylamore Coordinator	Paul Blore
Cartography	Robert H. Buecher, Debbie C. Buecher, Rondal R. Bridgemon

STANDING COMMITTEES

The Foundation has established five permanent committees to help conduct its business. The Science Committee is of primary importance and all committees are chaired by a director.

Science Committee: Coordinates the Foundation's diversified efforts in all areas of cave science. This includes the Fellowship and Grant Program, the Annual Report, and interaction with scientists in all fields.

John C. Tinsley, Chairman
William P. Bishop
David J. DesMarais
Jack W. Hess
Carol A. Hill
Arthur N. Palmer
Thomas L. Poulson
Patty Jo Watson
W. Calvin Welbourn
Steve G. Wells
Ronald C. Wilson

Administration and Objectives Committee: Sets goals, identifies problems and evaluates progress in the operation of the Foundation. Kip K. Duchon, Chairman

Finance Committee: Drafts Foundation budgets, provides advice to Treasurer and seeks sources of funds to support Foundation programs. Roger E. McClure, Chairman

Interpretation and Information Committee: Deals with the dispersal of information in a form that is understandable to the general public. This includes conducting training sessions and the preparation of interpretive materials. Ronald C. Wilson, Chairman

Conservation Committee: Identifies conservation issues of concern to the Foundation and maintains liaison with conservation organizations. Sarah G. Bishop, Chairman

AD HOC COMMITTEES

Computer Committee: Coordinates computer-related goals for the Foundation. R. Pete Lindsley, Chairman

Publications Committee: Supervises and advises on publications; manages CRF's Cave Books publishing and sales operations. Roger E. McClure, Chairman and Cave Books publisher

Contributors to this Report

Sarah G. Bishop
4916 Butterworth Place, N.W.
Washington, D.C. 20016

Peter Y. Bosted
Slac Box 4349 Bin 57
Stanford, CA 94305

Robert H. Buecher
2208 N. Sparkman
Tucson, AZ 85716

Donald G. Davis
441 S. Kearney St.
Denver, CO 80224

Duane DePaepe
744 Upland Drive
Richfield, UT 84701

David J. DesMarais
1015 Woodland Ave.
Menlo Park, CA 94025

James Eckstein
L.S. 330, Dept. Biology
Univ. of Louisville
Louisville, KY 40292

Daniel W. Fong
Dept. Ecology and Evolutionary Biology
Northwestern Univ.
Evanston, IL 60201

M. Susanna Goad
Dept. Renewable Natural Resources
Univ. of Arizona
Tucson, AZ 85721

Marilyn Hale
2804 Alice Ave.
Louisville, KY 40220

John W. Hess
SR 89038 Box 53
Las Vegas, NV 89124

Carol A. Hill
Box 5444A, Route 5
Albuquerque, NM 87123

Kathleen H. Lavoie
Dept. Biology
The Univ. of Michigan-Flint
Flint, MI 48503

Julian J. Lewis
L.S. 330, Dept. Biology
Univ. of Louisville
Louisville, KY 40292

Teresa M. Lewis
L.S. 330, Dept. Biology
Univ. of Louisville
Louisville, KY 40292

William S. McCuddy
4860 E. Fenon Rd.
Yellow Springs, OH 45387

Thomas J. Murphy
Dept. Chemistry
1036 West Belden Ave.
DePaul Univ.
Chicago, IL 60614

Edwardine Nodzenski
Dept. Chemistry
1036 West Belden Ave.
DePaul Univ.
Chicago, IL 60614

Arthur N. Palmer
Dept. Earth Science
State Univ. College
Oneonta, NY 13820

Thomas L. Poulson
Dept. Biological Sciences
Univ. of Illinois at Chicago
P.O.B. 4348
Chicago, IL 60680

Frank S. Reid
P.O. Box 5283
Bloomington, IN 47402

Bruce W. Rogers
889 Colorado Ave.
Palo Alto, CA 94303

John C. Tinsley
1040 Oakland Ave.
Menlo Park, CA 94025

Joseph W. Troester
Dept. Geology
Univ. of Puerto Rico
Mayaguez, Puerto Rico 00708

Patty Jo Watson
Dept. Anthropology
Washington Univ.
St. Louis, MO 63130

Richard A. Watson
Dept. Philosophy
Washington Univ.
St. Louis, MO 63130

Kathleen M. Williams
889 Colorado Ave.
Palo Alto, CA 94303

Richard B. Zopf
830 Xenia Ave.
Yellow Springs, OH 45387