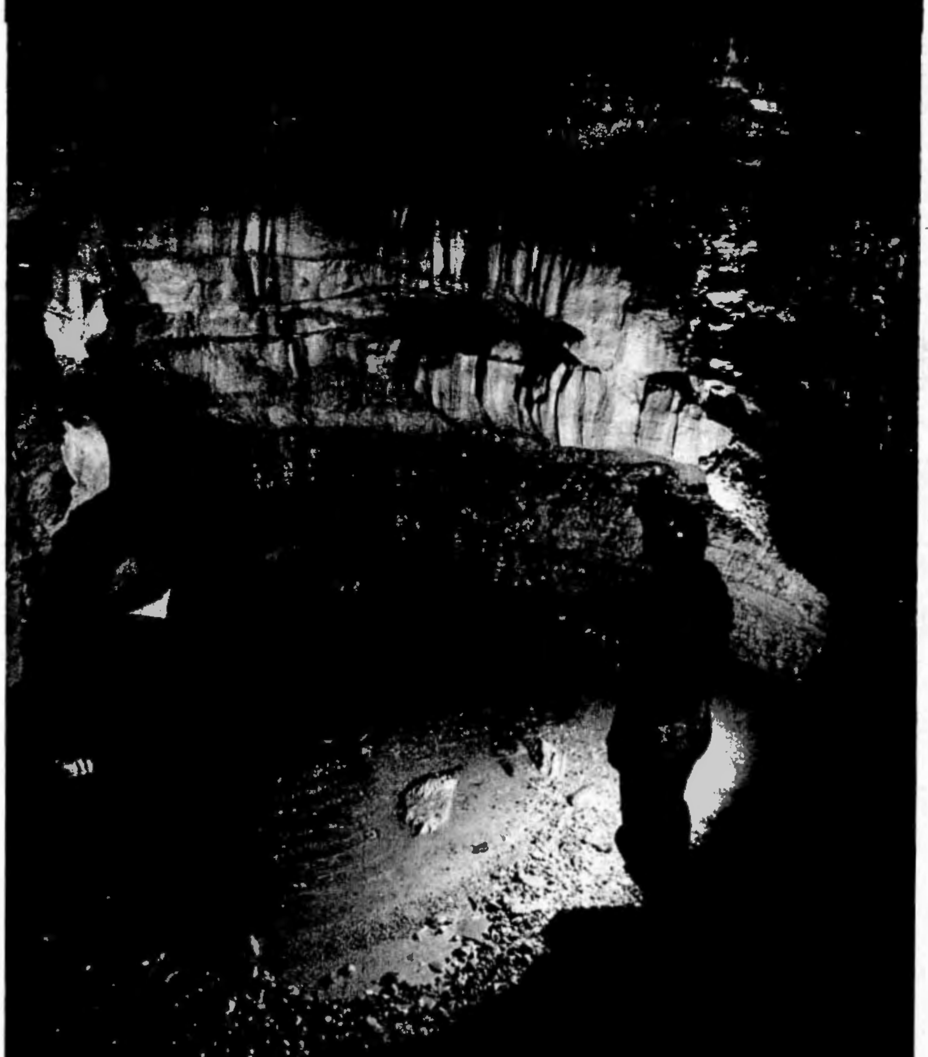
CAVE RESEARCH FOUNDATION 1980

# Annual Report



# Cave Research Foundation

# 1980 Annual Report

Cave Research Foundation
5507 Boca Raton
Dallas, Texas 75230

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.

EDITOR

Margaret V. Palmer

Cover: A small shaft at the head of a canyon tributary to Mud Avenue in Crystal Cave, Mammoth Cave System. The fluted upper beds of the Fredonia Member (Ste. Genevieve Limestone) contrast with the thin-bedded, shaly limestone at floor level. Photo by A.N. Palmer.



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## CAVE RESEARCH FOUNDATION DIRECTORS

January 1980

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# Acknowledgements

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, Wind Cave National Park, Lincoln National Forest, and Buffalo National River have contributed greatly to the success of these projects, and their assistance is greatly appreciated.

Dr. Donald Finkel received the Morton Dauwen Zabel Award from the American Academy and Institute of Arts and Letters in New York City for $2500. The prize acknowledged his contributions as a "poet of progressive, original and experimental tendencies".

Dr. Russell S. Harmon was supported in his isotopic study in the Central Kentucky Karst both by a CRF Fellowship in 1972 and grants from the National Research Council of Canada and the U.S. National Science Foundation.

Kathleen H. Lavoie's bacterial studies were supported in part by the Ralph Stone Research Award from the National Speleological Society.

Kathleen H. Lavoie and Dr. Thomas L. Poulson's research was supported in part by the National Science Foundation.

Julian J. and Teresa Lewis received a grant for travel and field expenses to study *Caecidotea* in Mammoth Cave National Park, from the Graduate School of the University of Louisville.

Barbara J. Martin's study of arthropods was supported by a CRF Grant in 1975.

Dr. Patty Jo Watson's Shellmound Archeological Project was supported in part by the National Science Foundation.

Dr. Richard A. Watson was awarded a Faculty Research Grant of $350 from Washington University, St. Louis, Missouri, for preparation for publication of "The Geomorphology of the Mammoth Cave Area" by Dr. Franz-Dieter Miotke. Watson and Miotke have been working on the translation and revision of this manuscript from German for several years.

The Cave Research Foundation has been awarded a second contract by the National Park Service and the United States Forest Service to survey and inventory 12 additional caves in the Sylamore District of the Ozark-St. Francis National Forests, Arkansas.

The inventory of cave resources at Sequoia-Kings Canyon National Park was supported by a National Park Service contract.

All of the projects in this report have been supported by the numerous CRF Joint Venturers that are the logistic backbone of our operation. Their enthusiasm and fellowship are especially appreciated.

# Highlights of 1980

As the Cave Research Foundation approaches its 25th year of existence it is considered by many to be the premier caving organization in the United States. Not only does the Foundation have a continuing exploration and cartography project in the longest cave in the world, we find that our members and Joint Venturers are supporting an ever increasing list of very industrious scientific projects throughout the speleological community. In fact, over 1000 articles, books, monographs and maps can be attributed to the support of the Foundation.

It is with great pleasure the Foundation welcomes our visitors from afar during the summer of 1981 at the Eight International Congress of Speleology. Quite appropriately, the Department of the Interior announced in late 1980 the nomination of Mammoth Cave National Park as one of its three nominations to the World Heritage List for 1981.

1980 was a year of diversified efforts for the Foundation. Our biologists were hard at work in quest of the Kentucky Cave Shrimp [*Palaemonias ganteri*], long feared extinct. But then in January, 1981, when the Green River base level waters were clear and lower than usual, several individuals were observed indicating that the regional sewage pollution has not yet destroyed this unique species. However it is a grim emphasis of the importance of the Regional 201 Sewage Plan towards the protection of the sensitive aquatic cave communities. There should now be no doubt that the shrimp qualifies as an Endangered Species!

The 1980's will mark the impact of computer processing on the world of speleology. The Foundation's present techniques of survey and cartography have evolved over the years with the assistance of hand calculators and even main frame computers. The 1980's will see the growth of these techniques as the acquisition of more efficient computer hardware becomes a reality. Not only will this technology support survey reduction and drafting skills, but also will impact word processing, file keeping and report coordination to assist in providing continuity to Foundation programs.

1980 has been a year of accomplishment for many projects. Our field program in Arkansas has continued with great success. Reports on both the Buffalo River and Sylamore Forest projects are either in work or published, including some excellent maps of caves under study. The cartography project in the Guadalupe Escarpment area has experienced new, increased interest and improved organization. And in the California area a new field station is under construction at the site of Lilburn Cave. In addition, a detailed survey and assessment of the karst resources at Sequoia and Kings Canyon National Parks has been completed.

Enjoy this year's report of the Foundation's 1980 activities. Contact our Treasurer if you wish to offer tax deductible financial support to our programs. Contact our scientists if you wish to offer direct support of our numerous programs.

# Scientific Program

Figure 1. Exploration of a cave for the Sylamore District Cave Inventory, Arkansas. Photo by Pete Lindsley.

# Cartographic Program

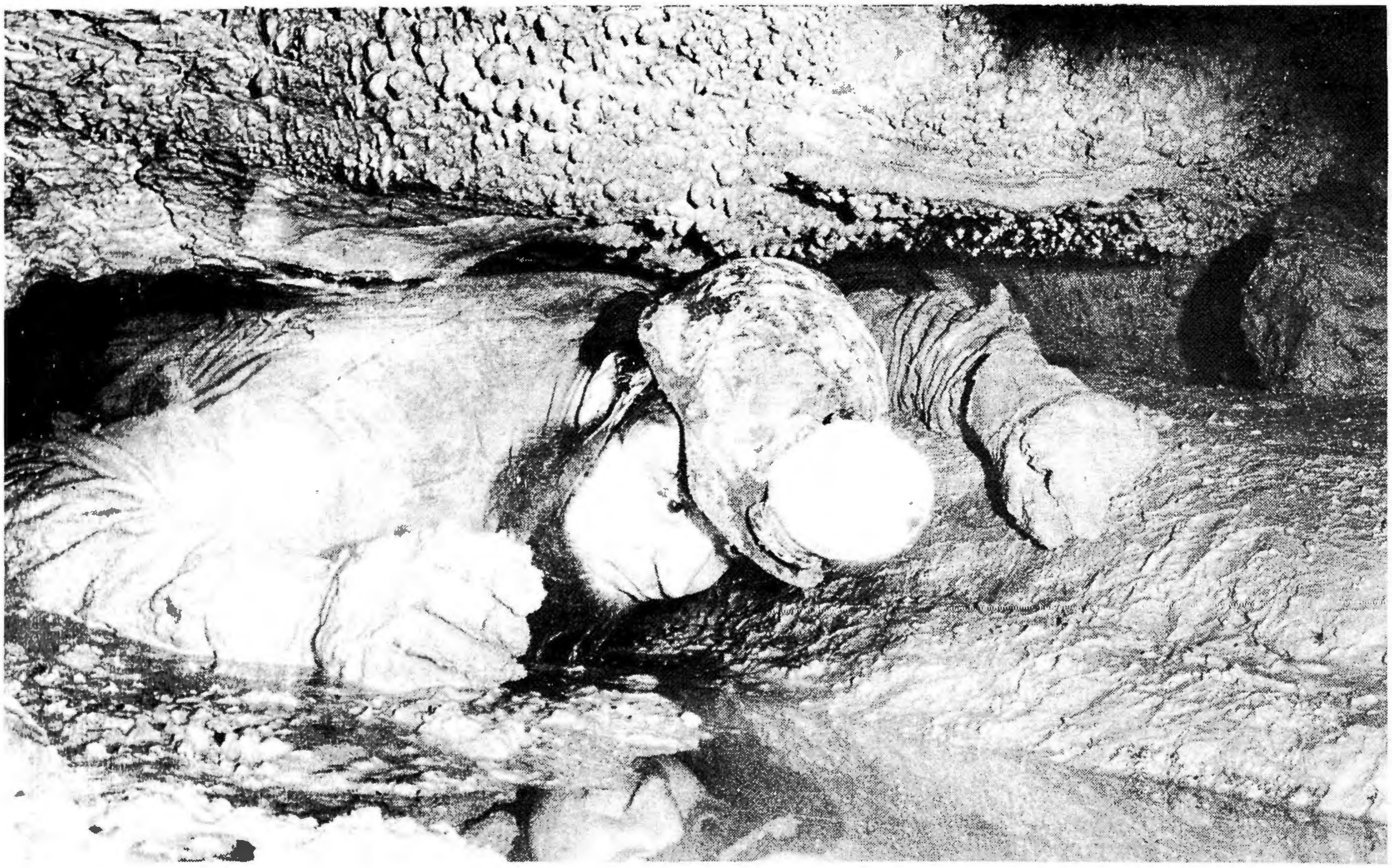

Figure 2. Ernst Kastning pushes a tiny shaft drain at the upstream end of the Lost Passage, Crystal Cave. Photo by A.N. Palmer.

# Exploration and Cartography in the Mammoth Cave National Park Area

**Roger W. Brucker, Tomislav M. Gracanin, Lynn Weller, and Richard B. Zopf**

### *Statistics*

As of 1 November, 1980, the surveyed length of the Mammoth System, which includes the integrated caves of Flint Ridge, Mammoth Cave, Proctor Cave, Morrison Cave, and the newly discovered river system, was 361.24 km (224.47 mi). This distance is calculated using the following techniques and these same methods have been applied to older surveys as accurately as possible.

The total length represents only passage measured with steel or fiberglass tape graduated in tenths of feet or inches and read to that nearest unit. Some distances have been measured through impassible openings, but all measured passage has been penetrated without leaving the cave. Distances start approximately at the dripline of a cave entrance. Distances used in computing survey totals are corrected to the horizontal, even if the passage slopes considerably. Presently we also keep a record of the total taped distance which excludes any corrections. Survey shots which lie between points previously surveyed are not added to the total. Single shots from a previously surveyed point into a side passage are counted. The line of survey through a passage is the most convenient line or the line which best defines the passage. Side shots in large rooms are added to the total. The original survey by CRF of a passage is used in length calculations unless a resurvey indicates specific error. Boundaries between parts of the system are traditional and usually reflect the point where exploration from different entrances met or where there are obvious passage intersections.

Survey recorded this year falls into three major categories (see Table 1). The bulk of the resurvey (83%) served to better define large passages. Approximately one mile of large, tourist trail passage remains to be resurveyed in Mammoth Cave. Resurvey of other inadequately described passage will continue throughout the system for years. 3.33 km of survey were officially recorded this year that was collected in previous years. CRF has, from time to time, surveyed passage when knowledge of location or characteristics was important for conservation purposes but disclosure to the public of the exact extent of the cave was deemed unwise. Experience now seems to indicate such caution is not as necessary as it might have been in the past. The third category of survey contains data from new passage, most of it previously unexplored.

### *Exploration*

Work was widespread in Flint Ridge; clean-up work in familiar areas of Crystal and Salts yielded most of the footage. Revealed surveys in Salts extended its boundaries to the east. Connections between upper and lower levels in both Salts and Colossal were found. The New Discovery section of Mammoth Cave still provides a steady stream of new survey. Work in the historic areas of the cave brought no major passage extensions. Revealed and new work in the East Bransford and East Cocklebur areas are still forming the backbone for ongoing work. In Proctor Cave, Mystic River Pit was redescended and its drains were pushed further, but no new connections to the river system were found. Other survey came from the intermediate levels between the river and the trunk. More of the neglected upper levels of Morrison Cave were surveyed. The obvious and easy main branches of the river system have been surveyed.

### *Cartography*

In 1980 work was begun on a poster map of the entire Mammoth Cave System. Within the confines of a scale of about 12000:1, relative locations, both horizontally and vertically, of major passages will be shown with reference to the surface topography. This map will give an impressive picture of the scope of the cave system as presently surveyed by CRF. The donation of an obsolete business computer and of finds for data processing have spurred thoughts and action towards a computer data processing system for the eastern cartography program. We are exploring the following possibilities: a) raising funds and purchasing our own, tailored system with primary focus on data storage and graphic plotting, b) developing a network of interested and dedicated individuals who will use their personal or business computers to process our data, c) processing data on a computer CRF already owns.

Efforts are continuing to engender more interest and participation in the cartography program. The output of the present workers is not meeting the needs of the exploration program. Recent work will be made more visible and funds will be sought to support willing, but time/money short cartographers. We may concentrate on making more simple and less time-consuming maps.

**TABLE 1**

**Survey Distances Recorded from 1 November 1979 through 31 October 1980**

| *TRADITIONAL DIVISIONS* | *TAPED DISTANCE km/mi* | *HORIZONTAL DISTANCE km/mi* | *RESURVEY km/mi* | *NEW km/mi* | *BEFORE 1980 km/mi* | *NEW 1980 km/mi* |
|---|---|---|---|---|---|---|
| FLINT RIDGE | 3.13/1.95 | 3.05/1.89 | 0.09/0.06 | 2.95/1.84 | 2.02/1.26 | 0.93/0.58 |
| MAMMOTH CAVE | 8.43/5.24 | 8.33/5.18 | 3.41/2.17 | 4.92/3.06 | 1.31/0.82 | 3.61/2.25 |
| PROCTOR CAVE | 0.89/0.55 | 0.88/0.55 | 0.09/0.06 | 0.79/0.49 | 0/0 | 0.79/0.49 |
| RIVER SYSTEM | 7.81/4.86 | 7.76/4.82 | 0.76/0.47 | 7.01/4.36 | 0/0 | 7.01/4.36 |
| MORRISON CAVE | 0.34/0.21 | 0.34/0.21 | 0/0 | 0.34/0.21 | 0/0 | 0.34/0.21 |
| SYSTEM TOTAL | 20.60/12.80 | 20.36/12.65 | 4.35/2.70 | 16.02/9.95 | 3.33/2.07 | 12.68/7.88 |
| SMALL CAVES | 0.04/0.03 | 0.04/0.03 | 0/0 | 0.04/0.03 | 0/0 | 0.04/0.03 |
| SURVEY TOTAL | 20.64/12.83 | 20.41/12.68 | 4.35/2.70 | 16.06/9.98 | 3.33/2.07 | 12.72/7.91 |

# The CRF Magnetic Repeat Station

## Tomislav M. Gracanin

The Cave Research Foundation has established a magnetic repeat station at the Flint Ridge Field Station in Mammoth Cave National Park. It is located west of the Austin House at approximately 37° 12' 38" Latitude, 86° 03' 19" Longitude. The station consists of five permanent posts: north, east, south, west and center. The posts are of five-inch polyethelene pipe set three feet into the ground and filled with concrete. The center of the brass cap set in concrete on each post is the precise location of the survey mark on east post. The four directional posts are about thirty feet from the center post.

The repeat station was constructed by Richard Zopf in May, 1979, using a compass and survey tape to position the posts. Tomislav M. Gracanin surveyed the course April 19th and 20th, 1980. He used a Kern DKM-2 one second theodolite (serial number 124316, OSU 533775) owned by the Institute of Polar Studies of Ohio State University, to turn the angles between the posts and take four Polaris sights to determine true north. The Polaris sights agreed within twenty seconds of arc, were averaged and reduced using a K&E solar ephemeris for 1980 (see Table 2).

**TABLE 2**

**CRF Magnetic Repeat Station**
**True Bearings of Posts from Center**

| | | |
|---|---|---|
| North | 359° 30' 30.3" | (359.51°)* |
| East | 90° 51' 24.3" | ( 90.86°)* |
| South | 179° 19' 04.8" | (179.32°)* |
| West | 270° 40' 42.3" | (270.68°)* |

*Rounded values

The magnetic repeat station lies on the site of the earlier CRF compass course. John Wilcox and Patricia Wilcox established the former course to determine eccentricities of CRF East compasses and observe long-term fluctuations in the local magnetic field. The course consisted of six wooden stakes set sixty degrees apart and thirty feet from a central stake. Aluminum nails indicated the survey mark on each stake. John Wilcox turned the angles between the stakes and sighted Polaris with his twenty-second transit. The compass course became useless after several years. Frost heave moved the stakes, they rotted, and mowers splintered and uprooted them. A rapidly changing magnetic field further complicated interpretation of values obtained there.

The magnetic repeat station is so named because it is a reasonably permanent facility at which compass bearings may be compared with true bearings, and the magnetic declination is known. For general use it is not necessary to know the declination. Readings obtained on the course are sums of the current local declination, and the compass or index correction. The correction factor applied to survey bearings is the sum of these two values. If the declination is known, however, changes in the index correction, perhaps due to rough treatment of a compass, may be detected. Declination may be determined by obtaining an estimate for the repeat station site from the USGS. Such values are generally within half a degree. A preferable method involves measuring the index correction of a very precise surveyor's compass at a magnetic repeat station maintained by the USGS. In the spring of 1981 a transit compass will be run at the Lexington, Kentucky repeat station, then taken to the CRF repeat station to directly determine current declination.

The magnetic repeat station provides data that significantly improves the precision of cave maps. It is important that each time a survey party enters the cave the compass person and one other party member run their compass on the course. A "run" involves two sets of fore-and-back sights, so that each agrees within two tenths degree. These bearings are recorded on the first page of the survey book.

The repeat station is a valuable asset to CRF, and certain precautions must be taken to preserve the site. No magnetic objects may be placed within one hundred feet of the center post. Heavy vehicles, including tractors and bush hogs, must not operate within ten feet of any post. Persons must take care not to strike any post. The posts should be periodically resurveyed to determine if they have shifted.

# Cartography and Exploration—Guadalupe Escarpment Area

## Robert H. Buecher

The pace of work in the Guadalupe Escarpment has slowed in the last year, as only five expeditions were held. In part this low level of activity was due to the fact that we have finished most of the survey of Carlsbad Caverns and are now trying to finish the map. Also there has been a major change in area personnel. Doug Rhodes has replaced Bob Buecher as Area Manager. Bob has now taken over the duties of Cartographer. Ron Lipinski is the new Personnel Officer. These changes have resulted in a dynamic group with more clearly defined goals.

Last year's goal of finishing 75% of the preliminary quadrangle maps of Carlsbad Caverns was reached. Twelve maps at a scale of one inch = 50 ft. allow us to better coordinate the survey work and give support to research projects in the Caverns. At present the quadrangle maps are done in pencil on vellum. This allows for ease of correction and addition of new surveys. During the past year these maps have been extensively field checked. The only large section of the cave that is currently missing from the preliminary map is the Main Corridor. One of our goals for the next year is to complete all of the quadrangle maps in time for the International Congress field camp at Carlsbad.

The preliminary maps are only the first step in producing the final map of the Caverns. First we need to compile all of our surveys into a common coordinate system and correct survey errors. To do this we have started a program to adjust the precise transit and theodolite surveys. The precision of these surveys range from one part in 400 to one part in 50,000. They were done by many methods from transit and hand chaining to 1" theodolite and electronic distance measurement. The majority of the work was performed by Tom Rohrer of California. He has given us a copy of his survey notes to use. The survey network has become so complex with multiple interconnected loops that it is extremely difficult to distribute the errors or to expand the network in a logical fashion. To solve this problem we have started to adjust the survey network by a Least Squares method. To date the Big Room and Lower Cave sections have been completed. When complete the precise survey will form the bases for the brunton compass surveys.

A parallel effort to keep our preliminary maps current and still allow for the future adjustment of the brunton surveys has been started. The survey data is being entered into a micro-computer and stored on a floppy disk. The data for each survey book is entered into the computer using a program which creates an individual data file for each survey book. This file contains the name of the cave, location in the cave, date, party members, passage dimensions and survey data. Each data file is identified by the accession number of the survey book. A separate computer program is used to calculate coordinates for each survey using the data file as input. Preliminary coordinates are generated and plotted on the maps. When the adjusted control survey is ready the brunton compass surveys will be adjusted into that system. Ultimately we hope that the data files created on the small computer will be transferred to a larger computer where a permanent data file on magnetic tape can be created.

The gypsum karst to the southeast of Carlsbad Caverns has received renewed attention in the last year. Aerial photographs in stereo pairs were provided by Jim Hardy. They have allowed us to start an inventory of the hundreds of sinks and caves in the area. A major stumbling block to earlier work was identifying and locating a single cave or sink from the neighboring features. Sinks are now identified and numbered on the photographs before going into the field. In the field the dimensions of the sink, entrance size and cave length are noted. At present caves less than 100 feet long are not being surveyed. Over 200 sinkholes have been investigated to date. As work progresses an overlay map traced from the aerial photos will be made. This will help to show how the caves and sinks relate to the topography.

*Expedition Highlights: 1980*

Thanksgiving: A total of 3834 feet was surveyed on this expedition. A science team conducted observations and collected samples of green clays, resolutioned spar and sediments throughout the cave. A survey of the Rookery was done; this was the last major area in Lower Cave that needed surveying. A survey of the boneyard passage discovered last year was started. A voice connection was made from this passage into the Talcum Passage. In the New Section unsuccessful attempts were made to follow the airflow. One cave was surveyed and numerous sinks in the Gypsum Karst were investigated.

New Year's: A vertical cave in the backcountry, Radiant Light, was surveyed. One of the deepest sections in Carlsbad Caverns, Nicholson's Pit was resurveyed and leads were checked. The new section of boneyard in Lower Cave was tied into Talcum Passage. The inventory of features in the Gypsum Karst was continued and one large cave, "Son of a Gun" was discovered and explored for 500 feet.

February: Son of a Gun was surveyed for 500 feet and explored to a downstream sump. Several side passages and the upstream section remain to be explored and surveyed.

Memorial Day: A surface survey was conducted over parts of Three Fingers Cave in areas suspected of being close to the surface. Another trip went into the Gypsum Passage of Cottonwood Cave to continue the gypsum block study.

Columbus Day: The expedition was a success with several important mineralogical discoveries and approximately 200 feet of virgin passage discovered in the Guadalupe Room. After the tragic death of a visitor to the Caverns, CRF JV's assisted the National Park Service in the body recovery and "forensic climb" to document the accident.

# Cartography at Lilburn Cave

**David J. Des Marais**

When the Foundation became involved in Redwood Canyon in Sequoia and Kings Canyon National Parks in 1977, it inherited more than 10 km of Lilburn Cave survey data from the old Lilburn Cave Project, headed by S. Ulfeldt and E. Hedlund. The cartographic effort continued under the direction of Mr. Hedlund until the beginning of the 1980 field season. In 1980 the Foundation evaluated the Hedlund data and concluded that the survey traverses appeared to be accurate, yet the sketches of cave passage features required substantial revision. Accordingly, a resurvey of the main cave passages was commenced, starting principally at the southeastern (downstream) end of the cave. A survey traverse which included very careful sketches was completed from Thanksgiving Hall to Davis Exit, a length of some 500 meters. Additionally, resurveys totalling approximately 300 meters were completed elsewhere in the cave as required for Gail McCoy's thesis work. The current cartographic objective is to combine these surveys with Hedlund's and with other data from recent scientific efforts to produce an interim manuscript map for the National Park Service in 1981.

# Sequoia-Kings Canyon National Parks Karst Inventory

**Bruce W. Rogers**

The karst resources at Sequoia and Kings Canyon National Parks, California, were investigated from May, 1970 to May, 1980, by the Cave Research Foundation. Bibliographic research was completed in mid February of 1980. All available sources have been perused and suitable material filed for use in the final report. Oral interviews with nine individuals were undertaken also. Several individuals also supplied their personal files of cave information on the Sequoia-Kings Canyon area which aided the project in locating several sites and some history of the various features. A total of 79 caves, 3 shelters, 6 springs, and one pseudokarst feature were researched. No major new caves were discovered. Of these sites, 61 of the caves, 5 of the springs, 2 of the shelters and the pseudokarst feature were unknown or very poorly known by the Park Service. A three-page inventory form was prepared for each karst feature. Geologic, biologic, archeologic, historiographic and hazard elements were treated in the form. Color transparencies of caves and their contents were assembled and large-scale duplication for inclusion in the final report was begun. An attempt will be made to include a photograph of every cave entrance located in the Parks for use in correlating names of caves with actual caves in the future.

Survey or sketch maps for each feature were prepared. The significance of each feature and its hazards were assessed and suggestions for future work as well as recommendations for management of the cave resource were presented.

Among the more significant findings of the inventory were several new spelean minerals: witherite, axinite, sepoilite, tremolite, diopside, and hornblende as either speleothems of petromorphs. Nine species of fossils were found in the caves. A biological survey of the karst features revealed 19 vertebrate species, 18 invertebrates, and 10 plants. Several endemic and/or troglobitic species include phlangids of the *Taracus* genus, an unidentified troglobitic millipede, and a pale scorpion of the genus *Uroctonus*.

Laboratory work continued on several of the samples collected last fall in the Parks. One sample of moonmilk from Clough Cave was intensively studied by X-ray diffraction and Scanning Electron Microscopy. Its identity remains somewhat in question, however, as it appears not to be any common mineral. The closest material found with its particular physical and chemical parameters is a barium, potassium phosphosulfate salt synthesized in the French National Research Laboratory in 1965. Positive identification of this salt will have to await further laboratory work.

The inventory was 328 pages long and weighed close to four pounds when completed.

# Arkansas Cave Resources Inventories

**W. Calvin Welbourn**

The Arkansas Project consists of two separate projects (i.e. contracts) to inventory cave resources for the National Park Service at Buffalo National River and the National Forest Service at the Sylamore District, Ozark-St. Francis National Forests. The Cave Research Foundation has been involved in cave resource inventory in north central Arkansas since 1977 when the National Park Service and CRF jointly funded a cave resource inventory at Buffalo National River. In 1980 our cave resource inventory work entered a new phase with an emphasis on more detailed cave inventory methods and extensive cave survey to provide the National Park Service and National Forest Service with more detailed cave management data. Our goal in inventorying cave resources is to provide the land manager with a much-needed data base to aid them in management and protection of the irreplaceable cave resources found in their lands.

In September 1979 CRF was awarded a National Forest Service contract to inventory and survey 23 selected caves on the Sylamore District of the Ozark-St. Francis National Forests (Figure 3). Each cave was to be surveyed and classified for content and hazards using the rating system originally developed and adopted by the National Forest Service, National Park Service, and Bureau of Land Management in New Mexico. Field work was initiated on December 1, 1979 and continued with monthly expeditions through May 1980. Each of the 23 caves and three additional caves was visited at least once with a survey and detailed inventory being completed. Total survey of cave passage was 26,373 feet (8,035.5 m) with an additional 396 feet (120.7 m) of surface survey. The caves ranged in length from 12,768 feet (3,891.7 m) in Gunner Cave to 20 feet (6.1 m) in Cripple Turkey Cave. The average cave length, excluding Gunner Cave which accounted for nearly half of the total survey, was 616.5 feet (187.9 m). The field inventory form and methods were adopted from CRF cave inventory work at Buffalo National River, Arkansas and Sequoia-Kings Canyon National Parks, California. In addition to the content and hazard rating, specific resources (i.e. biology, geology, speleothems, etc.) were described and their scientific significance, recreational value, and protection needs evaluated (Figures 4 and 5). Management recommendations were made for each cave. A map was drafted for each cave (see Figure 6). The final report was submitted within nine months of initiation of field work.

Figure 3. Entrance to Indian Cave, Sylamore District, Arkansas. Photo by W.C. Welbourn.

More than 45 Joint Venturers from Arizona, Arkansas, Illinois, Missouri, Nebraska, Ohio, Oklahoma, Tennessee, and Texas participated in field work and map preparation. The local group of investigators (i.e. from Arkansas) made important contributions to the field work.

In September 1980, CRF successfully bid and won a second contract from the National Forest Service to continue the cave resource inventory of the Sylamore District. The second contract involves survey and inventory of 12 specified caves and placing identification markers in the entrances of 35 specified caves. Three caves (Rowland Cave, Bonanza Cave, and Hidden Springs Cave), to be completed on this contract, are major caves on the Sylamore District, with an estimated four to five miles of passages in Rowland Cave and approximately one mile in each of the other two. The remaining nine caves are expected to total less than one mile of passage. Field work started in October and was halted in December due to endangered species of bats hibernating in several caves. Work accomplished in October and November included five caves inventoried, three caves surveyed, and identification markers placed in seven caves. Field work will

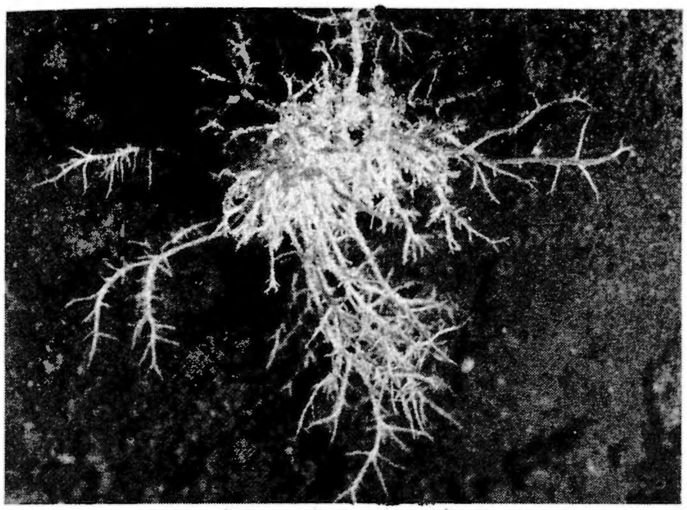

Figure 4. Fungus growing on rat feces, Breakdown Cave, Sylamore District, Arkansas. Photo by W.C. Welbourn.

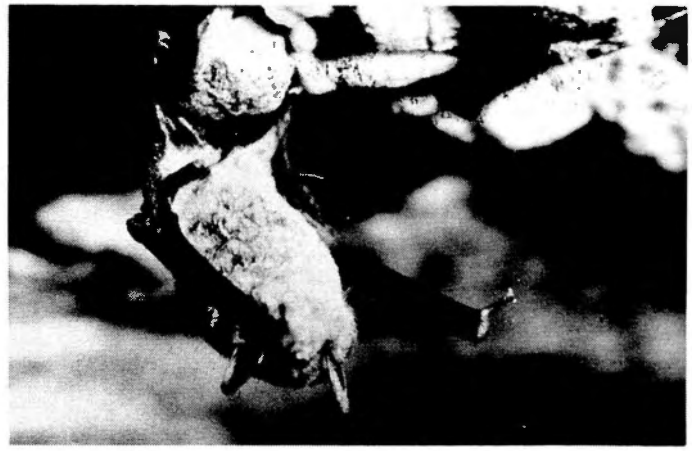

Figure 5. Bat in Bat Cave, Sylamore District, Arkansas. Photo by W.C. Welbourn.

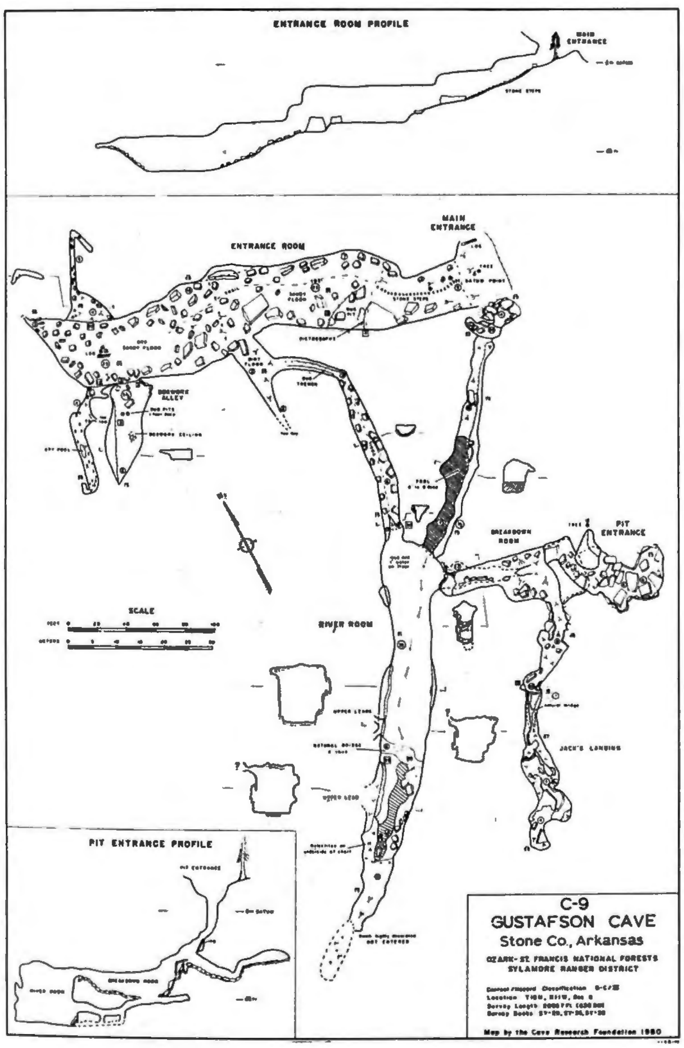


Figure 6. Map of Gustafson Cave, for Sylamore District Cave Inventory, Arkansas.

resume in the spring and continue through 1981 with the draft and final reports due in early and mid-1982 respectively.

In addition to the cave resource inventory of the Sylamore District, the second cave inventory contract at Buffalo National River was completed in 1980 and a third contract was initiated. The new Buffalo National River contract started in February, 1980 and will continue through mid 1981. Field work will concentrate on detailed inventory and survey of five selected caves representing different types and levels of recreational use at Buffalo National River. The inventory included completion of detailed resource inventory, photo monitoring, collecting data on recreational use, and additional biological data in each cave. All data will be compiled into detailed cave reports and specific management recommendations for all Buffalo National River caves. Field work in 1980 was limited to establishing photo monitoring points, cave surveying, and collecting additional biological data for each cave. In addition several new caves were investigated and inventoried. A total of 1,535 feet (470 m) were surveyed. Most of the field work in 1980 was accomplished by Joint Venturers from Arkansas.

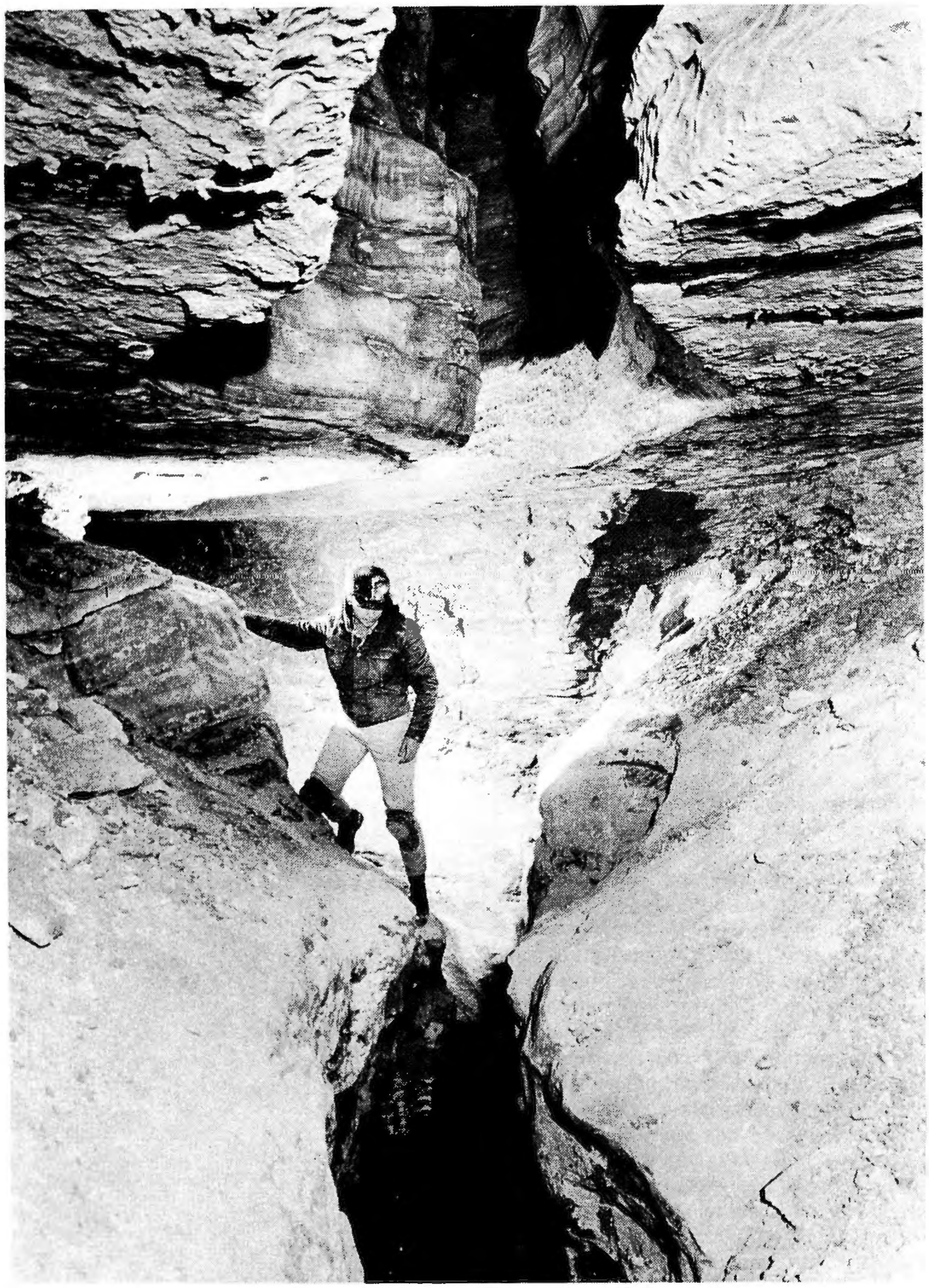

Figure 7. Straddle Canyon, Crystal Cave. Granular limestone (biosparite) of the Aux Vases Member forms the rough-walled, upper canyon. The recessed niche is formed by incompetent shale at the base of that member. Smooth, mound-like bodies of dolomite at the top of the Joppa Member are separated from the Aux Vases by a local disconformity. The lower canyon is in biosparite of the Joppa Member. Photo by A.N. Palmer.

# Speleochronology and Paleoclimatology in the Central Kentucky Karst

**Russell S. Harmon**

Since 1972 the Central Kentucky Karst has been the focus of an isotopic study aimed at deciphering the age of the Flint Ridge-Mammoth Cave System and the Late Pleistocene paleoclimatic history of the region. As a part of this program, the following analytical techniques were employed:

(i) $^{230}Th/^{234}U$ disequilibrium dating of calcite speleothems;
(ii) $^{18}O/^{18}O$ analysis of calcite speleothems;
(iii) D/H analysis of fluid inclusion waters extracted from calcite speleothems;
(iv) D/H and $^{18}O/^{16}O$ analysis of precipitation, vadose recharge and ground waters.

The results of this work, largely published in the papers cited at the end, are summarized below:

1. $^{230}Th/^{234}U$ dating of speleothems from the Flint Ridge-Mammoth Cave System and Great Onyx Cave has shown that( (i) the upper levels of the cave system (e.g. Collins Avenue) are greater than 350,000 years old; (ii) the lower, active levels of the cave system (e.g. Mud Avenue) are young, most likely formed during the penultimate glacial period, approximately 190,000 to 135,000 years ago; and (iii) speleothem deposition in cave passages in areas near valley entrenchment, where the caprock has been removed (e.g. Davis Hall), has been continuous over at least the past 250,000 years.
2. Calcite $^{18}O/^{16}O$ and fluid inclusion D/H variations in a stalagmite from Davis Hall which was deposited from approximately 230,000 to 100,000 years ago, indicate that: (i) the calcite-water isotopic fractionation was the predominant factor determining the oxygen isotopic composition of speleothem calcite at this site; (ii) precipitation during the penultimate glaciation from approximately 190,000 to 135,000 years ago was depleted in deuterium by about 10°/oo relative to that at present and during the last two interglacial periods; and (iii) surface temperature in Central Kentucky during the penultimate glaciation was about 10-12°/oo less than at present.
3. The isotopic composition of the karst groundwater body in the Central Kentucky Karst is about $\delta^{18}O$ = -5.6°/oo and $\delta D$ = -40°/oo relative to the SMOW standard. The temperature effect for meteoric precipitation in the region is 0.38°/oo/°C. The residence time of seepage water in the vadose zone feeding active dripstone deposits at sites near the edge of the caprock is about two weeks, but short-term fluctuations in the isotopic composition of this vadose water do not effect the oxygen isotopic composition of speleothem calcite.

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# Mineralogy of Piscah Lava Tubes

**Carol A. Hill**

The Piscah lava tubes are located between Barstow and Ludlow, California. Salt Cave is a short lava tube with white thenardite ($Na_2SO_4$) mineralization on the floor of its termination room. The thenardite occurs as small mounds of cotton 3-4 cm in diameter. The temperature in the termination room in December was 68°F (20°C) and the humidity 37%. The ceiling was covered with ivory-white linings of gypsum ($CaSO_4 \cdot 2H_2O$). Just before the termination room white fuzzy hairs of halite (NaCl) 1 cm long hang from the roof of the cave.

The longest (approximately 330 m) lava cave, Glove Cave, has extensive thenardite deposits in it. The thenardite occurs as 30 cm thick mounds on the cave floor dirt or in seams of rock near the floor.

The sodium carbonate minerals trona ($NaHCO_3 \cdot Na_2CO_3 \cdot 2H_2O$) and natron ($Na_2CO_3 \cdot 10H_2O$) and the potassium chloride mineral sylvite (KC1) were not identified in any of the lava tubes visited as has been reported by Harter (1976).

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# Mineralogy of Hidden Cave, Lincoln National Forest, Guadalupe Mountains, New Mexico

**Carol A. Hill**

Hidden Cave is one of the most visited caves in the Guadalupe Mountains. It is a small cave and was once a beautiful cave before being badly vandalized. Hidden Cave is formed in the Seven Rivers Formation approximately 30 m below the Yates contact (Jagnow, 1979). Canyon backcutting has exposed flowstone at the cave entrance. All of the speleothems observed were carbonates. No primary gypsum blocks or secondary sulfate speleothems were noted, which was not surprising considering the abundance of dripstone and flowstone in the cave.

Speleothems found in the cave are: soda straws, stalactites, stalagmites, columns, flowstone, rimstone dams and shelves, bell canopies, helictites, popcorn draperies, and small shields and welts. Most of the speleothems are desiccated and broken, but many are in the process of regrowth.

The most noteworthy speleothem type in Hidden Cave is the rimstone dams. The rimstone dams at the lower level of the cave are over 1.8 m deep and are the most impressive dams in any Guadalupe cave I have visited. When visited in August, the dams were not filled with water.

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# Geology and Origin of Wind Cave, South Dakota

**Arthur N. Palmer**

### *Introduction*

A geologic study of Wind Cave, in Wind Cave National Park, South Dakota, was undertaken during the summers of 1978-1980 by A.N. Palmer and M.V. Palmer at the request of the National Park Service and the Wind Cave Natural History Association. The results of this study are presented in a tourist-oriented guidebook published by the latter organization (1981).

Wind Cave is a complex network maze containing several superimposed levels, containing more than 50 km of mapped passages (Figure 8). The mapping is under the direction of John Scheltens, a member of the National Speleological Society and presently City Engineer of Hot Springs, South Dakota. The three-dimensional character of the cave makes it one of the world's most complex caves. It spans a vertical range of 170 m, terminating at its lower end in a series of water-table pools. The only accessible natural entrance is a tiny body-sized hole in the floor of a dry canyon, where the cave was fortuitously intersected by surface erosion. Roughly two km of passages are open to the public, with access via an artificial walk-in entrance and by an elevator.

The cave is noted for its extensive boxwork, which consists of intersecting crystalline fins that project from the walls, ceilings, and floors as much as one meter. The fins are joint fillings of calcite that are brought into relief by differential weathering. The intersection of two or more sets of fins produces the appearance of a honeycomb or post-office boxes. In addition, there are many delicate speleothems such as aragonite crystals ("frostwork"), cave popcorn, and wall coatings of calcite crystals. Flowstone and dripstone are rare.

### *Geologic Setting*

The cave is located on the southeastern flank of the Black Hills in the Pahasapa Limestone of Mississippian age. Except where it is exposed directly at the surface by erosion, the Pahasapa is overlain in the cave area by semipermeable sandstone of the Pennsylvanian Minnelusa Formation. Because of the local southeasterly dip away from the center of the Black Hills uplift, the limestone is exposed in a northeast-southwest band and is overlain by progressively thicker insoluble rocks toward the southeast. Water enters the limestone mainly by sinking streams that drain the insoluble rocks in the center of the Black Hills. Diffuse infiltration also takes place into the exposed limestone, as well as through the overlying sandstone.

In most limestone aquifers having an insoluble cap-rock, groundwater exits only in areas where the limestone occurs at the surface because of erosional removal of the overlying rocks. The Pahasapa aquifer is unusual, because the groundwater flow extends to depths of several hundred meters and rises under artesian pressure through the rather permeable sandstone to large springs at the surface, 5-20 km from the recharge areas. Most of the springs are located along prominent anticlines that bring the sandstone/limestone contact relatively close to the surface. Although fractures along the crests of the anticlines must aid the flow of water through the 200-meter-thick sandstone, the sandstone is still far less permeable than the limestone. There is a 40-meter elevation drop between the water-table pools in Wind Cave and the nearest spring. Well records show that the groundwater loses almost all of this head in flowing through the sandstone.

Considering its fame and unusual setting, Wind Cave has received little previous attention from geologists. Although many minor references to the cave occur throughout the literature, only those papers by Darton (1901), Tullis and Gries (1938), White and Deike (1962), Howard (1964), and Deal (1965) have made new and solid contributions to understanding the origin and geology of the cave. Of these, only the work of White and Deike, done in connection with the 1959 NSS expedition, deals exclusively with Wind Cave. The following paragraphs review the results of our 1978-1980 study.

### *Relationship of Wind Cave to the Limestone Stratigraphy*

Geologic mapping on the surface and in the cave shows that the Pahasapa Limestone in the southeastern Black Hills can be subdivided into three units, each of which is 25-35 m thick. Wind Cave extends through almost the entire 100-meter thickness of the limestone. Each of the three units produces a distinct type of cave passage, as described below:

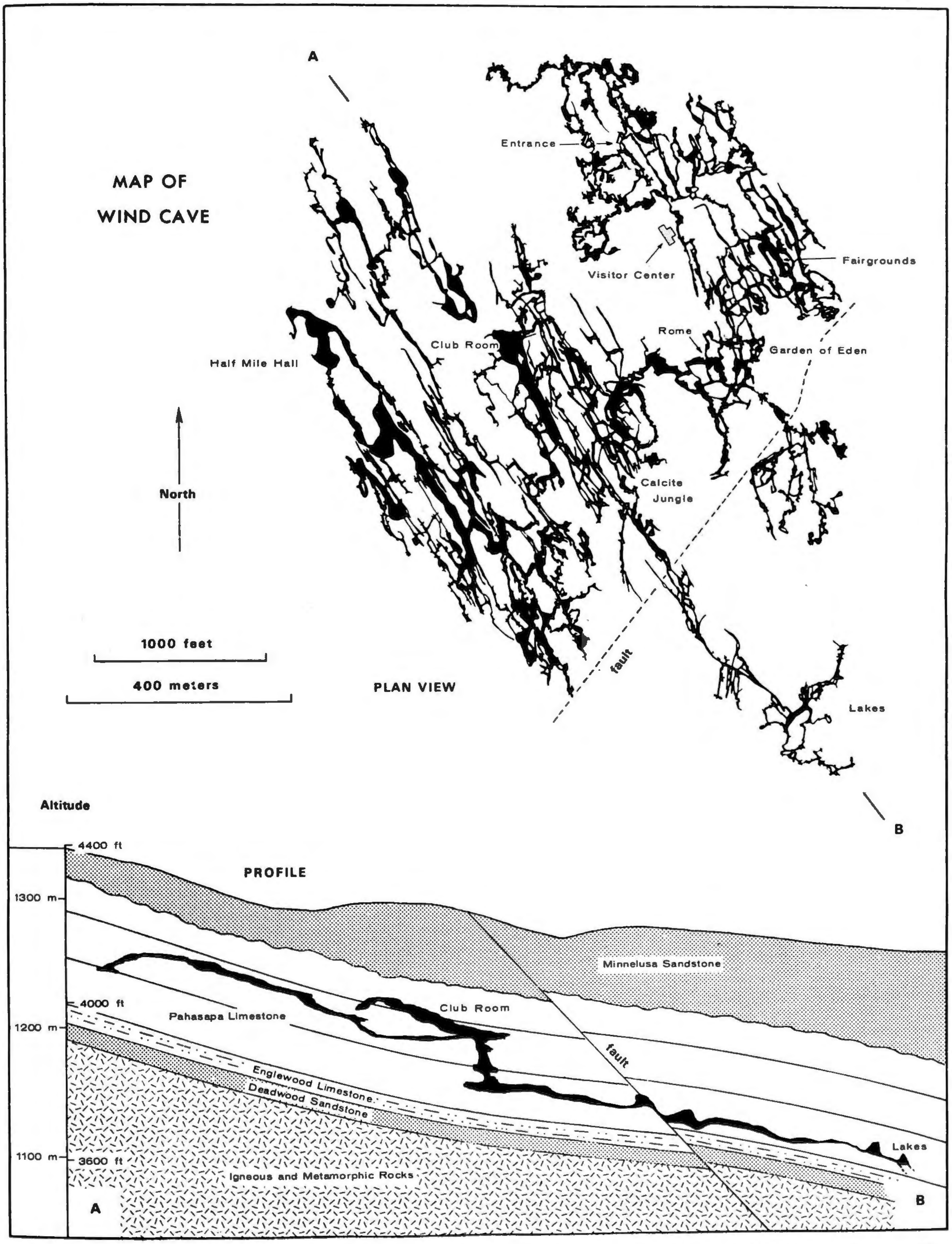


Figure 8. Map and profile of Wind Cave, South Dakota. Plan view reduced from maps by J. Scheltens, Herb and Jan Conn, and the National Park Service.

(1) The lower third of the Pahasapa Limestone is a massive, dolomitic limestone containing prominent joints, as well as numerous small pores where fossils have been selectively dissolved from the rock. Bedding is indistinct. In surface canyons this unit forms high, prominent cliffs with conspicuous solutionally widened joints. In the cave it forms joint-controlled fissure passages. Coating of the cave walls with calcite crystals is most common in this unit.
(2) The middle third of the Pahasapa is a distinctly bedded unit, with beds averaging 20-100 cm thick. The rock is silty and dolomitic with prominent chert beds near the top. In surface canyons this unit generally forms slopes interrupted by small ledges. In the cave it most commonly forms low, wide irregular rooms and passages. Most of the boxwork and aragonite "frost" occur in this unit.
(3) The upper third of the Pahasapa Limestone consists of a single massive unit having virtually no bedding. Beds and lenses of chert occur near the top. The upper surface of the unit was deeply weathered and eroded prior to the deposition of the overlying Minnelusa Sandstone. The contact between the two rock formations is highly irregular with relief of at least 15 meters. Solution pockets filled with sand and clay ranging in size up to 10 meters in diameter occur in the upper part of the limestone, diminishing in frequency downward. These are probably the result of the pre-Minnelusa weathering, and their sediment fill is probably of roughly the same age as the Minnelusa (Pennsylvanian). Where it is exposed in surface canyons, unit 3 tends to form massive cliffs. In the cave it forms irregular rooms with rather smooth solutional walls and ceilings interrupted in places by the older filled solution pockets. It is common for the sediment in these pockets to subside into the cave to form cones of sediment extending into the later passages.

The Pahasapa is underlain by the Englewood Limestone, a sandy, thin-bedded limestone 10 meters thick. Because it is fairly impure, very little cave development has taken place in this formation. No known passages in Wind Cave extend into the Englewood, although the lowest levels in the cave lie within 10 meters of its top. The Englewood Limestone overlies the 10-meter-thick Deadwood Sandstone, which in turn overlies the Precambrian igneous and metamorphic rocks which form the mountainous center of the Black Hills. Most of the groundwater recharge to the limestone originates as surface streams draining these insoluble rocks.

Patchy deposits of gravel and boulders occur on the surface, mainly on ridge tops. They consist mainly of fragments of Precambrian igneous and metamorphic rocks eroded from areas to the north, apparently during the Oligocene Epoch. Except for isolated pebbles and boulders near the entrance, none of these deposits were found in the cave.

### *Geologic Structure*

The dip of the beds in Wind Cave averages five degrees to the southeast. Joints control the direction of most cave passages and appear to be mainly tensional in origin. They occur in two major sets, one concentric and one radial to the Black Hills uplift. Minor faults are fairly common. They have the same general trends as the two major joint sets and their effect on the cave is rather similar. Most are vertical, but one major fault dipping 45° to the southeast extends across the southeastern end of the cave. Although the fault apparently formed before the cave, the few passages that extend across it are nearly blocked by breakdown. Terminations and constrictions in the cave may be related to similar faults. There seems to be evidence of post-cave movement along some faults, where rock spans are offset as much as 30 cm, with both vertical and horizontal components of movement.

### *Weathering and Boxwork*

The walls of the cave show an unusual amount of weathering, which has produced a soft, granular, multi-colored surface in most areas. The thickness of weathering appears to be much less in the walls of the solution pockets containing pre-Pennsylvanian fill, which suggests that the weathering is associated mainly with the present stage of cave development.

Boxwork is the most conspicuous weathering product (Figure 9). The calcite vein-filling projects into the cave as the surrounding limestone is weathered away. In many places the gaps between the boxwork fins are still occupied by crumbly, weathered bedrock that falls out at the slightest touch. Some boxwork is paper thin and delicate, but in most places it has been coated with thin laminations of calcite and clay as the result of periodic flooding. In air-filled passages, water seeping out of pores and fractures in the walls deposits aragonite crystals and popcorn on the edges of the boxwork.

The traditional explanation for boxwork is that joints in the limestone were filled with calcite before the cave began to form, and that the cave simply intersected these calcite veins. If this is the case, the origin of the initial vein filling is unclear, and the rarity of boxwork in other caves is unexplained. Most of the boxwork occurs in the middle unit of the Pahasapa, which is porous, silty, and dolomitic. It is almost entirely absent from the purer limestone above. Why was the calcite not deposited in the many fractures that occur in this upper unit?

Boxwork in most other caves also occurs in dolomite and is commonly associated with hydrothermal activity. There are hot springs 20 km south of Wind Cave, plus evidence in the cave for warm-water mineralization (White and Deike, 1962), but the association with hydrothermal activity is still tenuous.

An alternate explanation relates the boxwork directly to the weathering process. According to this interpretation, the boxwork began to form only after the cave became air filled, and it continues to form today. Moisture in the bedrock is drawn toward the dry cave by the difference in capillary potential. In the porous dolomite the water begins to lose $CO_2$ to the cave air through the numerous pores before it reaches the cave. Therefore, many of the pores and cracks in the outer 10-30 cm of the rock become filled with precipitated calcite. As the wall weathers or is dissolved further by subsequent flooding, the veins of calcite project into the cave. Evidence for this idea are as follows: (1) Most of the boxwork is located along minor fractures oriented differently from the major joints that control the passage trends. Some of these minor fractures are curved or radiate outward from a common point. These characteristics are typical of cracks that form while the rock is being weathered. (2) Where the bedrock has been broken, the calcite veins extend into the unweathered bedrock only a few tens of centimeters. The veins seem to be concentrated only along weathered walls in the cave and (rarely) at the surface. In some broken rock faces in the cave, the limestone shows a light gray weathering rind 10-20 cm thick. Pores in the weathered zone are filled with yellow, crystalline calcite, whereas those in the unweathered rock remain unfilled, indicating that the calcite was deposited during the weathering process. (3) Elsewhere in the world, boxwork occurs at and near the surface in certain highly porous limestones, in which infiltrating water loses most of its $CO_2$ in the vadose zone. Excellent examples can be seen in porous, granular dune limestone of late Pleistocene age in Bermuda

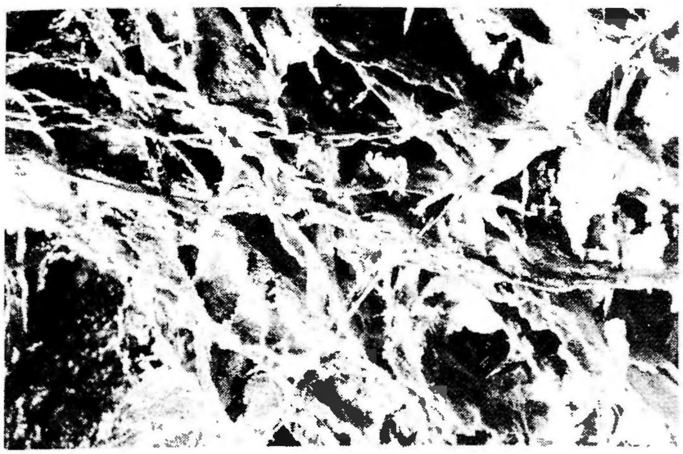

Figure 9. Boxwork in Wind Cave. Horizontal scale is one meter.

(Figure 10). The origin of this surficial boxwork is essentially the same as that proposed for the porous limestone of Wind Cave.

*Origin of Wind Cave*

Interpreting the origin of Wind Cave is difficult because it is almost totally dry today, and the pattern of water movement that formed it is obscure. Water-table pools are presently saturated with respect to calcite. Scallops and coarse-grained sediment, which are useful indicators of flow direction and velocity, are generally absent.

The complex, three-dimensional network of passages has traditionally been linked to an origin by slow-moving artesian water. However, there is no evidence that this kind of flow can produce a network maze (Palmer, 1975). Very similar caves, such as Wind Cave in New Mexico, can form with no insoluble cap-rock, whereas some simple tubular passages have been shown to form under artesian conditions, as in the lower end of the Butler Cave System in Virginia.

The artesian flow at Wind Cave is unusual because it exits *through* the overlying cap-rock. No matter how much water passes through the sandstone cap-rock, its openings hardly enlarge at all by solution. So, regardless of how large the cave passages become in the limestone, the amount of flow in each of them is limited by the low permeability of the sandstone. The inefficient outlet nearly equalizes the flow through each passage. If any passage receives more water from the surface than the neighboring ones, the water will spread out rather uniformly among the various interconnecting openings. Because the flow is governed in this way, many passages enlarge to cave size, instead of just a few.

The known parts of Wind Cave are no longer active. It is clear that a major source of aggressive water once existed at or near the cave, and that this source has either greatly diminished or now drains to a different area. With this idea in mind, the area of insoluble rocks northwest of the cave was examined for evidence of past drainage patterns. A broad valley apparently of Tertiary age, was found that once drained water from the igneous and metamorphic rocks in the core of the Black Hills and terminated at the outcrop of Pahasapa Limestone less than two km northwest of Wind Cave. This valley is obscured by Pleistocene entrenchment and has been segmented by several stages of stream piracy. As a result the valley remnants are nearly dry today, as its water drains out through several piracy routes. The water that once sank into the limestone at essentially a single point now passes both north and south through the pirating streams, several of which sink into the limestone at places remote from Wind Cave. The site of active cave development has therefore shifted, leaving Wind Cave as a relic of the previous drainage pattern. Although the origin of Wind Cave probably dates from early in the Tertiary Period, when the Black Hills were uplifted and exposed to erosion, the maximum rate of enlargement of the presently known cave probably occurred during the late Tertiary, when it was located near the surface and directly down-dip from the large Tertiary sinking stream described above.

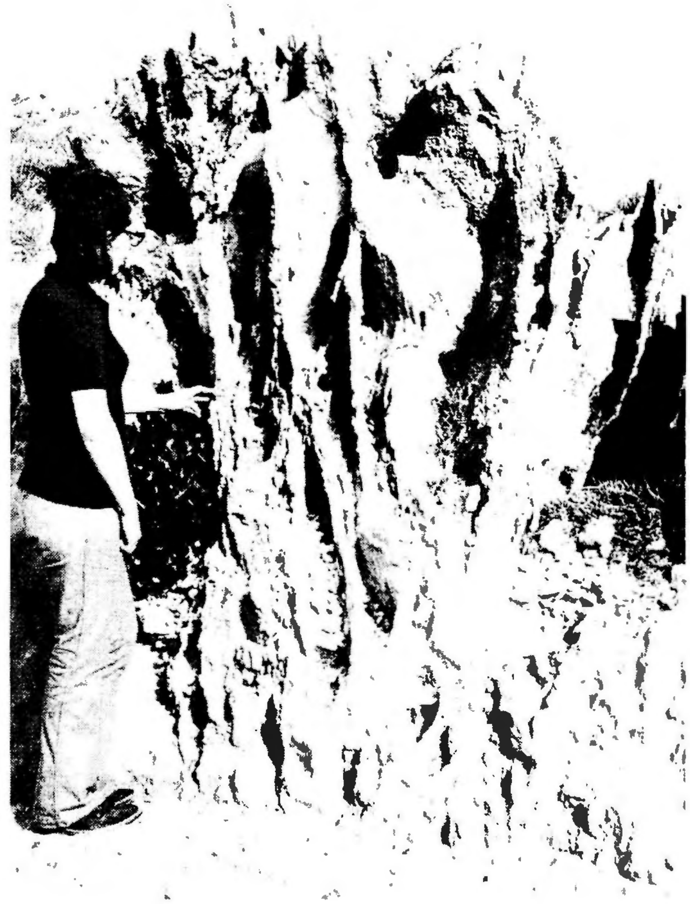

Figure 10. Surficial boxwork in late Pleistocene dune limestone, Bermuda.

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# Analysis of the Structural Control of Speleogenesis of Lilburn Cave, California

**Gail McCoy**

Lilburn Cave is a complex marble cave 12,000 m long formed by a subterranean stream system. Located in the southern Sierra Nevada, the cave lies at 1585 m elevation. The marble, along with schist and metachert forms a roof pendant surrounded by granitic rocks of the Sierra Nevada batholith.

The frequency, orientation and effect of jointing on cave development vary throughout the cave. Larger passages, developed along sets of parallel, gently dipping joints display rectangular cross-sections. Passages dissolved along steeply dipping joints have acute angular bends clearly associated with the intersecting joints. Pits develop along steeply dipping joints. In contrast, some passages show minor fracture-control of orientation but enlarge along joints where they intersect the passage.

All measured joints have been plotted on Rose diagrams. Surface fractures show strong, perpendicular trends of 345 and 70 degrees. In contrast, subsurface joints have a strong trend of 325 degrees. While the 345 degree trend of the surface joints subparallels the dominant subsurface trend, the other strong surface trend has no comparable subterranean equivalent but rather, aligns with a minor direction for subsurface joints.

Two major components in cavern development, regional water flow and bedrock features, have reinforced each other in this cave. Orientation of the marble lens, approximately coincident with the major stream, favors subterranean water flow. Extensive joint sets trending 335 degrees enhance subsurface flow. The strong linearity of Lilburn Cave, trending 350 degrees, apparently results from interaction of joints and regional water flow.

# The Natural History of Lilburn Cave, Sequoia-Kings Canyon National Park, California

**John C. Tinsley, David J. Des Marais, Gail McCoy Bruce W. Rogers, and Stan R. Ulfeldt**

*Introduction*

Lilburn Cave, a 12-km-long maze, is formed in foliated marble by a subsurface stream draining Redwood Canyon. The marble and its associated metasedimentary lithologies comprise the Redwood Mountain pendant in the Sierra Nevada batholith. The U.S. National Park Service manages the cave as a research facility because multidisciplinary research in speleology at Lilburn contributes new perspective to the region's natural history and to the interpretive program of the parks. Bedrock fractures and the regional hydrologic gradient are subparallel and apparently both are responsible for the strongly linear trend (345°) of the cave. However, the orientation of passages seems to be independent of (Ca,Mg)$CO_3$ variations witin the marble. The waters of the Redwood Creek drainage have a resurgence at Big Spring, an ebb-and-flow spring situated at the downslope terminus of the marble at a contact with a schist. Lilburn Cave provides access to the upstream ends of conduits and siphons which cause the flushing action. The cave's sediments indicate an initial period of varve-like clay and silt sedimentation followed by an influx of gravelly granitic detritus. The former phase lasted at least 8000 years, indicated by paleomagnetic studies; the latter phase apparently reflects downcutting in Redwood Creek, gaining direct acess to the central cave system. An unusual mineralogy, locally rich in iron and copper, occurs in the schist, marble, and granite and is shown by the varied speleothemic and petromorphic mineralogy observered in the cave. A study of radon levels and stable isotope conenctrations show that poor circulation characterizes the present cave atmosphere, which has high concentrations of radon (3.0 Working Levels) and $CO_2$ (0.2%) gases. Seasonal variations in concentrations of these atmospheric gases reflect a "chimney" effect.

*The Bedrock of Redwood Canyon*

The local geology is similar to much of the southern Sierra Nevada. Cretaceous granitic batholiths described by Ross (1958) intrude and contain the pre-Cretaceous Redwood Mountain pendant. The pendant chiefly consists of foliated biotite quartz schist, pods of metachert and foliated marble. The marble has a distinctive appearance due to a foliation defined by alternating white to light gray bands and dark gray to black bands. Cave development is confined to the marble. The resurgence (Big Spring) occurs at a marble contact with schist. Granite dike and schist contacts are exposed locally in the cave.

Subtle variations in composition and texture within soluble rock can affect cavern development (Rauch and White, 1970; Des Marais, 1971). Bruce Rogers measured Ca:Mg compositions and textures of 56 marble samples collected from surface and subsurface outcrops in Redwood Canyon. Table 3 and Figure 11 indicate that the marble is chiefly almost pure calcite. The dolomitic portions tend to be finer-grained, darker and more carbon-rich. The four Ca:Mg compositional ranges appear to be distributed irregularly across the marble (Figure 11). Apparently the cave passages indiscriminantly traverse these broad domains; hence, marble composition does not appear to control the gross location or dimensions of this cave system.

Chiefly responsible for the distinctive orientation and character of the cave are: the groundwater gradient from north to south, the diversion of surface water via subterranean routes to Big Spring, and the orientations of fractures in the marble. For example, the lowest known levels in the cave are a set of sub-parallel braided tubes created by the large perennial ground water discharge that flows from north to south. A second set of upper-level conduits chiefly consists of subrounded tubes, deep narrow canyons and occasionally pits 10-40 m deep which

## TABLE 3
## Marble Composition and Grain Sizes in Lilburn Cave

| *Marble Type* | *No. of Samples* | *Percent Calcite* | *Grain Size, mm Mean* | *Range* |
|---|---|---|---|---|
| Calcite | 32 | 93-96 | 4.3 | 0.25-7 |
| Magnesian Calcite | 14 | 54-86 | 1.9[a]<br>1.4[b] | 0.25.5[a]<br>0.5 -3.5b |
| Limy Dolomite | 7 | 36-39 | — | — |
| Dolomite | 3 | >6 | 2.5 | 0.25-9 |

[a] Calcite grains only. [b] Dolomite grains only.

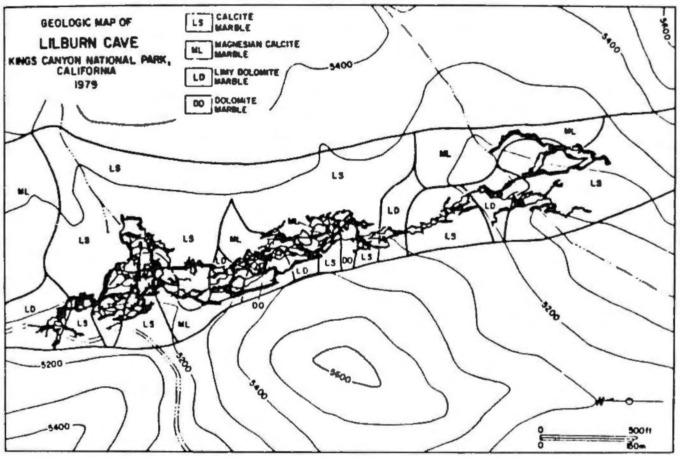


Figure 11. Map showing the relation between Lilburn Cave, the topography and variations in the composition of the marble in Redwood Canyon. The contour interval is 100 feet.

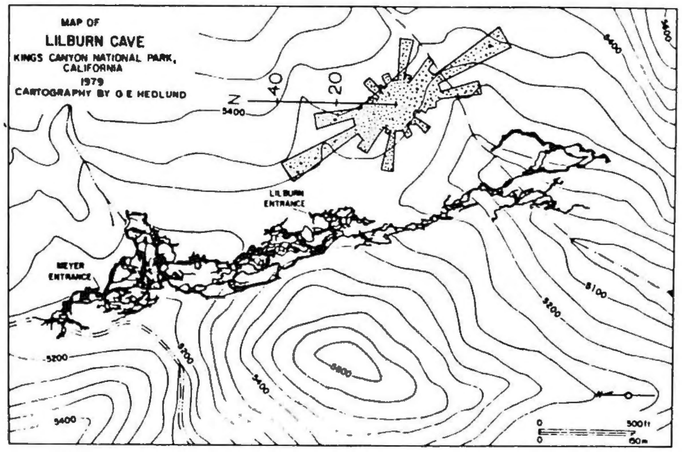


Figure 12. Rose diagram depicting orientations of all fractures measured in selected passages in Lilburn Cave in relation to the cave and the topography of Redwood Canyon. Contour interval is 50 feet. Fracture orientations are grouped in 10-degree increments of arc. The lengths of rays are proportional to the number of fractures per group.

convey water into the cave from localized sources such as tributary valleys, hillslopes and ravines. The low-level tubes and many of the upper level conduits carry water during spring snowmelts or heavy precipitation. Gail McCoy studied the orientation, spacing and extent of fractures in surface outcrops and in six passages selected as representative of the cave. A Rose diagram (Figure 12) illustrates how the dominant orientation (325°) of the subsurface fractures, which corresponds to the local structural grain of the Sierra Nevada, compares to the long dimension of Lilburn Cave (345°) and to the direction of the hydrologic gradient (345°-350°). These factors apparently cause the linear trend of the Lilburn system.

### *The Ebb and Flow of Big Spring*

During seasonal rainfall or snowmelt, Big Spring becomes a periodic spring and exhibits intermittent short pulses of very high discharge. Such ebb and flow behavior has been reported elsewhere, including the Ozard region (Bridge, 1923). Inside Lilburn Cave, about 700 m north of the spring and about 10 m above it, we observe water rising slowly in a chamber while the spring discharge increases slowly (Figure 13). At a critical point, the water drains suddenly from the chamber and the spring discharge increases abruptly, sometimes tenfold or more. A decade of water level records reveals that the greater the discharge of Redwood Creek, the more frequently large discharges occur in groups rather than as isolated events. We favor an explanation whereby a system of siphons at different levels is activated by rising water to deliver the surge at Big Spring. The

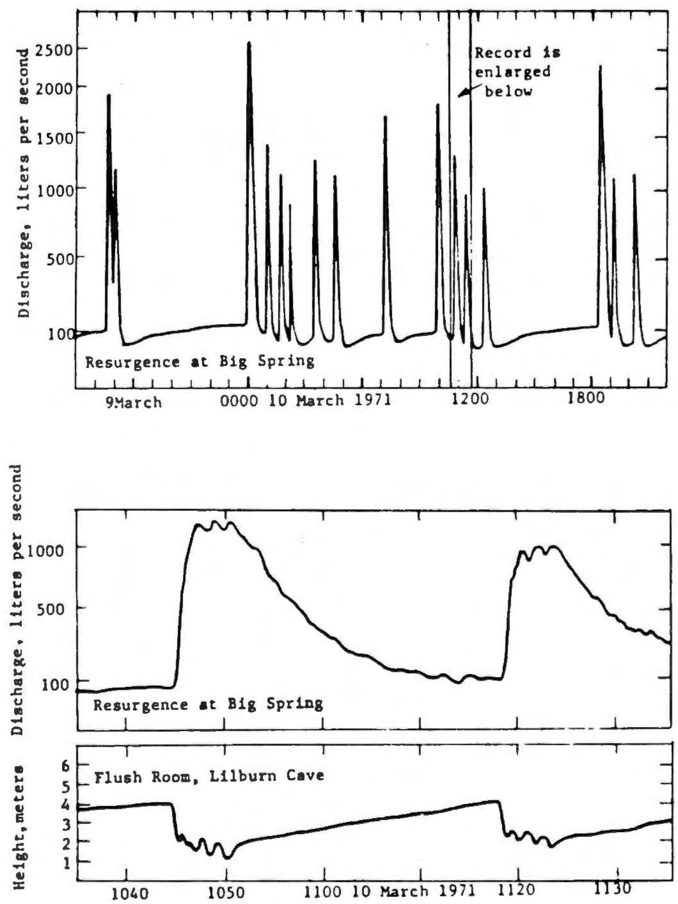


Figure 13. Ebb and flow behavior at Big Spring, Redwood Canyon, and the corresponding fluctuations in water level observed within Lilburn Cave.

system operates when base flow exceeds the discharge capacity of a lower-level conduit that carries the entire flow during seasons when no surges occur. Observations and models of this hydrologic behavior promise to sharpen our understanding of this spring system.

### *Sedimentology*

Central Lilburn Cave contains a sequence of three distinctive sedimentary deposits which are interpreted by John Tinsley to record major changes in the evolution of this karst system. The stratigraphically lowest sediments are chiefly thinly laminated rhythmites of micaceous silt, clayey silt, silty clay and clay rarely containing laminae of fine to very fine granitic sand. Ulfeldt and Packer (1977) conducted paleomagnetic studies of some of these deposits and concluded that deposition of these fine clastics lasted at least 8 x $10^3$ years. Dissected conglomeratic deposits, composed of a matrix of granitic sand and clasts of stream-rounded gravels, cobbles and boulders, are derived from the Redwood Canyon drainage and overlie the rhythmites. The pervasive cementation, the bleached biotite grains and pervasive stains of iron oxides throughout the matrix distinguish the older coarse clastic unit from the texturally similar but uncemented, unbleached young coarse clastics associated with the modern underfit streams.

We ascribe the older coarse clastic deposits to an episode of aggradation which occurred as a downcutting Redwood Creek gained direct access to the cave system. Anastomoses and ceiling channels and related modifications to phreatic passages developed as aggradation directed chemically aggressive water against the ceiling. If the ages of these deposits can be independently determined, we can identify the timing of these fundamental sedimentologic changes.

### *Mineral Deposits in Lilburn Cave*

The close proximity of marble, schist, granite and the metal-bearing tactite has created a noteworthy collection of minerals as identified by Bruce Rogers. Common speleothemic minerals include calcite, aragonite, hydromagnesite and gypsum. Less common speleothemic minerals include azurite, birnessite, goethite, hematite, malachite, and witherite. Petromorphic minerals occur locally in the cave, chiefly in close proximity to the schist or granite and include axinite, azurite, bornite, chalcopyrite, diopside, goethite, hornblende, sepiolite, sphalerite, and tremolite.

### *Radon and $CO_2$ in the Cave Atmosphere*

Measurements of radon, produced by natural decay of the element radium, and stable isotopes of carbon were performed to assist the National Park Service studies of the origin and abundance of radioactive substances in Park caves and to study the circulation of the cave's air. Observations made in Lilburn and in other Park caves are summarized below and in Table 4.

Carbon isotopic measurements of $CO_2$ from cave air ( $\delta^{13}C_{PDR}$ = -21.1), soil ( $\delta^{13}C_{PDB}$ = -20.8), dissolved bedrock ( $\delta^{13}C_{PDB} = \sim 0$), and cave waters ( $\delta^{13}C_{PDB}$ = -12.5) indicate that the $CO_2$ derives almost exclusively from the biological activity in the forest soil. Measurements of radon levels at selected sites indicate that the cave sediments, the cave stream, and the forest soil are not principal sources of radon gas. The primary source of radon at Lilburn appears to be the decay of radium located in the marble bedrock. Concentrations of radon and $CO_2$ decrease among in-cave samples taken successively closer to Lilburn's entrances, or from Park caves which are shorter in length than Lilburn Cave. Radon and $CO_2$ are diluted by the exchange of cave air with surface air, and radon concentrations are expecially sensitive to this dilution

## TABLE 4
## Radon and $CO_2$ Concentrations in Caves Within Sequoia and Kings Canyon National Parks

| | *Radon, W. L.*[a] | | *$CO_2$ Percent*[b] | | |
|---|---|---|---|---|---|
| *Locality* | *Range* | *Median* | *Range* | *Median* | *$\delta^{13}C_{PDB}$* |
| LILBURN CAVE | | | | | |
| Summer | 2.3-4.2 | 3.2 | 0.17-0.30 | 0.23 | -21.1±0.2 |
| Winter | 2.1-3.2 | 2.7 | 0.12-0.13 | 0.13 | -18.8±0.2 |
| Cave Sediment[c] | d | e | e | e | —— |
| REDWOOD CANYON | | | | | |
| Air | 0 | 0 | 0.03-0.04 | 0.035 | -10.5±0.2 |
| Forest soil[c] | d | 0.1 | d | 0.8 | -20.8±0.2 |
| SOLDIERS CAVE | | | | | |
| Summer | 0.9-2.2 | 1.7 | 0.20-0.21 | 0.21 | -20.1±0.2 |
| Winter | e | e | d | 0.05 | -13.0±0.2 |

[a] One Working Level is defined as any combination of radon daughters in one liter of air causing the ultimate emission of $1.3 \times 10^5$ Mev of alpha radiation energy.
[b] Percent by volume of cave air.
[c] Prior to sampling, the pits were covered and allowed to equilibrate with the sediments.
[d] Only one locality sampled.
[e] Not measured.
[f] $\delta^{13}C_{PDB} = [(R_x/R_s)-1](1000)$ where $R_x$ is the $^{13}C/^{12}C$ for the sample and $R_s$ is the $^{13}C/^{12}C$ isotopic ratio for the PDB standard.

rate. The concentrations of radon and $CO_2$ attain their maximum values in late summer and their minimum values in late winter. The generally higher radon levels in Lilburn reflect the relatively weak chimney effect causing the rather slow rate of circulation of forest air through this cave compared to other park caves.

### *Significance of the Lilburn Cave Studies*

Several immediate and practical benefits have accrued from the Lilburn research. For example, the radon measurements offer guidelines for controlling radiation exposure to future cave visitors. More importantly, the cataloging of rare features in Lilburn has heightened concern for the proper management of Lilburn and other park caves. Experienced scientists and laypersons are available and willing to assist the National Park Service in cave interpretation and in other responsibilities related to cave protection. Des Marais and others (in press) present an earlier, more detailed version of this paper.

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# Seismic Stratigraphy of Alluvial Deposits and Tephrochronology of Sinkhole Deposits in Redwood Canyon, Kings Canyon National Park, California

**John C. Tinsley**

### *Introduction*

Studies of the sediments in the karst of Redwood Canyon have been expanded this year to include seismic studies of the thickness and distribution of alluvium above Lilburn Cave. We also report the first locality in the Grant Grove section of Kings Canyon National Park found to contain tephra (volcanic ash) erupted from the Mono Craters-Inyo Craters area. The seismic studies are intended to elucidate the nature of the mantled karst in Redwood Canyon and the tephra studies may assist us by providing time control for cave sediments within the Lilburn system and sediments elsewhere in the Redwood Canyon karst.

### *Seismic Stratigraphy*

The Redwood Canyon karst and Lilburn Cave are mantled with alluvium deposited by Redwood Creek and its tributaries. To investigate the distribution and thickness of the alluvial mantle near Lilburn Cave, we recorded five seismic profiles using shallow refraction techniques and a sledge hammer as a seismic source. Interpretation of the P-wave time-distance relations indicates two velocities characterize the seismic stratigraphy in the alluvium. A surficial layer generally not exceeding two meters thick includes the most recently deposited sediments in the area and has a velocity of about 350 meters per second (m/s). The subjacent thickness of alluvium studied seismically is characterized by P-wave velocities of about 500 m/s and is 10 to 15 or more meters thick. The P-wave velocities in the marble bedrock are about 4250 m/s. This large velocity contrast enables easy recognition of the bedrock. Thickness of the alluvial cover ranges from less than one meter near the valley margin to at least 15 m above the central cave. Two hundred meters north of Meyer Entrance, 10 to 15 m of alluvium overlies the marble. There is much local relief on the bedrock surface, but we do not have enough data to define detailed subsurface geometry. The seismic stratigraphy is summarized in Table 5.

### *Tephra Found in Redwood Canyon*

Volcanic ash (tephra) was sampled from exposures in a sinkhole 0.5 km north of the Meyer Entrance to Lilburn Cave.

**TABLE 5**

**Summary of Seismic Stratigraphy from Redwood Canyon**

| *Seismic Stratigraphy* | *Thickness (m)* | *Average $V_p$(m/)* |
|---|---|---|
| $Qal_1$ | 0-2 | $380 \pm 70$ |
| $Qal_2$ | 0-15 | $670 \pm 150$ |
| Marble | — | $4250 \pm 2020$ |

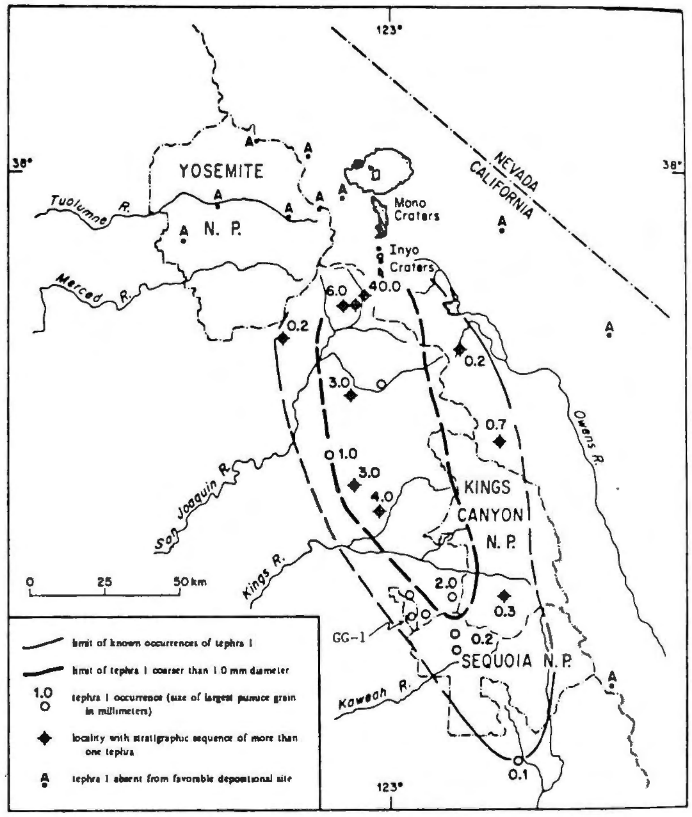


Figure 14. Map showing the distribution of tephra 1, from Wood (1975, figure 4, p. 140). The Grant Grove tephra locality is labeled as GG-1.

The ash is interbedded with sands and silts and is contained in a stratigraphic interval located one to two meters below the surface. Petrography of the ash shows glass shards are abundant and that the sample contains abundant (25% or more) sanidine. These characteristics suggest that the tephra is probably the younger of two late Holocene layers of tephra recognized in meadows of the southern Sierra Nevada at widely distributed localities between latitude 36° and 38° (Figure 14). Detailed studies by Wood (1975, p. 139) show these are the only significant tephra layers found within mountain meadow sediments on the western slope of the Sierra Nevada, excepting two deeper and older tephra layers known only from the upper San Joaquin River basin.

Samples of the ash (GG-1) were submitted for analysis to

Dr. Andrei M. Sarna-Wojcicki, Chief of Tephrochronology Studies, Western Region, U.S. Geological Survey. The ash in the sinkhole is chemically similar to the youngest pumice layer in the Red Meadow area based on the high content of zirconium and strontium. The probable source of the tephra is a dome and tephra ring located just south of Deadman Creek in the Inyo Domes area of Long Valley, California. The preliminary chemical data indicate the tephra was produced by the 1240 $\pm$ 40 A.D. eruption (A.M. Sarna-Wojcicki, personal communication, 1980; Kilbourne and others, 1980). Additional geochemical studies to determine the trace element content of the glass fraction of this sample are in progress and will provide definitive data for correlating the ash with eruptive centers and eruptive phases in the Long Valley area.

The two tephra units known from the western slope of the Sierra Nevada have been dated at roughly 740 and 1250 years ago respectively. We are initiating a systematic search for these deposits in other sinkholes and in Lilburn Cave itself to try to use these markers to help resolve stratigraphic problems and to obtain sedimentation rates in the Redwood Canyon karst.

### *Acknowledgments*

The author thanks Dai McClurg, Eric Last, and Ken Chainey for their assistance with the seismic profiling. Dr. Andrei M. Sarna-Wojcicki and Marta Woodward (U.S. Geological Survey, 345 Middlefield Road, Menlo Park, California, 94025) identified the tephra from Redwood Canyon and are completing additional geochemical studies to confirm the correlation.

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# Ecology Program

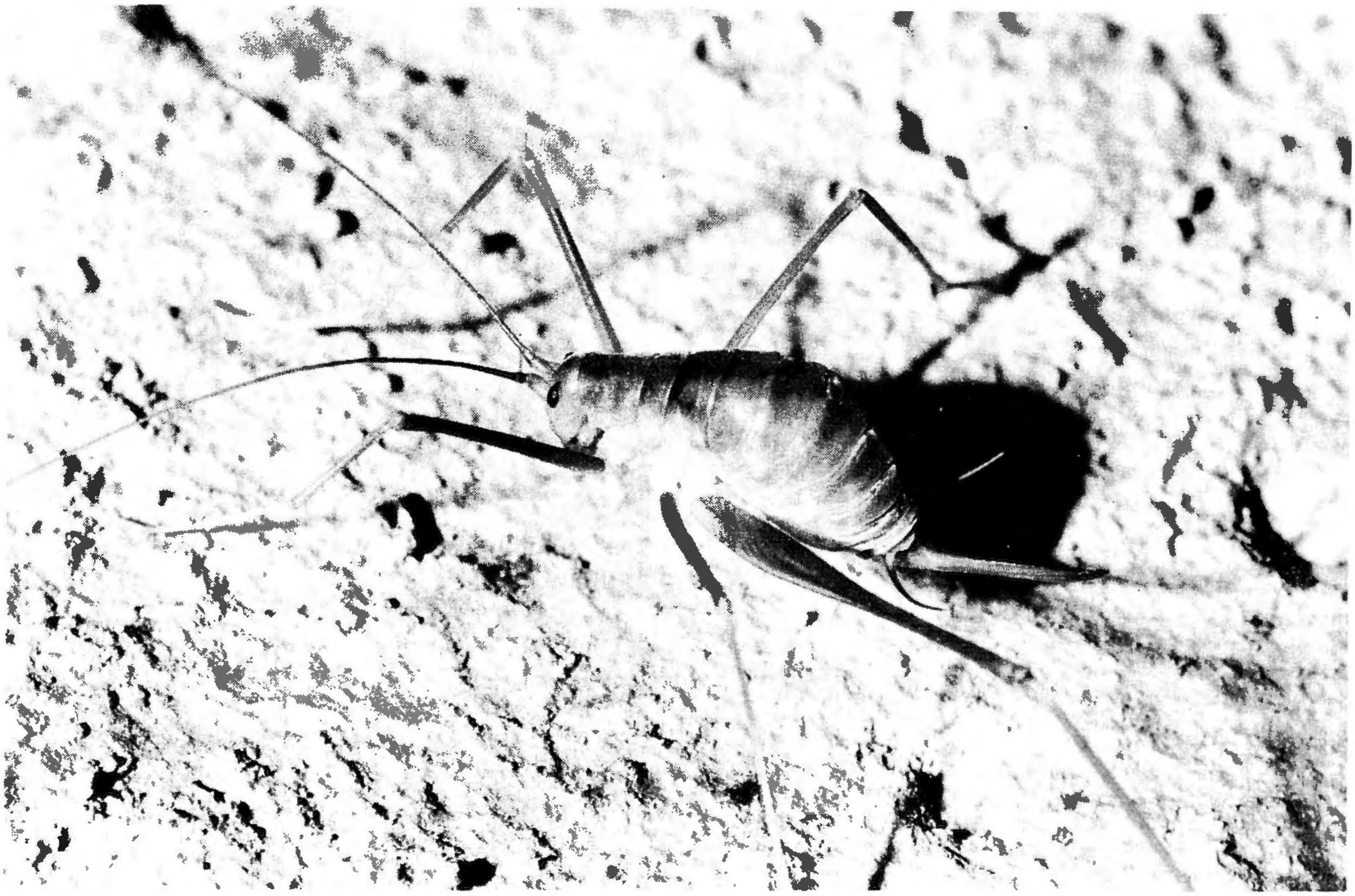

Figure 15. Cave Cricket (*Hadenoecus subterraneus*) in Mammoth Cave. Photo by A.N. Palmer.

# Microbial and Invertebrate Interactions During Dung Decomposition

**Kathleen H. Lavoie**

Put forth is the subject of dung,
Those land mines if foot wrongly flung.
How it decomposes,
Knobody knowses.
I'd learn but have fear for my lungs.
J.S. Kaufmann, 1979

In caves where nutrient input is limiting, there is a competition among scavenging invertebrates and microbes for ephemeral food resources such as dung. As dung decomposes there are regular changes in the microbial and invertebrate populations associated with it at different times. I have been studying the interactions among invertebrates and microbes during the successional decomposition of cave rat dung, as well as the effects of abiotic factors such as size, shape, and consistency. This article presents some preliminary data, field observations, and speculation about microbial colonization of substrates in caves.

An introduction to the process and theories of succession and some of the methods used were presented in the 1979 annual report. The rat exclosure pens proved their worth in Little Beauty Cave. The resident rat gnawed on the wood, kicked in sand at the corners, and finally built a nest on the roof of the cage. The basic field experiment consisted of grinding up fecal pellets from *Neotoma* cave rats which are kept in the laboratory and fed a diet with a controlled fungal inoculum. The dung was ground in a Willey Mill to coarse (20 mesh) and fine (60 mesh) consistencies and formed (by hand) to resemble the size and shape of three fecal types which occur naturally in caves—rat pellets, raccoon scats, and cricket guano veneers. The amount of material, nutritional value, and moisture content were constant in each. The samples were incubated in a variable entrance area (Little Beauty Cave) and a constant, deep cave area (Columbian Avenue). Duplicate samples were exposed to invertebrates in the rat proof cages and only exposes to microbes in invertebrate exclusion cones.

Field and laboratory studies have shown that establishing dominance first in the pile, by either microbes or invertebrates, limits the use of the resource by the other group. The early dominance of invertebrates, especially the scavenging beetle *Ptomaphagus hirtus* and the larvae of the fly *Sciara*, eliminated any succession of fungi. This inhibition of the fungi persisted after the invertebrates had abandoned the dung pile. Only a single type of fungus was found on older dung and even it was limited in occurrence. An early dominance of fungi and/or bacteria reduced or slowed down the reproductive success of the invertebrates but did not eliminate them, presumably since the microbes themselves serve as a source of food for the scavenging invertebrates. Laboratory experiments are in progress now to quantify the effects of the microbial conditioning of dung on the reproductive success and survival of *Ptomaphagus* and *Sciara*.

Deep cave and entrance areas show similar patterns of microbial succession when invertebrates are excluded. Shape was the most important determinant of succession, with fungi dominant on imitation cricket, bacteria dominant on imitation raccoon, and both on the intermediate-shaped imitation rat pellets. Consistency had little effect on the microbial succession. Keeping the invertebrates out proved to be harder than keeping the rat out, but failures of the exclusion system did provide some good data on invertebrate reproductive success on dung previously conditioned by microbes.

**TABLE 6**

**Weight Loss of Dung +**

| *Columbian Avenue* | Start | W1 | W3 | W6 | W12 |
|---|---|---|---|---|---|
| Real Rat | 5.0 | 3.7 | 2.8 | 2.2 | 1.7 |
| Ps Rat 20 | 5.0 | 3.4 | — | 2.3 | — |
| Ps Rat 60 | 5.0 | 2.9 | 3.1 | 2.0 | 1.8 |
| Ps Coon 20 | 5.0 | 3.4 | — | 2.6 | — |
| Ps Coon 60 | 5.0 | 2.5 | 2.6 | 1.6 | — |
| *Little Beauty* | Start | W1 | W3 | W6 | W12 |
| Real Rat | 5.0 | 3.1 | 3.2 | 3.4 | 2.8 |
| Ps Rat 20 | 5.0 | 4.5 | — | 3.3 | — |
| Ps Rat 60 | 5.0 | 4.1 | 3.0 | 2.4 | 2.9 |
| Ps Coon 20 | 5.0 | 3.9 | — | 3.5 | — |
| Ps Coon 60 | 5.0 | 2.6 | 2.1 | 2.0 | 1.2 |

+ Weight loss of dung during decomposition caused by the activity of microbes and invertebrates. Dry weight (grams) of samples at the start of the experiment and at one (W1), three (W3), six (W6), twelve (W12) weeks later. Samples included are real rat and both coarse (20 Mesh) and fine (60 Mesh) consistencies of imitation rat (Ps Rat) and imitation raccoon (Ps Coon).

Invertebrates did not select among the three dung shapes and two consistencies equally, preferring the raccoon-shaped dung and the finer consistency as shown by the weight loss data presented in Table 6.

Invertebrate colonization was influenced by the local species pool and the mobility of the colonizers. The abiotically variable entrance area had a higher density and diversity of fly species, whereas the constant deep cave area had higher densities of scavenging *Ptomaphagus hirtus* beetles. Cave rat dung is normally found in the entrance area which may harbor a larger species pool for colonization than the deep cave. Predatory Staphylinid beetles invaded the piles in Little Beauty, causing a rapid decrease in other invertebrate species. No predators have been observed on or in dung at the Columbian Avenue site.

After twelve weeks, the exposed piles in the entrance area showed very little invertebrate activity with moderate densities of fungi present. Most of the material retained some recognizable shape. In the deep cave area all piles still had some invertebrate larvae active, predominantly *Ptomaphagus*, with no fungi present. The form of the piles, except for the imitation cricket, was uniformly fragmented.

The colonization of dung by fungi is affected by their relative immobility and the need for stimulation before the spores of some species will germinate. Bacteria face similar problems. A

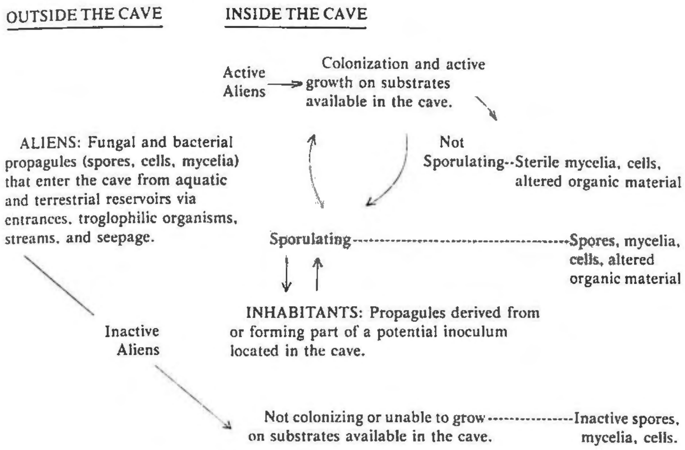


Figure 16. Colonization of substrates in the cave by microbes and their contributions to the energy flow.

scheme for microbial colonization based on terminology proposed by Dick (1971) for lakes is given in Figure 16. There are several possible patterns of colonization, and the method used by a particular organism or group may vary under different conditions. My experiments with colonization of sterilized dung have shown that most species of "sugar fungi" are inhabitants of the cave and can colonize directly from the sediment and, to a lesser extent, from the air. Others (or the same species) can be brought in by invertebrates or other troglophiles on their bodies or in their guts.

New organic material enters the cave ecosystem from terrestrial and aquatic reservoirs. Some energy is lost when material is washed, leached, or carried out of the cave. The primary contribution of microbes to the energy flow in the cave involves the conversion of organic material into microbial biomass, released nutrients, and modified organic material. Energy-rich foods such as rat and raccoon dung and animal carcasses can be used directly by generalist/opportunist organisms and by microbial decomposers. The microbial biomass can then be utilized by fungus feeders, scavengers, or omnivores. This conversion of energy-rich substrates usually occurs rapidly over short periods of time. Energy-poor foods such as cricket guano, organic mud, and the recalcitrant material left after initial conversion of energy-rich food (e.g. skin, chitin, hair, cellulose, etc.) can be used by more specialized invertebrates and degraded further by microbial action. The contribution to the energy flow in the cave from the energy-poor substrates is generally a slow process occurring over long periods of time. Energy contained in the cave organisms will re-enter the cycle as growth substrates when the organisms defecate and eventually die.

The field experiment discussed in this paper is still in progress and will be repeated in late January 1981 to determine if seasonal effects are important in influencing succession. Laboratory determinations of fungal biomass are being done to support my field observations. Further manipulative lab experiments are planned.

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# A Comparison of Intraspecific Competition in Two Cave Spiders: *Phanetta subterranea* and *Anthrobia monmouthia*

**Devon M. Lee and Thomas L. Poulson**

### *Introduction*

In the past (Poulson, 1975) it had been suggested that *Phanetta subterranea* and *Anthrobia monmouthia* have life histories that fit the extremes implied by the "r- vs K-selected" models respectively. More recently (Poulson, 1978) some of the implications of the r-K model were questioned and the extremes in life history were described as follows. *Phanetta* is time efficient in that it quickly produces large numbers of offspring during "good times". Good times are generally predictable, based on seasonal changes in temperature and moisture near cave entrances, and these changes also affect the prey and predators of *Phanetta*. When prey are abundant the risk from meeting predators is also high. However, the variability of seasonal timing from year to year makes the duration and degree of "good" and "bad" times unpredictable. Thus, as the r-selection model implies, mortality would be mainly density independent and so a high rate of population growth (r) would insure that some young survive to perpetuate the population. In contrast to *Phanetta, Anthrobia* lives farther from entrances where the environment is very stable and the spiders are not subject to tremendous risks from abiotic or biotic agents of selection. However this environment is very rigorous with respect to the very low food supply. To us this is sufficient reason for the resource efficient characteristics of *Anthrobia*. It puts little energy into reproduction, with one offspring per egg case and egg cases produced intermittently over a long lifespan. The K-selection model ascribes this reproductive pattern and resource efficiency to a density dependent competition. According to that model *Anthrobia* must be resource efficient since its populations are always near the carrying capacity of the environment (K). In this report we make an experimental test of the r-K-selection model's predictions about the intensity of intraspecific competition.

We set out to test two contrasting hypotheses concerning intraspecific competition within the two species of spider. The r- vs K-selection model predicts that intraspecific competition should be greater in *Phanetta* than in *Anthrobia*. If *Anthrobia* is at the carrying capacity (K) of its environment, then competition among individuals would be high both for food (exploitation competition) and to maintain the most favorable web site (interference competition). On the other hand, if *Phanetta* is generally below the carrying capacity, because it is always recovering from population lows that result from yearly mortality cycles, then competition among conspecifics (both indirect exploitation and direct interference) would be low because of abundant food supply and space for webs. The contrasting hypothesis is that intraspecific competition is greater in *Phanetta* than in *Anthrobia*. In apparent contradiction to the r-selection model, *Phanetta* populations are denser than for *Anthrobia* at some times of year. Coupled with a larger body size and higher metabolic rate for *Phanetta* this would suggest intense intraspecific competition (both exploitation and interference). Of course the problem with this is that the food supply for *Phanetta* is higher than for *Anthrobia*. It is just such complications of scale that make it difficult, if not impossible, to compare two species with respect to the degree that their population densities approach the carrying capacities of their environments. That is why we decided to test the correlate of departure from carrying capacity, namely the intensity of intraspecific competition.

### *Method*

In order to test the alternative hypotheses, we made observations both in the laboratory and in the field. The spiders used in the lab were collected from several locations. *Anthrobia* were collected from the following sites in Mammoth Cave National Park: the "drill hole" in New Discovery of Mammoth Cave Ridge and Great Onyx Cave and Columbian Avenue of Flint Ridge. The *Phanetta* were all taken from Parker's Cave in the sinkhole plain southeast of the Park. After feeding each spider for a week it was kept without food for a week before setting up the competition experiments. The experiments were done in eight-inch observation bowls which contained a bottom layer of smoothed cave mud. Each bowl contained either one, two, or three individuals of a species. Regular observations were made of the spacing and movements of individuals and of the locations and areal extents of all webs.

In December of 1979, two field sites were chosen to determine the spacing and dispersion patterns for each species. Flags were placed marking the locations of individuals and egg cases of *Anthrobia* in the "larval island" and "larval area" of Great Onyx Cave. Then a map was made of the locations. The same procedure was performed for *Phanetta* in Parker's Cave. In January 1980 the sites were remapped.

The following criteria were used for intraspecific competition:

1. The amount of web "built" in the bowls, including web position and the area covered, may be a measure of the effects of competition. This may be an indicator of exploitation competition in that more web will catch more prey. However, maintaining position in a web might require interference competition.
2. Killing or harming of conspecifics is the most stringent form of interference competition.
3. The spacing of spiders in the bowls and in the field may be an indicator of interference competition. Presumably maximal and even spacing will result if interference is strong.
4. Two scales of movement might be indicators of interference competition. These movements are wandering of spiders within the bowls and losses of spiders from the bowls.

### *Results*

There did not appear to be any between-species differences in the amount of intraspecific competition in any of the studies for any criterion.

1. Comparing webs of *Phanetta* to those of *Anthrobia*, we did observe that *Phanetta* constructs more web covering a larger area for an equivalent time period. One might argue that, because *Phanetta* webs are larger and cover more area, exploitation competition is greater in this species. On the other hand we know that the metabolic costs for *Phanetta* are greater than for *Anthrobia* and so *Phanetta* requires more web to catch more food.
2. There was no clear evidence for killing of conspecifics. Two spiders, one of each species, were found dead and partially eaten in their bowls. It is probable that the spiders died from starvation or other natural causes.

## TABLE 7
## Dispersion of Spiders at Different Quadrat Sizes

| *Collection Data* | *Quadrat Sizes (in meters)* .25 x .25 $s^2/\bar{x}$* | .5 x .5 $s^2/\bar{x}$ | 1 x 1 $s^2/\bar{x}$ | 2 x 2 $s^2/\bar{x}$ | 4 x 4 $s^2/\bar{x}$ | 8 x 8 $s^2/\bar{x}$ | *Number of Spiders* |
|---|---|---|---|---|---|---|---|
| Anthrobia | | | | | | | |
| Larval Island 12/79 | — | 1.2 | 1.0 | 0.7 | Not big enough for these areas | | 10 |
| Larval Area 12/79 | 1.0 | 1.1 | 2.1A | 3.0A | 3.0A | 0.5U | 19 |
| 1/80 | 0.9 | 1.1 | 1.3A | 0.1U | Didn't census whole area | | 9 |
| Phanetta | | | | | | | |
| Parker's Cave 12/79 | 1.0 | 1.0 | 1.4A | 1.6A | 1.2 | — | 16 |
| 1/80 | 1.0 | 1.6A | 2.4A | 3.0A | 1.3A | — | 10 |

* $s^2/\bar{x}$ = variance/mean
A = variance/mean ⩾ 0 ← Aggregation
U = variance/mean ⩽ 0 → Uniformity
Random = 1.0

3. Measurements of spacing in the bowls and in the field did not suggest greater intraspecific competition in either species. In the field, data for distribution of individuals of both species show that they are sometimes aggregated for quadrat sizes of 1 x 1 to 4 x 4 meters (Table 7). This is probably a result of local abundance of hiding places and food and/or scarcity of predators. The modal areas for the webs were 3 x 4 cm for *Anthrobia* and 4 x 12 cm for *Phanetta*. Thus the 25 x 25 cm (.25 x .25 m) quadrat is the scale at which we should look for evidence of even spacing that reflects competition. As Table 7 shows, we found no evidence of even spacing for the variance/mean index of dispersion. They even seem to be random in dispersion if we test 25 x 25 cm quadrats only in those subareas of the census location that have the highest local population densities.
4. *Phanetta* showed more wandering and loss of spiders from the bowls than for *Anthrobia* but there was no trend of increased wandering or loss with increased density for either species.

### *Conclusion*

The data presented does not clearly falsify either the hypothesis that intraspecific competition is greater for *Anthrobia monmouthia* or for *Phanetta subterranea*. Despite the small sample sizes, the data are consistent and the results do not support either of the original hypotheses. The data better support the null hypothesis, that there is no difference in the intensity of intraspecific competition for the two species.

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# The Distribution and Ecology of Two Species of Subterranean *Caecidotea* in Mammoth Cave National Park

**Julian J. Lewis and Teresa M. Lewis**

### *Introduction*

During 1980 much progress has been made in understanding the distribution and ecology of the two species of troglobitic *Caecidotea* which inhabit caves in Mammoth Cave National Park. These two species, *Caecidotea stygia* Packard, and a new species referred to herein as *Caecidotea* sp. (Lewis and Bowman, in press), both occur widely in Kentucky, but are sympatric only in the Central Kentucky Karst. The Flint Mammoth Cave System is unique as the only place where both species occur together.

### *Distribution*

Since collecting began in July, 1979, a total of 43 collections consisting of about 350 specimens from 18 localities in the Flint Mammoth Cave System, Owl Cave, Mill Hole and Parker Cave have been made. In contrast to the collections reported in the 1979 annual report (Lewis, in press), the geographic scope has been expanded to include some localities which are hydrologically connected to the Flint Mammoth System (Quinlan and Rowe, 1977; 1978), both in (Owl Cave) and out (Parker Cave, Mill Hole) of the national park.

The collection localities can be divided into two categories: (1) habitats in the upper levels, and (2) habitats at or near base level. The upper level habitats can be further divided into those associated with shafts, and others found at terminal breakdowns (Table 8). Several shaft related habitats were sampled, ranging in size from streams such as Shaler's Brook (Figure 17),

**TABLE 8**

**Summary of 1979-1980 Collection Localities of Troglobitic Isopods in the Mammoth Cave Region**

*Upper-Level Habitats*

1. Lookout Mountain (*C. stygia*)
2. Devil's Cooling Tub (*C. stygia*)
3. Shaler's Brook (*C. stygia*)
4. Wandering Willie's Spring (*C. stygia*)
5. Richardson's Spring (*C. stygia*)
6. Cathedral Domes (*C. stygia*)
7. pool at end of Dyer Avenue (*C. stygia*)

*Lower-Level Habitats*

1. Styx River:
   A. Breakdown downstream from Charon's Cascade (*C. stygia and C.* sp.)
   B. downstream from Lake Lethe (*C. stygia*)
2. Echo River:
   A. 3rd Arch (*C. stygia*)
   B. 4th Arch (*C. stygia*)
   C. Minnehaha Islands (*C. stygia*)
3. Roaring River:
   A. Shrimp Pools (*C. stygia* and *C.* sp.)
   B. pool area upstream from Shrimp pools (*C. stygia* and *C.* sp.)
4. Hawkins River (*C.* sp.)
5. Owl Cave (*C.* sp.)
6. Mill Hole (*C.* sp.)
7. Parker Cave, Parker River (*C.* sp.)

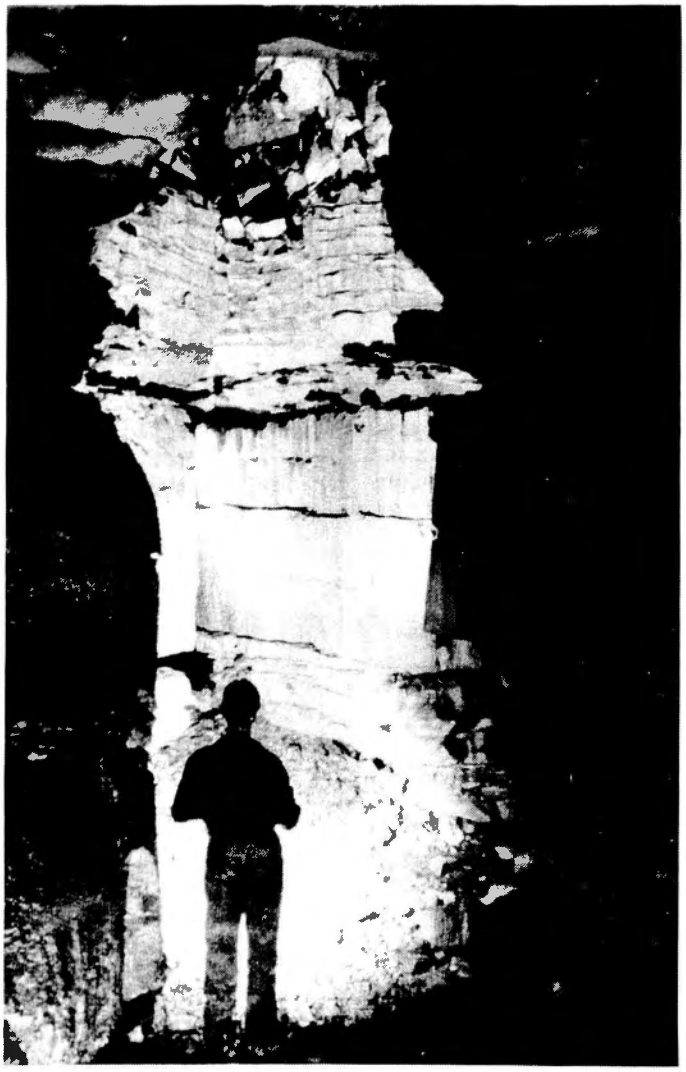

Figure 17. View looking upstream in the population density study area in Shaler's Brook, Gratz Avenue, a small shaft drain stream inhabited by the isopod *Caecidotea stygia*.

down to small pools, like the Devil's Cooling Tub (Figure 18). Isopods have been identified from only one terminal breakdown stream, Lookout Mountain, the terminus of Rafinesque Hall, but a single unidentified female *Caecidotea* was collected recently by other CRF personnel from the terminal breakdown of Blackall Avenue. Other terminal breakdowns probably support isopod populations, but the water often flows immediately down through the breakdown without flowing across pools, formed on sediments which clog the breakdown, which provide both a habitat for the animals and a place to observe them.

Of all of the samples taken in the upper-level habitats only *Caecidotea stygia* has been found. Populations of this species are sometimes threatened by the vagaries of water supplies in the upper levels. Some habitats, such as Shaler's Brook, shrink considerably as seasonal dryness ensues. Others, notably Wandering Willie's Spring, dry up altogether. Populations in small pools are low due to poor habitat diversity. For example, in Richardson's Spring, the bottom of the pool is a uniform substrate of sand and it was not uncommon to observe no isopods at this location. In the larger shaft drains, like Shaler's

Figure 18. The Devil's Cooling Tub in Gratz Avenue.

Brook, greater microhabitat diversity is present and differential utilization of these microhabitats is apparent, as discussed below.

Several base-level streams were sampled: Styx, Echo, Roaring (and the adjacent Shrimp Pools) and Hawkins Rivers, Owl Cave, Mill Hole and Parker Cave (Parker River). Many individual collections were made along the Styx, Echo and Roaring Rivers (Figure 19).

The distribution of *Caecidotea* at base level is more complicated to interpret than in upper level habitats. Base level streams typically exhibit greater microhabitat diversity, and perennial water supplies, but in Mammoth Cave environmental disturbances have reduced habitat diversity and introduced physical and chemical conditions which cause animal communities to deteriorate. Green River Lock and Dam #6 causes water to pool in Mammoth Cave National Park (Figure 20), which backfloods waters from not only the Green River, but also water released from Nolin Reservoir, into caves in the park. This results in the ponding of Echo and Styx Rivers, which causes siltation that reduces habitat diversity. Seasonal flooding regimes are also modified, which introduces water from the Green River into the cave which is dissimilar physically and chemically (Duchon and Lisowski, 1980). Disturbances also enter from the sinkhole plain, the upstream source of the streams, such as the recent chemical spill which flowed through Hawkins River. However, these disturbances do not seem to have caused specific distributional changes through habitat modification, but rather contribute to a general degradation of the habitat.

*Caecidotea* sp. is the common isopod expected in base-level streams in the Mammoth Cave area and much of the rest of Kentucky. In Styx and Echo River, however, *C. stygia* has been found to be more abundant. In these areas the gravel bars which are the preferred microhabitat of *C.* sp. are absent because of heavy siltation. For the most part isopods do not occur in Styx or Echo Rivers, except where large breakdown slabs have remained above the silt, or where boards from old tourist trails have been discarded into the stream, creating artificial microhabitats harboring isopods. In between rocks and boards lie vast areas of sand, which are an aquatic biological desert.

To check the possibility that the isopods were evading collection by remaining in deep pools in the silted areas, 6 jars baited with uncooked marine shrimp were placed in the Styx River. This technique has been very successful in collecting isopods and other invertebrates from difficult-to-reach habitats in other caves and wells. However, no animals of any kind were found during the three months the jars were in place.

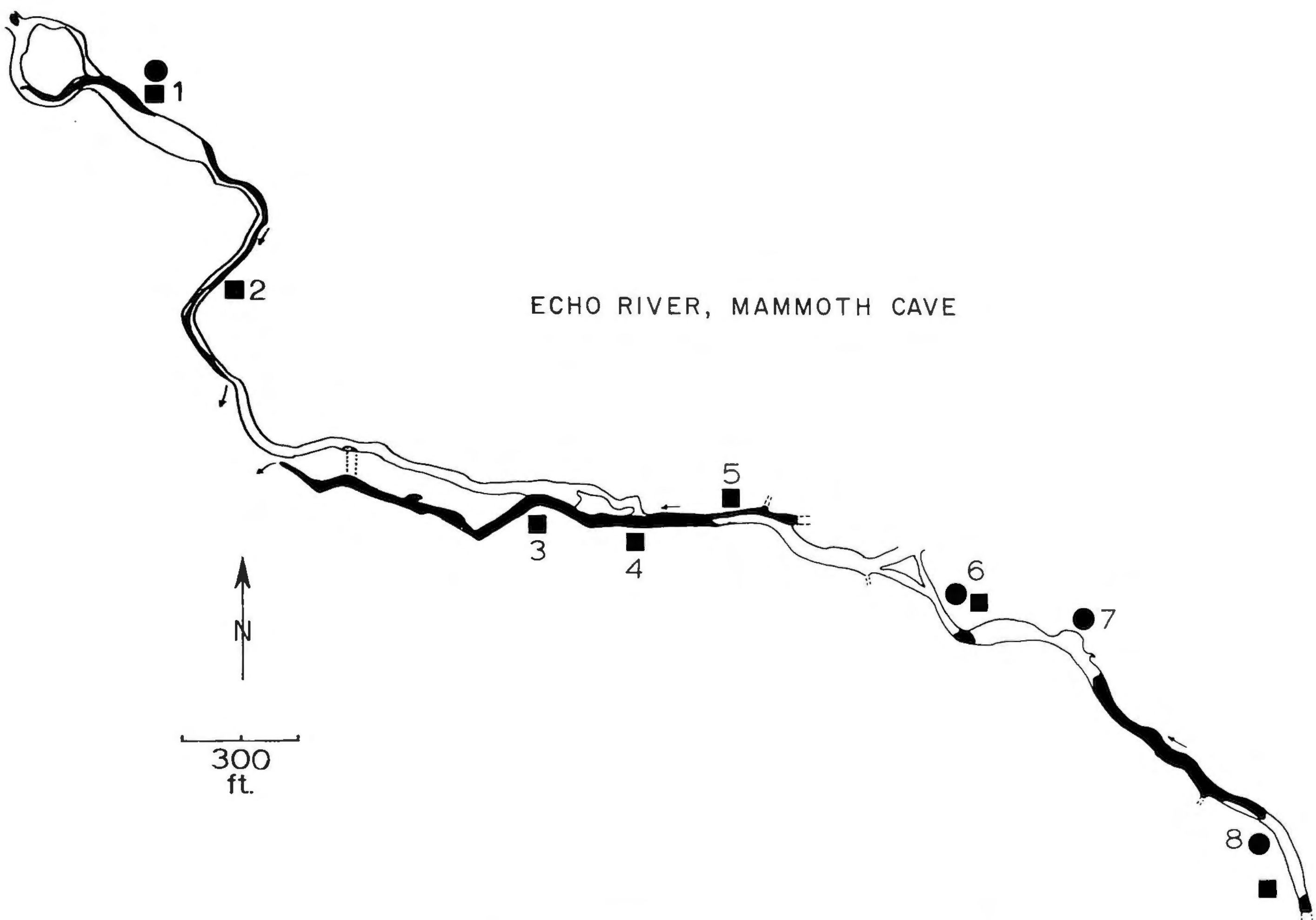


Figure 19. Collection localities for troglobitic isopods, *Caecidotea stygia* (squares) and *Caecidotea* sp. (circles) in Styx, Echo and Roaring rivers, Mammoth Cave. Numbered localities are (1) Styx River, breakdown pile; (2) Styx River, Great Walk; (3) Echo River, Third Arch; (4) Echo River, Fourth Arch; (5) Echo River, Minnehaha Islands; (6) Roaring River, Shrimp Pools, downstream section; (7) Roaring River, Shrimp Pools, upstream section; (8) Roaring River, unnamed pool area upstream of Shrimp Pools.

Figure 20. Lock and Dam #6 on the Green River, downstream from Mammoth Cave National Park.

To investigate the distributional relationships of each of the species at base level, we have sampled a number of habitats, starting at Echo, Styx and Turnhole Springs and working upstream from the Green River and the effects of its backflooding. In Echo and Styx Springs, only epigean isopods, presumably *Lirceaus fontinalis*, were found, despite reports by Hay (1902) that *C. stygia* (actually *Caecidotea* sp.?) was common at these springs. Turnhole spring was visited, but ponded water over the spring prevents making isopod collections there. Within Mammoth Cave, in the heavily silted parts of Styx and Echo Rivers which lie adjacent to the tourist trails, only *C. stygia* has been found. As one progresses upstream in either river, *Caecidotea* sp. begins to appear sporadically. In Styx River, a single specimen of *C.* sp. has been taken from the breakdown downstream from Charon's Cascade, but in this same place *C. stygia* is relatively common.

Similar to the situation found in Styx River, as one moves upstream on Echo River, only *C. stygia* is present until the Shrimp Pools are reached. On the downstream end of the Shrimp Pools, *C.* sp. occurs, but is greatly outnumbered by *C. stygia*. *Caecidotea* sp. has not been found to occur on the same rock or even the same pool with *C. stygia*. On the upstream end of the Shrimp Pools is a small pool (about 1 $m^2$) where *C.* sp. is abundant, but no *C. stygia* have been found. A few hundred feet upstream from the Shrimp Pools lies another pool area, which can be reached only by boat or swimming through the deep, wall-to-wall water of Roaring River. In this pool area *C. stygia* and *C.* sp. occur in roughly equivalent numbers, although again they have not been found in the same pools. Larger samples may reveal that both species do co-occur in the same pool.

In other areas in the Flint Mammoth System, Hawkins River and Owl Cave, *Caecidotea* sp. is abundant on rocks in the streams. *Caecidotea stygia* has not been found from these localities. Moving upstream far away from the effects of the Green River to Mill Hole and Parker Cave, only *Caecidotea* sp. occurs.

Of the two species of isopods, *Caecidotea* sp. appears to be a habitat specialist which will live only at or near base level in breakdown or gravel bars where perennial water is present. *Caecidotea stygia* is a habitat generalist, but is excluded from base level habitats by the presence of its close relative, *C.* sp. In the highly disturbed areas of Styx and Echo Rivers, *C.* sp. is almost entirely displaced by the lack of suitable habitats, and *C. stygia* has grasped the opportunity to reinvade the base level streams in these areas. Interface zones occur in the upstream parts of Styx and Roaring (and in the Shrimp Pools) Rivers, where both species are present.

### *Microhabitat Utilization*

With the knowledge that Shaler's Brook was consistently inhabited by only *C. stygia*, in June a project was initiated to study the effects of microhabitats on population densities. Six randomly placed stations were established and monthly censusing commenced using a 15 cm$^2$ area. Each of the six

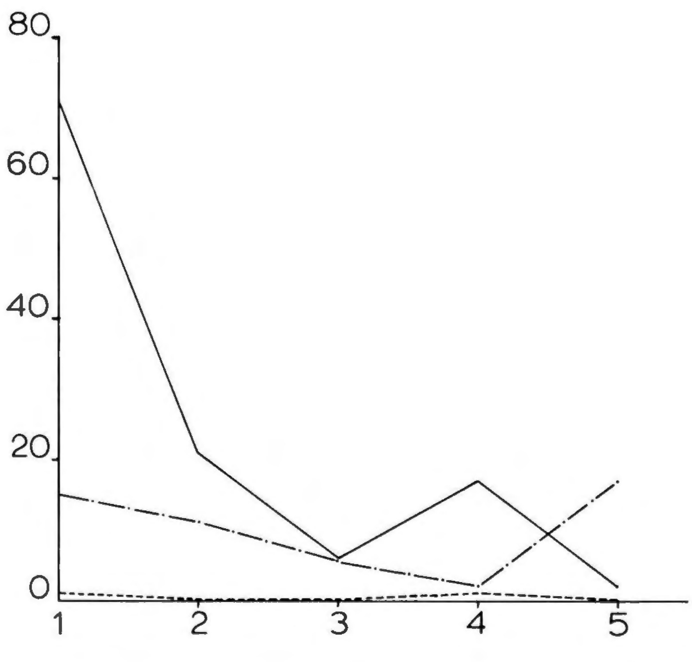


Figure 21. Seasonal variation in the population density of the isopod *Caecidotea stygia* in Shaler's Brook. (Vertical axis denotes individuals per 15 cm$^2$ areas). Solid lines indicate data for station #1; dot/dashed line data for station #2; and dashed line data for station #3 (see text for explanation of habitat present at each station). Survey dates are deonted on the horizontal axis: (1) 28 June 1980; (2) 2 August 1980; (3) 30 August 1980; (4) 16 October 1980; (5) 27 November 1980.

stations happens to occur in a very different type of microhabitat. For example, #1 is sand bottom; #2 is sand covered by scattered pebbles; and #3 is pitted rock covered by pebbles. Seasonal population densities for these three habitats are illustrated in Figure 21. Two pieces of information are apparent. First, it is obvious that *C. stygia* does not readily inhabit areas where only sand is present without other cover. However, areas where some cover is present, are used to much greater extents. Secondly, a great seasonal decline in population has occurred from the spring through autumn. The first samples taken in June during the peak of seasonal reproduction may represent the maximum population density for this stream. The seasonal population decline is probably attributable to a combination of mortality (starvation?), wash out, or predation by the Cave Salamander (*Euycea lucifuga*), which lowers the population to the carrying capacity of the stream.

Besides Shaler's Brook, three other areas have been selected for censusing: (1) Devil's Cooling Tub; (2) Lookout Mountain in Rafinesque Hall; and (3) Styx River below Lake Lethe. The Styx River was abandoned as an area for conducting a census of randomly placed stations after the first survey revealed a population density of zero at each of ten stations. In its place, a general census of the area has been substituted, but with the exception of four isopods found on a board, no specimens have been taken from this silted stretch of the river. It is not surprising that the abundant *Orconectes pellucidus* reported by Hay (1903) in the River Styx are no longer common, since the food source of the crayfish has disappeared.

Only two surveys of the Devil's Cooling Tub and Lookout Mountain have been conducted, which does not provide enough data for discussion.

A final question which is being looked into is the stability of small pool populations. Are pools replenished by individuals from higher populations which enter through ceiling seepage, or are the populations mostly perpetuated by reproduction within the pool? A third possibility, the invasion from below, seems unlikely when large pits are involved. To evaluate the extent of invasion from above, a five-gallon bucket has been placed below the trickle of water that flows into Devil's Cooling Tub to trap any animals that might enter from this route. After five months in place, no animals of any type have yet been found in the bucket.

We would like to thank the Research Advisory Committee of the National Speleological Society for the grant of funds used to defray travel and field expenses for this research. Additional travel funds were provided to J.J. Lewis by the Graduate School of the University of Louisville. Finally, we thank the many members of the Cave Research Foundation who have made collections in Hawkins River, and assisted in many other ways.

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# The Community Structure of Arthropods on Bat Guano and Bat Carcasses in a Missouri Cave

**Barbara J. Martin**

The community structure of arthropods associated with bat guano and bat carcasses was examined in Tumbling Creek Cave, southern Missouri. Bat guano is the most abundant food resource in the cave. Sixty-seven species of arthropod were collected during a year's sampling. Distribution of species was very patchy at a local level. At the community level there was no discernible seasonality of either total number of species, total density, or total biomass. There was a successional sequence of arthropods associated with the decomposition of guano and carrion.

Dominance was high, both in terms of numbers and biomass, at all times and sites. Mites predominated on the guano piles both in number of species and relative abundance. A few species were consistently dominant: within the guano the fungivorous mite, *Polyaspis* sp., and the pseudoscorpion, *Hesperochernes occidentalis*; on both fresh guano and carrion the predatory mite, *Erynetes* sp.; and at areas away from high concentrations of guano the fly, *Bradysia* sp., and the collembolan group, *Arrhopalites* sp. High predation seemed to exclude the flies and collembolans from high concentrations of guano (i.e. the piles).

The decomposition of carrion in the cave differed from that of epigean carrion in three main respects: 1. The prominence of Collembola and absence of Hymenoptera; 2. The prominence of fungi; and 3. The great prolongation of decomposition.

Guano pile size was positively correlated with number of species (significantly), density of individuals (significantly), and total biomass of arthropods. It was negatively correlated with numerical dominance and with percent of primary consumers in terms of numbers (significantly) and in terms of biomass.

Age of guano piles, that were periodically renewed, was related to the various community characteristics in the same manner as size of the guano pile.

Age of carrion, which unlike guano is not renewed, was negatively correlated with number of species, density of individuals (significantly), and total biomass of arthropods (significantly).

The amount of annual guano input was positively correlated with number of species, density of individuals, and total biomass of arthropods (significantly). It was negatively correlated with numerical dominance (significantly), biomass dominance, and percent of primary consumers in terms of numbers and biomass (significantly).

Energy availability was positively correlated with number of species, density, and biomass of arthropods but more troglobites were associated with food resources of lower energy availability such as old, dispersed guano and wood.

This is a summary of a Masters Thesis submitted to the University of Illinois at Chicago Circle under the direction of Dr. Thomas Poulson and was supported in part by a grant from the Cave Research Foundation.

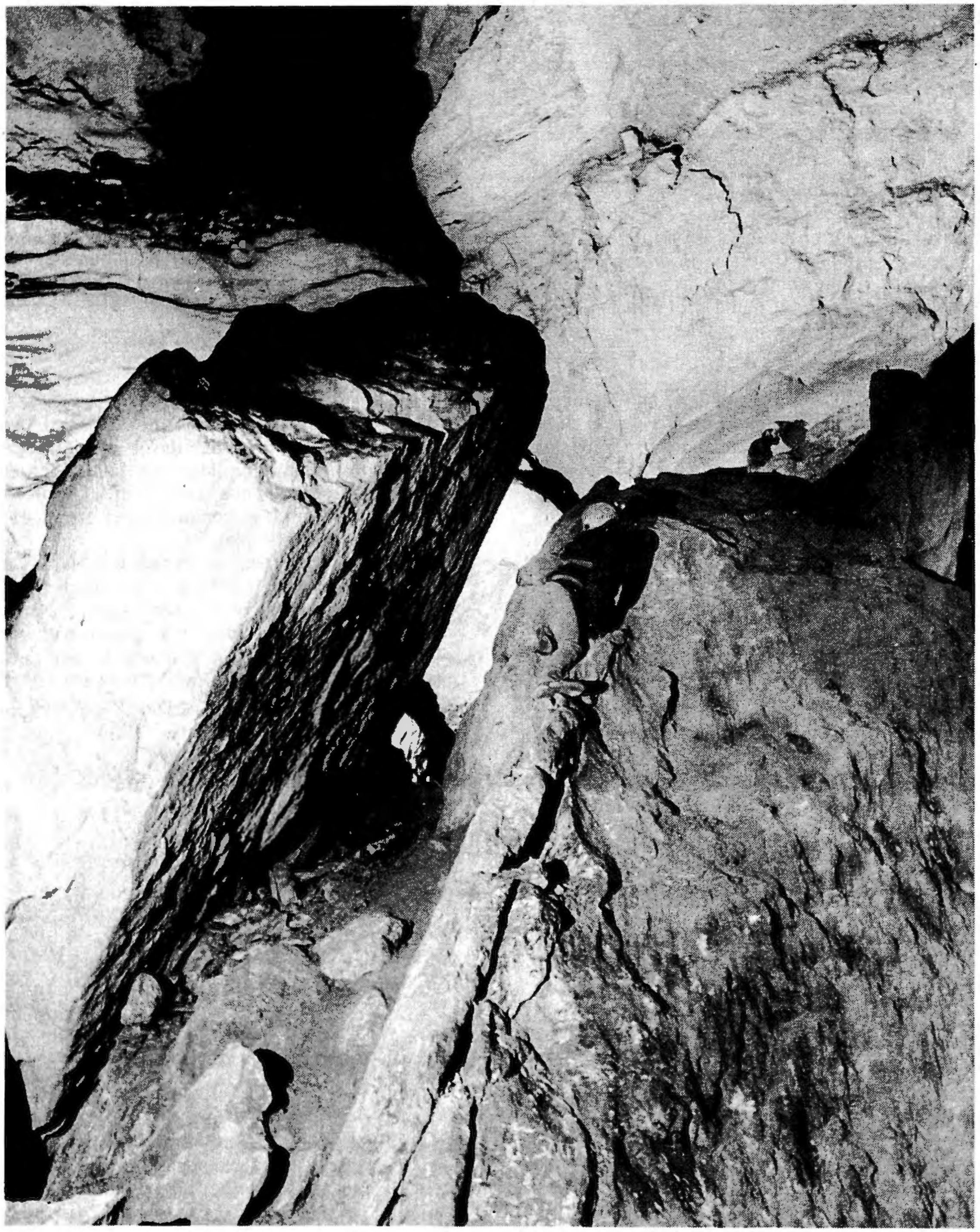

Figure 22. Jaguar Cave, Tennessee. Upper end of the Towering Inferno, part of the route followed by the prehistoric cave explorers on their way to Aborigine Avenue. Photo by D. Daunt and W. McCuddy.

# CRF Archeological Project and Shellmound Archeological Project—1980

## Patty Jo Watson

The close relationship between these two archeological endeavors has been explained and illustrated in earlier annual reports (especially those for 1977, 1978 and 1979). In brief, we are investigating a number of aspects of prehistoric life in the middle Green River drainage of western Kentucky, particularly aboriginal cave exploring and cave mining and the subsistence patterns of the ancient cavers. The significance of archeological materials from Mammoth Cave National Park (Watson et al., 1969; Watson ed., 1974) is highlighted in a volume to be published soon by the University of New Mexico Press: The Origins of Plant Husbandry in North America, edited by Richard I. Ford. Chapters by Pat Watson and by another archeologist—Wes Cowan—who has been working at a rockshelter site in the Red River Gorge of eastern Kentucky summarize the botanical evidence from this part of the midwestern and midsouthern United States. Botanical remains we have recovered from two shell mound sites in the Big Bend of Green River (near Logansport) downstream from the Park in Butler County are also crucial to understanding horticultural origins in the middle Green River region (Figure 23).

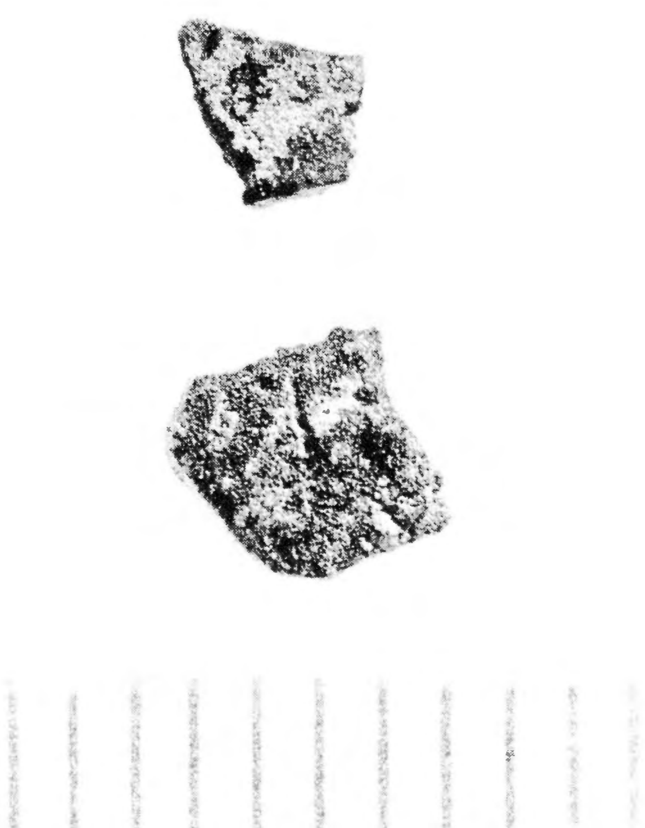

Figure 23. Fragments of charred squash rind from the Carlston Annis shellmound (Bt 5), excavation unit C 13. This squash is over 4000 years old. Scale is in millimeters. Photo by Garry Crawford.

At about 700 B.C., the pre-Columbian Indians who mined and explored Salts and Mammoth Caves in Mammoth Cave National Park were growing squashes and gourds (tropical plants first domesticated in Mexico about 9000 years ago) and also some native western and midwestern species (sunflower and a related plant called sumpweed, as well as goosefoot weed). At about 2500 B.C. the shell mound dwellers in the Big Bend of Green River, who were predecessors of the caving Indians, grew squash but apparently none of the other species just listed. Over the past year we have been working on the prehistory of both regions, as well as continuing the mapping of 4500 year old human footprints in Jaguar Cave, Tennessee (see 1977, 1978, and 1979 annual reports) (Figure 24). Hence, the following summary is organized under headings appropriate to each of the three research foci.

### *I. Archeological Work in Mammoth Cave National Park, 1980*

On February 9, Pat Watson and Gail Wagner led a group of archeobotanists (David Asch and Nancy Asch of the Northwestern University archeological program in Kampsville, Illinois; and Wes Cowan, field director of the Cloudsplitter excavations on Red River, Menifee County, Kentucky) on an archeological trip through Upper Salts Cave. We went from Salts Vestibule to the Chapman Entrance and back, examining archeobotanical remains along the way.

Archeobotanical work continued in July when Pat Watson and Gail Wagner spent three days floating dirt samples from rock shelter sites in or near the Park and from the Carlston Annis shell mound in the Big Bend.

In August and again in October, George Crothers aided by Tammy Bennington (both are Washington University undergraduates majoring in anthropology and archeology) carried out archeological investigations in Sand Cave supervised by Pat Watson (Antiquities Permit #81-KY-006). They are now working on a wide variety of historical materials left from the attempts to rescue Floyd Collins in January, 1925. The artifacts have been cleaned, labelled, and cataloged in the archeology laboratory laboratory at Washington University. They will be described in detail and interpreted by Crothers in a Senior Honors Thesis to be completed in March, 1981. The archeological research in Sand Cave was instigated by Roger Brucker, and was assisted materially by Richard Zopf and Mark Elliott. On October 12, Mike Fuller and Jeff McKee made a plane table map of the shelter above Sand Cave (which is a prehistoric archeological site).

### *II. Archeological Work in the Big Bend, 1980*

Limited fieldwork (primarily archeological survey in the Big and Little Bends of Green River) was carried out under the direction of William Marquardt from May 17 to June 5. The season culminated in a two-day, pre-publication conference at Logansport attended by all those contributing chapters to the forthcoming detailed report on our shell mound research from 1972 to the present. There are 14 people included in the research group; their various contributions are being coordinated and edited by Bill Marquardt with some assistance from Pat Watson.

### *III. Archeological Work in Jaguar Cave, Tennessee, 1980*

As of this writing one trip has been made to Jaguar Cave (October 11) and another is planned for Thanksgiving Day. The October trip resulted in some very good photos (by D. Daunt and W. McCuddy) as well as the mapping of all but the last, small

Figure 24. Entrance of Jaguar Cave, Tennessee, October 11, 1980. Photo by W. McCuddy.

footprint area at the end of Aborigine Avenue. The photo party concentrated on the Towering Inferno and one or two other parts of the main cave passages to supplement previous photo coverage by Roger Brucker, Mark Elliott, Jim Goodbar, and Ken Russell. A final trip to Jaguar on Thanksgiving Day should complete the footprint mapping and the photographic documentation. Louise Robbins also hopes to complete her series of footprint casts on the Thanksgiving trip by making casts of the three individuals (from a total of 9) whose prints have not yet been recorded in this manner.

*Acknowledgments*

Archeological work in Mammoth Cave National Park in 1980 was facilitated by Superintendent Deskins and Assistant Superintendent James Wiggins; we are grateful to them for their interest and assistance. Research in the Big Bend is made possible and pleasant by the continuing enthusiastic hospitality of Mr. and Mrs. Waldemar Annis (who own the Carlston Annis shell mound), John L. Thomas (Logansport postmaster and manager of the general store), and all the residents in that special part of Butler County around Logansport. In the Jaguar Cave area we are thankful to the owners of the land above the cave—Mr. and Mrs. J.C. Copley, the Misses Lera and Loma Pile, and Mr. James Williams—for their continued cooperation.

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# Sand Cave Archeological Project

**Patty Jo Watson and George M. Crothers**

The Sand Cave Survey is part of an investigation of the 1925 Floyd Collins tragedy. It was decided a thorough study could not be made of the site without also including an analysis of the prehistoric material at the cave entrance.

The site is a small rock shelter (approximately 15 m wide) which forms the entrance to Sand Cave. The aim of the proposed work is to conduct a controlled surface collection from the ground in and around the shelter. Such a collection, using a 1m x 1m grid, will yield information on the density and scatter of artifacts. By taking into account disruptive activities (such as erosion along the drip line as well as historical disturbance), we will be able to make estimates of the intensity of prehistoric occupation, length of occupation, seasonality, and subsistence technology. No excavation is planned in the proposed project, but the results obtained would determine whether future excavations might be significant.

The prehistoric material resulting from the collection is part of a comprehensive archeological survey that will also encompass the recording, collecting, and analysis of historic material in Sand Cave. This historic material stems from the attempts to rescue Floyd Collins, trapped in Sand Cave in January-Feburary of 1925. There is no evidence of prehistoric exploration inside Sand Cave, and the debris there is associated with the 1925 rescue activities.

A trip was made into Sand Cave on August 30, 1980, to look at the historic artifacts. The majority of the artifacts were in two areas. The first was in what is known as the "Artifact Room" or "Turnaround Room". Most of the time was spent in this room making drawings of the artifacts and recording their dimensions. The second area was at the end of the cave, approximately where Floyd Collins was trapped.

The majority of artifacts were glass bottles. Other artifacts include: a Maxwell House Tea can, tobacco tin, a long L-shaped iron rod, fragments of two lanterns, sledge hammer head, an unbroken lightbulb with an intact filament, mason jar, fragment of a white china cup, copper wire, pieces of shoring, various metal fragments, broken glass, and woven fabric. All the artifacts were left in the cave.

# History Program

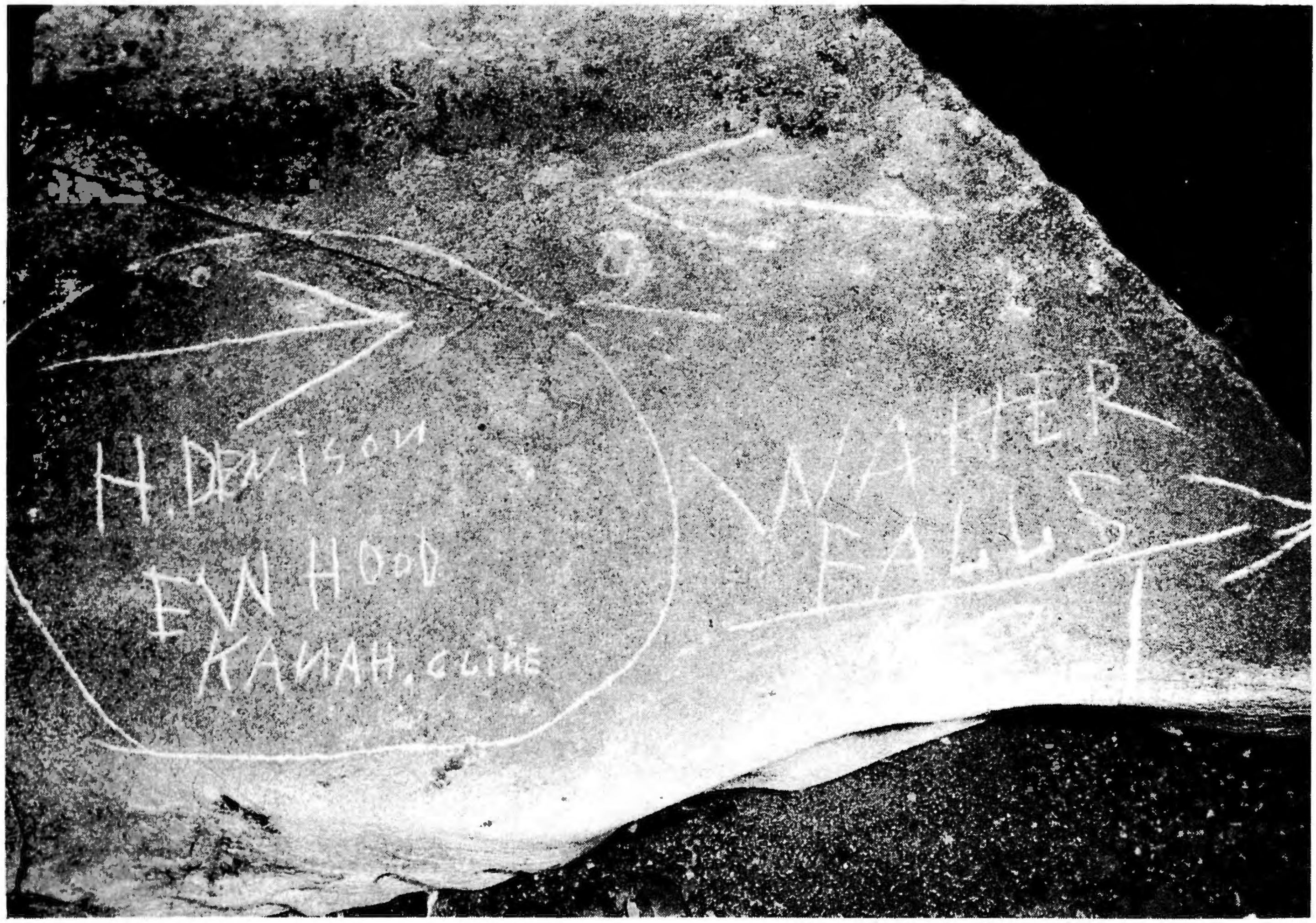


Figure 25. Signatures of early explorers (about 1940) in Waterfall Trail, Crystal Cave. Photo by A.N. Palmer.

# Mammoth Cave and the New Madrid Earthquakes of 1811-1812

**Duane De Paepe**

The New Madrid earthquakes of 1811 and 1812 are regarded as among the most cataclysmic events ever recorded in this country. Initial shocks occurred after 2 AM, monday morning, December 16, 1811; with subsequent major shocks occurring on January 23 and February 7, 1812. The epicenter was located near the town of New Madrid in southwestern Missouri. Thirty to fifty thousand square miles in Arkansas, Illinois, Kentucky, Missouri and Tennessee (Figure 26) suffered the most impact. In this area, permanent landscape deformation resulted in uplifted and depressed topography, including the creation of twelve-mile-long Reelfoot Lake in Tennessee. Local legends recall "the time the Mississippi River flowed backward". Series of major shocks were felt from Canada to New Orleans and all along the eastern seaboard. In Charleston, South Carolina, clocks stopped and church bells rang maniacally. Chimneys collapsed and stone and brick houses became fractured at Pittsburg, Cincinnati, Louisville and St. Louis. Some observers at the time attributed the earthquake to a passing comet—a time-honored harbanger of doomsday theories—which was visible over the midwest from September 5, 1811, to about January 15, 1812. One viewpoint explained that the earth had become positioned between the two "horns" of this comet, resulting in the dramatic seismic events as it attempted to extricate itself (Penick, 1975).

The saltpetre miners in Mammoth Cave, while working their winter season operation, were witnesses to the 1811-1812 shocks, but detailed accounts are limited. Ward (1818) in his imaginative account of the cave remembered:

> "One of my guides informed me he was at the second hoppers (Booths Amphitheatre) in 1812, with several workmen, when those heavy shocks came on which were so severely felt in this country. He said that about five minutes before the shock, a heavy rumbling noise was heard coming out of the cave like a mighty wind; that when that ceased, the rocks cracked, and all appeared to be going in a moment to final destruction. However, no one was injured, although large rocks fell in some parts of the cave".

Considering permanent disturbance left by the shocks, Bretz (1956) postulated that speleothem separation in Fairy Cave, in Stone County, Missouri was caused by the New Madrid earthquakes. This cave is located at approximately the same linear distance away from the epicenter as is Mammoth Cave.

However, a contradictory view of resultant damages was given by Bird (1837):

> "Many shocks—the concussions that succeeded the great New Madrid earthquake of 1811—were experienced by the nitre-diggers while at work in the cave; but though sorely frightened on each occasion, they never saw a single rock shaken from the roof or walls."

Meriam (1844), who participated in the saltpetre mining operation, recorded the earthquake episode, but did not mention underground rock-falls or other damage.

Several years of detailed field investigations in Mammoth Cave to record saltpetre mining sites (De Paepe, 1977) have not found what would appear to be fresh breakdown caused by seismic activity. The 5.1 Richter scale earthquake which occurred on July 27 of this year is reminiscent of these tantalizing insights from the early historic period at Mammoth Cave.

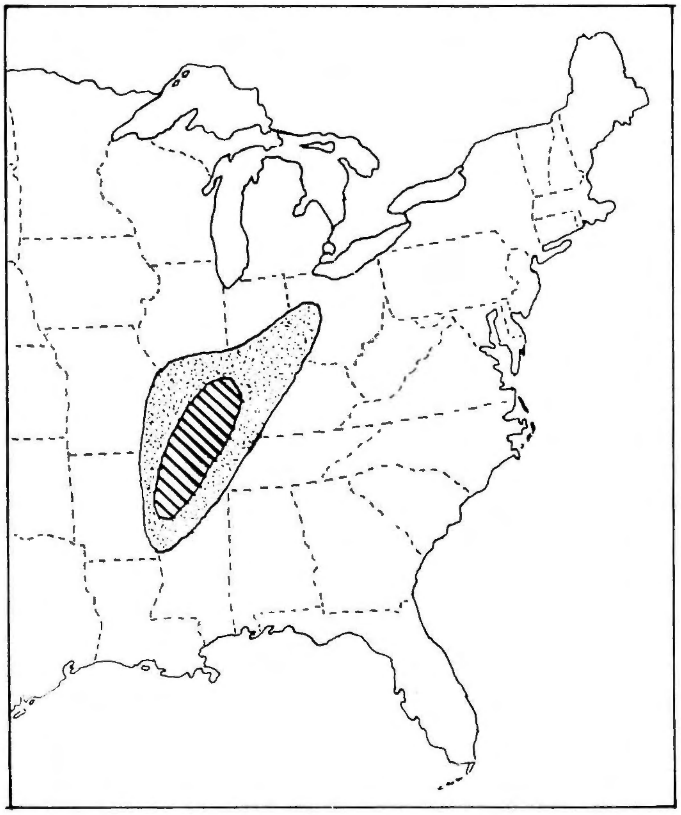

Figure 26. Map of central Mississippi and Ohio River Valleys, showing primary and secondary zones of seismic influence. Adapted from Algermissen, 1969.

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# History of CRF

## Richard A. Watson

The following three historical volumes of materials relating to the origin and the continuation of CRF are being prepared:

CRF: Origins and the first 12 years, 1957-1968
CRF: 1969-1973
CRF: 1974-1978

All three volumes are ready for publication. Volumes II and III consist merely of the annual reports for those years reprinted and rebound. Volume I consists of a number of early papers, several previously unpublished, and reprints of the first ten annual reports 1959-1968.

# Conservation Program

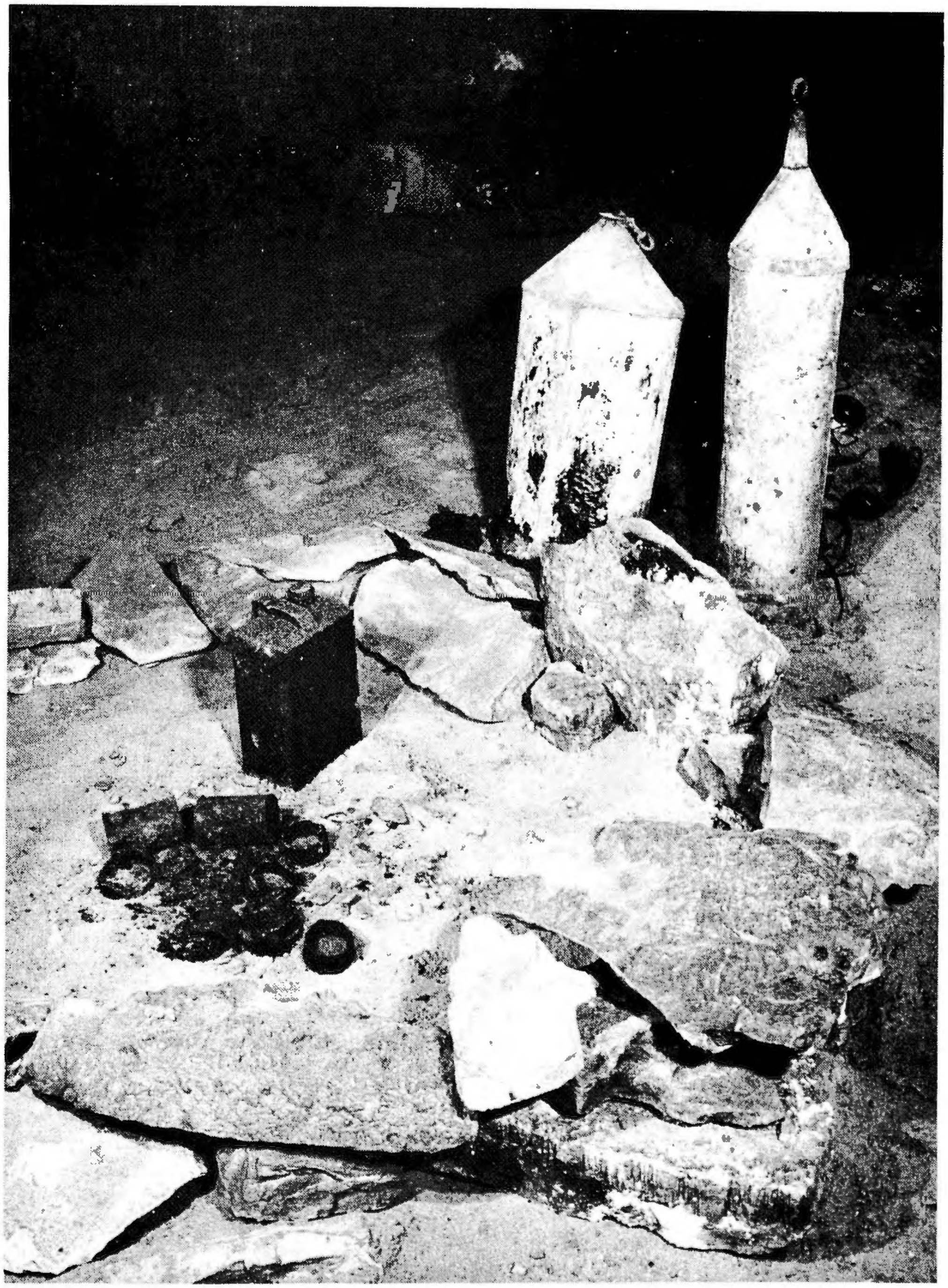

Figure 27. Cast-off equipment from past explorers in the Lost Passage of Crystal Cave. Floyd Collins' bean cans and kerosene can are isolated from traffic by a ring of stones. In the background are a Gurnee can from the 1954 C-3 Expedition and a slender E-can (designed by Burnell Ehman) of a slightly later date. As a conservation measure, all refuse and equipment, except for that which pre-dates the C-3 Expedition, has been removed from the cave by the CRF. Photo by A.N. Palmer.

# Nomination of Mammoth Cave National Park to the World Heritage List

**Sarah G. Bishop**

In December 1980, Olympic National Park, the Wright Brothers National Memorial, and Mammoth Cave National Park became the U.S. nominees to the World Heritage List for 1981. A large portion of the nominating statement for Mammoth Cave National Park was prepared from a Cave Research Foundation document, "The Mammoth Cave region: a nomination for the World Heritage List" published in April, 1980.

The Convention Concerning the Protection of the World Cultural and Natural Heritage established a means by which natural and cultural properties of outstanding universal value to mankind may be recognized and protected. In the nominating document, Mammoth Cave National Park is noted for the following features of universal value:

1) Stages of the earth's evolutionary history are recorded in cave passages,
2) Ongoing geological processes are evident in the 80-square-mile Mammoth Cave region, the premier karst model in the world,
3) The Mammoth Cave System, at 225 miles, is by far the longest-mapped cave in the world. It is known for its unique and rare minerals,
4) The most diverse cave ecosystem in the world exists here, including unique, rare, and endangered species.

Mammoth Cave National Park will join the seven U.S. properties already on the World Heritage List. They are: Everglades, Grand Canyon, Mesa Verde, Redwood, and Yellowstone National Parks, Independence Hall, and a joint listing with Canada—Kluane-Wrangell/St. Elias National Monument. There are presently 85 properties in 53 countries on the World Heritage List.

# Water Resources Management in the Mammoth Cave Area

**Kip Duchon**

It is now known that the Mammoth Cave resource is not limited to the area which was historically recognized as the cave area. Systematic cartographic efforts for the past four decades have found previously unknown areas of the cave system and connections between what were thought to be separate systems. Recent hydrologic research over the past two decades has defined the extent of the Mammoth Cave watershed as well as adjacent watersheds. This information shows that the Flint Mammoth Cave System greatly extends beyond the boundary of the Mammoth Cave National Park. Coincident with the discovery of some major underground streams in the late 1970's was the discovery of water pollution in some streams. This has necessitated the concern for future watershed management to protect the Mammoth Cave research.

Watershed management efforts in the past two years has been a long-term planning effort for future actions and has focused upon two areas, (1) The Environmental Impact Statement prepared by the EPA for the Mammoth Cave Area Sewerage Study, and (2) Lock and Dam Six. CRF involvement on these fronts is primarily as an informational source on area problems rather than in a decision-making level.

### *The Recent Problem*

Prior to establishment of the National Park, much of the Mammoth Cave area was lightly farmed, while the steep slope areas remained forested. The forested areas also separated many agricultural areas and helped prevent some problems resulting from poor agricultural practices that plagued many other areas at the turn of the century. This subsistance farming did not use intensive agricultural management techniques that are practised today. Fertilizers and chemical pesticides were not used, nor were concentrated feedlots. The worst impact was soil erosion, which tended to increase the sediment load to underground streams.

The region surrounding Mammoth Cave National Park has not been a growth area; in fact, population levels have been stable or slightly decreasing for the past fifty years. Migration of rural populations to urban centers has been a long-term trend for the entire southeastern United States and has not been a phenomenon only of this area. Displacement of families during acquisition of lands for Mammoth Cave National Park contributed to this exodus, but was only one of several factors. Concurrent with the urban migration was a reforestation program in the region. This included more than the lands acquired for the National Park, including many areas abandoned as farming families headed for urban centers. Although the local economy suffered, the natural resources benefited from this change in land uses.

As population shifted towards urban communities, the Horse Cave/Cave City corridor benefited through a higher growth rate than the surrounding area. The underground drainage for that corridor drains away from the Mammoth Cave watershed; however, the result has been the severe degradation of the Hidden River Cave System to the east of Mammoth Cave. That cave has suffered both domestic organic pollution from inadequate municipal sewage treatment and industrial wastes, principally metal plating wastes and dairy wastes. Mammoth Cave's good fortune has been another cave system's demise.

Although Mammoth Cave has not been subject to pollution impacts in the past, the projection for the near future is a potentially devastating situation. Urbanization of large portions of the watershed is expected within the next 15 years, with commercial development within the next 10 years between the Park and Cave City. An additional factor is modernization of the area's wide agricultural practices which result in more intensive uses of the land and increased use of fertilizers and chemical pesticides, etc. The combined effects of these potential pollution sources can upset the ecological balances that presently exist.

### *EPA Sewerage Study*

For the past two years, the Environmental Protection Agency has sponsored the preparation of an Environmental Impact Statement for Sewerage Needs in the Mammoth Cave Area. This study is part of the 201 Facilities Planning Program under PL 92-500. The study area includes the communities of Park City, Cave City, Horse Cave and Munfordville, as well as Mammoth Cave National Park. The study has been a highly complex one in that several consultants have provided input and a citizen's advisory committee has helped in making decisions.

The progress of the study is currently hindered due to several complications. The first is the lack of agreement among the participating organizations as to which plan is to be selected. This depends upon the other two considerations. The second complication is the need for a decision by the National Park Service as to what level of financial participation in the selected plan can be expected from them. This is subject to the results of Master Planning Implementation by the National Park Service. A last complication is the need for a decision by the State of Kentucky on acceptable levels of water quality in area streams. This will determine what amounts, if any, of pollutants can be discharged into area streams.

The last point is presently being discussed between the CRF, the State of Kentucky, and the Federal Environmental Protection Agency. CRF has recently proposed that Kentucky re-designate all underground streams in the Mammoth Cave area and the Green River from Munfordville to Brownsville as "Outstanding Resource Waters" which would enhance protection and prevent legal discharges of wastewaters to underground streams. CRF and the State of Kentucky are presently discussing required documentation.

### *Lock and Dam Six*

The U.S. Army Corps of Engineers constructed a navigation lock and dam on the Green River just downstream of the western side of what is now Mammoth Cave National Park in 1906. This was the furthest upstream of several navigation structures. In the early 1950's this structure was deactivated and abandoned.

Recently, the Corps has been conducting a water-management study for the Green River. This study is not yet complete. CRF proposed to the Corps that this abandoned structure be removed and the river allowed to revert to its former state. In January, 1980, a Draft Environmental Assessment was given to the Corps for their review. Nothing has been decided on this matter since that time, due to federal budgetary cutbacks this year.

### *1981 Prospect*

CRF expects to continue to press both these studies forward in the coming year. It will also be necessary to review the revised implementation plans of the National Park Service for the Master Plan for Mammoth Cave National Park and how that will affect area water resources. It is believed that many of the delays in regional studies will be resolved in the coming year, with implementation strategies assuming a greater importance. Innovative solutions to the area's problems may be necessary to adapt to limited finances in an era of Federal Budgetary cutbacks.

# 1980 National Cave Management Symposium

**James Goodbar**

Blue Kentucky skies and brilliant autumn colors were the setting for the 1980 National Cave Management Symposium hosted by Mammoth Cave National Park. The symposium was well attended by nearly 100 land managers, scientists, cave owners, and others interested in cave management. Participants came from all reaches of the United States and British Columbia. The welcoming address was given by Mammoth Cave National Park Superintendent, Robert Deskins, and the keynote address was delivered by Jay Gogue, the National Park Service's regional chief scientist.

A new topic in this year's symposium was the issue of karst and cave protection in urban and developed land areas, with sessions on the hydrologic impact of land development in karst areas, karst management in urban areas, and subsurface movement of pesticides in karst areas. Other sessions were held in cave-guide training and cave interpretation and a panel discussion on the management problems of private caves. One full day was given to the case study of specific management problems such as cultural resource management, evaluation and management of cave bone deposits, the endangered Kentucky blind cave shrimp, the ecology of Hawaiian lava tubes and many more. The final day presented sessions on underground wilderness, radiation hazards in caves, cave restoration, formulating cave management plans, and others. Evenings offered field excursions to Mammoth Cave led by National Park Service personnel.

The symposium was attended by more than 15 CRF JV's and members. Participants from CRF at the symposium are as follows: Bill Austin, Tom Bemis, Roger Brucker, Patty Daw, Kathleen Dickerson, Jim Goodbar, J.B. Hummel, Ernst Kastning, Ron Kerbo, Julian Lewis, Ed Lisowski, John Mylroie, Gordon Smith, Michael and Susan Warshauer, and Ronald Wilson.

Copies of the proceedings can be obtained by writing Ron Wilson, Department of Biology, University of Louisville, Louisville, Kentucky, 40292.

# Interpretation and Education Program

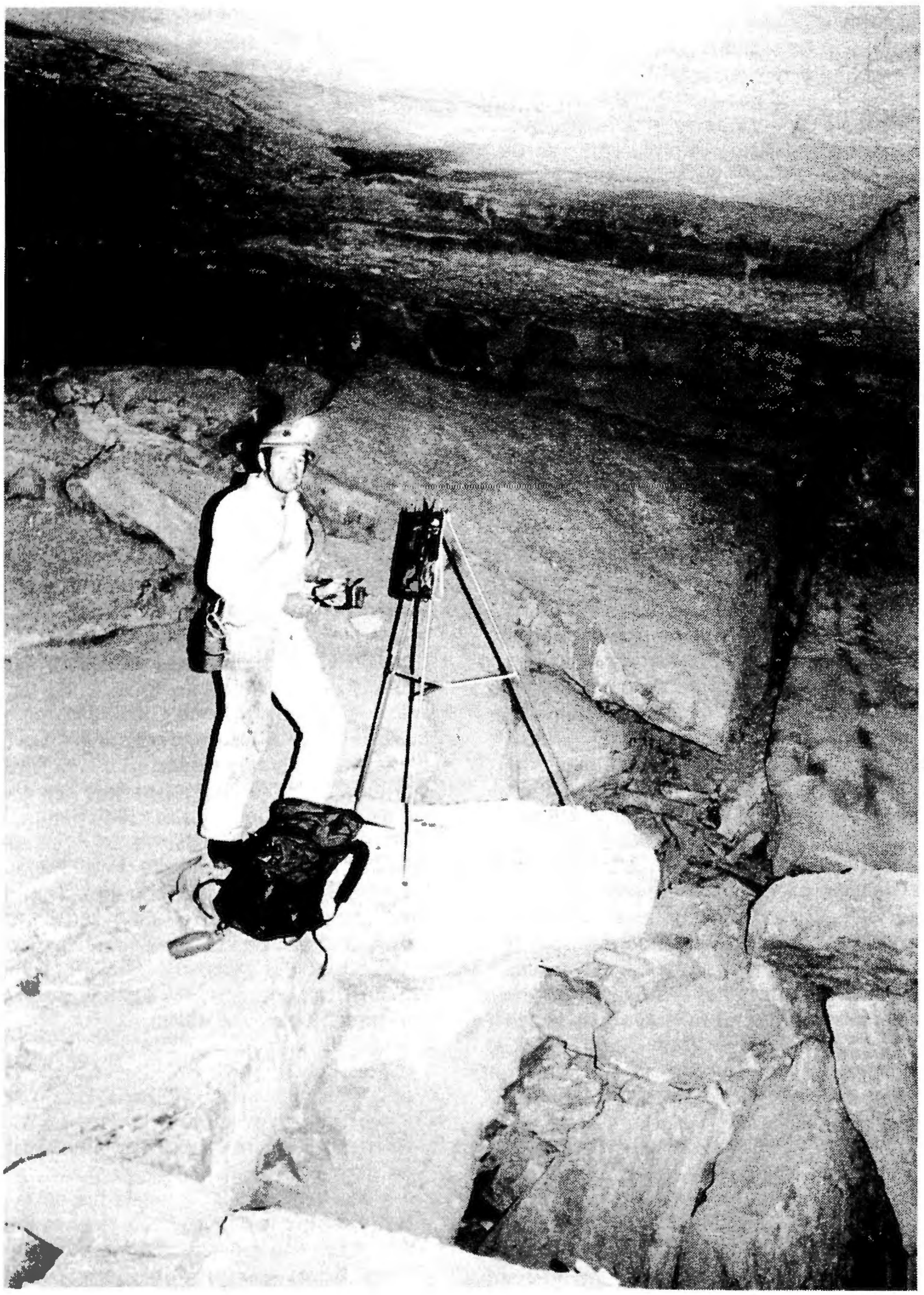

Figure 28. Jean Truel painting in Floyd Collins Crystal Cave, August 1980. Photo by Hauvlette Truel.

# Summer University in the Park

Dr. Nicholas Crawford, associate professor and director of the Center for Cave and Karst Studies at Western Kentucky University in Bowling Green, in cooperation with Mammoth Cave National Park, coordinated a series of one-week summer courses focusing on cave and karst landscapes. The series of courses lasted from June 9-July 5 at Mammoth Cave National Park. The courses could be audited or taken for three hours of undergraduate or graduate credit. Visiting professors were chosen who were internationally recognized as authorities in their field and were also excellent teachers. Courses relied heavily on field observations and techniques with formal lectures and texts used as a secondary source of information. The courses offered were as follows:

Roger Brucker—Speleology
Derek Ford—Karst Geomorphology
Thomas Barr—Cave Ecology
James Quinlan—Karst Hydrology
Arthur Palmer—Karst Geology

The help of Whit Crawford and Jim Goodbar contributed to the smooth operation of all the courses. The courses were highly successful and received enthusiastic evaluations from students, and a similar program will be given again in the summer of 1981.

# CRF Support for the Eighth International Congress of Speleology

The Cave Research Foundation is one of the cooperating organizations for the 1981 International Congress, and approximately half of the 48 officers and activities chairmen are affiliated with CRF. Congress activities coordinated by CRF as a group are listed below:

Caving camps will be offered at the Flint Ridge field station, one during each of the two weeks preceding the Congress, led by Roger Brucker, Pete Lindsley, and Richard Watson.

Caving in the Guadalupes will be offered at a post-Congress camp at Carlsbad Caverns National Park, organized by Robert Buecher, Carol Hill, Doug Rhodes, Ron Bridgemon, and Ron Kerbo.

Two four-day science camps will be proved at the Flint Ridge field station after the Congress. Geology/speleogenesis, archeology, and biology will be emphasized. Leaders are Arthur Palmer, Patty Jo Watson, and Thomas Poulson.

During the Congress a two-hour, slide-illustrated presentation will be given on CRF research and cartography activities. This event is coordinated by Thomas Poulson, with individual talks by specialists in the various fields.

A science-oriented tour of the Historic Route of Mammoth Cave will be offered for all Congress attendees on the Monday of the main Congress week. The trip is organized by Arthur Palmer, Margaret Palmer, and William White. A descriptive guidebook has been prepared by them specifically for this event. Approximately seven separate tours will be led by CRF and Park Service personnel; and CRF members specializing in various scientific and historical aspects of the cave will be stationed at key spots along the tour route to provide short discussions.

During June and August, 1981, the Flint Ridge field station will be available for foreign speleologists who wish to pursue research in the Mammoth Cave area. CRF will provide guides and field assistance. Research in the geosciences, archeology, and biology/paleontology is being coordinated by Arthur Palmer, Patty Jo Watson, and Thomas Poulson respectively.

# Emergency and First-Aid Supplies at Mammoth Cave National Park: Safety Officer Report

**Kenneth Sumner**

Over the years, CRF has maintained an impressive safety record. Among our precautionary measures we carry a compact first-aid kit and maintain Emergency Rescue Equipment on the surface. Fortunately, this equipment has not been required. However, these supplies have been depleted, lost, or stolen. One such incident in mid-1979 seriously damaged our capability to conduct an in-cave rescue. For a period of time, we have trusted our skills and luck without the benefit of adequate safety equipment.

Late in 1979, a program was instituted to correct the safety supply situation, starting with the appointment of Ken Sumner as Safety Officer. The task has required a great deal of time and money to bring our supplies up to an acceptable level. It was therefore necessary to establish priorities and an ambitious schedule to implement the priorities.

### *First Aid Kits*

The first task to be performed was construction of a sufficient quantity of cave-party first-aid kits. The restrictions on the kits included: physical size limitations, simplicity of use, ease of replenishment, ruggedness, and re-useability.

CRF had considerable experience with the former first-aid kits. However, those older kits were quite elaborate in that injectable medications and similar supplies were included. It was decided that these more exotic medications had proved to be a disadvantage, for the average JV could not adequately utilize them and was largely reluctant to open the kit for minor problems. In addition, the kits were very well packed and sealed, but once opened could never be reassembled, especially in the cave.

With none of the older kits remaining, it was decided to use a new approach. The kits were to be designed with medications that require no specialized knowledge to apply or maintain. It is believed that should injuries of a more serious nature arise, proper medical attention and supplies could be quickly brought in and administered. Therefore, the contents of the first-aid kits should serve to provide comfort to the distressed person until the more experienced medical help could arrive. In addition, past experience has shown that the bulk of first-aid requirements has been to relieve minor cave-related problems such as cuts, headaches, and other mundane ailments. Therefore, the kits should not be so complex as to discourage their use in these situations.

A "Tupperware" sandwich box measuring five inches square by one and a half inches deep was selected as the container for the first-aid kits. These can be readily carried in a small cave pack, along with the other standard supplies. They are essentially waterproof and can be easily resealed in the cave. The kits were prepared using some donations which significantly reduced the cost to the Foundation in preparation, resulting in a savings of 60% over the market value. A list of the contents and cost breakdown is shown in Tables 9 and 10.

After completion of the first ten units, a field evaluation period will be conducted to determine the suitability of the kit contents. An additional ten kits as backup supply will be completed for use on a rotating basis. Thus, an adequate number of fresh first-aid kits will be maintained in service at Mammoth Cave National Park. To aid in use of the kits, a poster using photographs and text has been prepared and is displayed in the Austin House at Mammoth Cave National Park.

*Emergency Rescue Supplies*

The emergency rescue supplies are seriously depleted. Due to a break-in and subsequent theft, these supplies are very low at present. An inventory was conducted in early 1980 to determine the extent of damage. It was discovered that the majority of missing equipment, though costly, could be replaced. Equipment such as special bandages, splints, and litters were left intact. Equipment such as jacks, pry bars, and carabiners have been purchased to replenish our rescue supplies. While this project has not been completed, it is nearing 70% completion and should be finished before mid-1981.

Additional rescue equipment is also being added to the list as the need becomes apparent. Our aim is to be adequately prepared for each contingency but not to duplicate those items that would be made available to us should a rescue become necessary.

A more secure area for stockpiling of the emergency supplies is being considered, but the removal of the Job Corps Camp may significantly reduce the threat. Careful evaluation is required in order that these supplies will be quickly available in the event of an emergency. Also, it is important that frequent inspections be made.

*Future Projects*

Upon the completion of the Emergency Equipment and First Aid Kits, another area of concern is the "In-Cave Supply Caches". These are in need of inspection, while still other areas of the cave system require a complete assembly of supplies. This project will be implemented with as much expediency as possible, but will require some additional time and thought. Particular concern is being given to a major supply spot in the Hawkins River and Proctor Cave areas. This will be the first area of concentrated effort. Possibly the project may begin in early to mid-1981.

**TABLE 9**

**First-Aid Kit Contents**

| | |
|---|---|
| Tupperware sandwich box | |
| Space blanket | |
| 2x2 gauze sponges | 2 per kit |
| Aspirin tablets | 8 per kit |
| Tylenol tablets | 4 per kit |
| No-Doz tablets | 6 per kit |
| Antacid tablets | 4 per kit |
| Band-aids | 4 per kit |
| Adhesive tape | 5-10 yard roll |
| Ammonia inhalent | |
| Scissors | |
| Tweezers | |
| Foille antiseptic ointment | |
| Alcohol prep pads | 5 per kit |

**TABLE 10**

**Approximate Cost**

| | |
|---|---|
| Market value of supplies | $236.00 |
| Average cost per first-aid kit | $12.00 |
| Donations (medications, containers, etc.) | $147.00 |
| CRF expenditure | $89.00 |
| Actual cost per kit (less donations) | $4.50 |

Continuing projects are being implemented to maintain and improve our safety record and rescue preparedness. During 1980, some of these have occurred, with more planned. Some of these include: vertical training (in cave), simulated cave rescues, call-outs and practices at unspecified intervals. It is hoped that through these programs our skills will increase and our safety record will remain good. Overall, the establishment of emergency supplies, first aid kits, and safety training will be on-going for many years but is progressing satisfactorily for the moment.

We have been exceedingly fortunate in our cave endeavors and this is a direct result of successful CRF methods. Our choices of personnel and their skills have made for a very clean record, but we must maintain an adequate level of rescue and first-aid supplies. We must continuously train ourselves to a competent level of rescue preparedness.

# CRF Sponsorship of Artists

## Richard A. Watson

Jean Truel, 27 rue Selferino, 34500 Beziers, France

Jean and Hauviette Truel spent three weeks in August, 1980, as guests of CRF. Jean made more than 100 watercolor sketches in the Flint Ridge Cave System, Owl Cave, Hidden River Cave, and other caves in the Mammoth Cave area. He was provided assistance by Richard A. Watson, Patty Jo Watson, Anna M. Watson, Christine Gerace, and William T. Austin. He is now making oil paintings from his sketches for exhibition at the Eighth International Speleological Congress.

Donald Finkel, Dept. of English, Washington University, St. Louis, MO 63130

Donald Finkel was awarded the $2500 Morton Dauwen Zabel Award for his contributions as "a poet of progressive, original, and experimental tendencies" by the American Academy and Institute of Arts and Letters in New York on 21 May, 1980. This is in part for two books he wrote with CRF support: *Answer Back* (NY: Atheneum, 1968) and *Going Under* (NY:Atheneum, 1978).

Robert Wykes, Department of Music, Washington University, St. Louis, MO 63130

Robert Wykes is recording water noises in the Flint-Mammoth Cave System. He will use this as a base for composing electronic music for the Eighth International Speleological Congress. CRF is providing a small grant (sum not yet determined but not over $350) to cover costs.

Sheldon S. Helfman, Dept. of Architecture, Washington University, St. Louis, MO 63130

Sheldon Helfman will make at least two trips into the Flint-Mammoth Cave System in the following year, and at least one in 1980, to continue his painting. He completes most of his watercolor paintings in the cave.

# Publications and Management

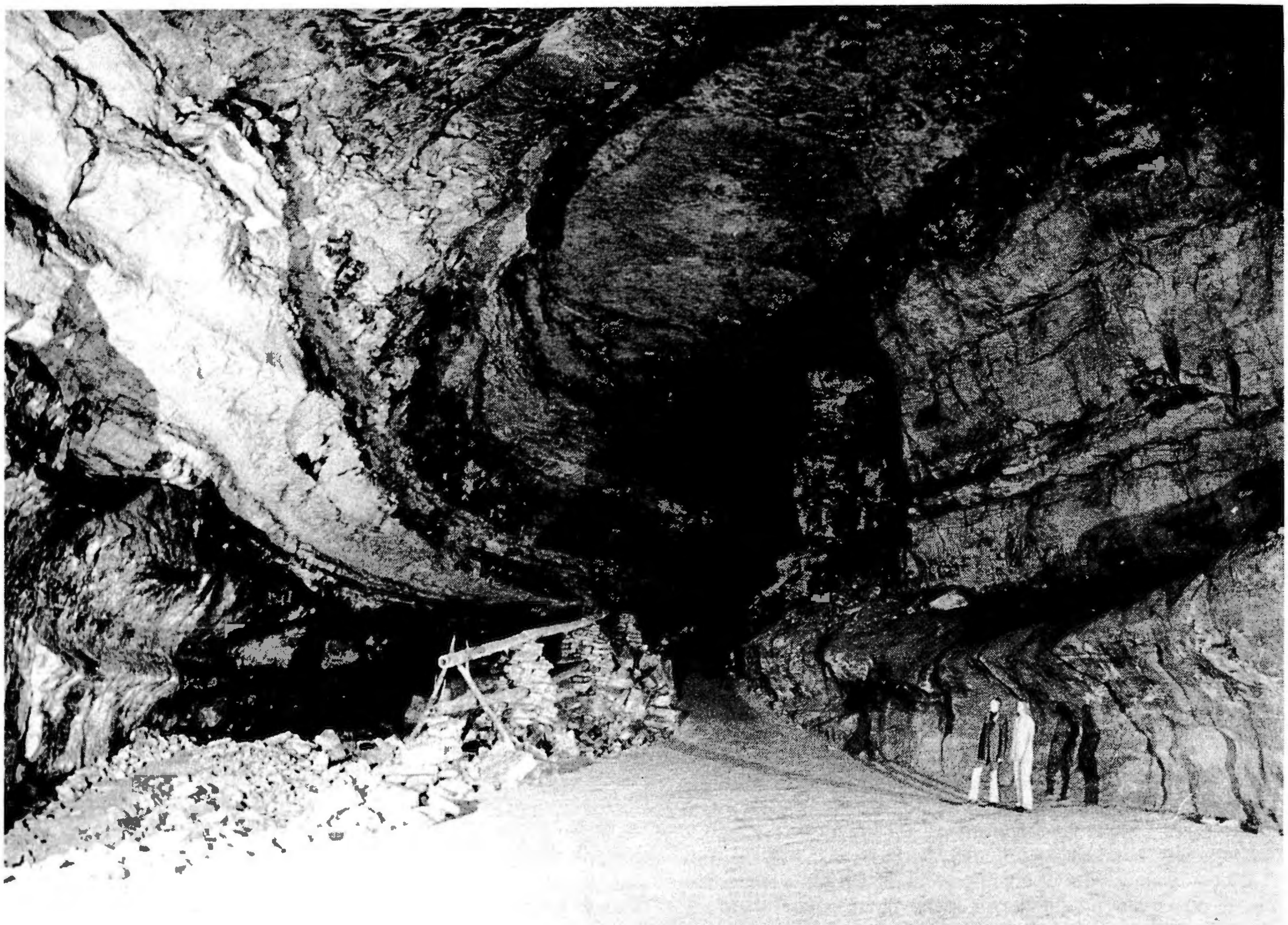

Figure 29. The highest levels in Mammoth Cave are broad, canyon-like passages, formed during the late Tertiary Period, 2-20 million years ago, by large but slow-moving underground streams. This kind of passage indicates long periods of very slow deepening of the Green River valley, into which the underground streams flowed. Sediment on the floor reaches thicknesses as great as 25 meters as a result of periodic rises in river level. Well-preserved remnants of saltpeter workings from the War of 1812 are also shown here. Photo by A.N. Palmer.

## THESES

Carstens, K.C., 1980, Archaeological investigations in the Central Kentucky Karst (unpublished Ph.D. thesis): St. Louis Missouri, Washington University, Department of Anthropology.

Quinlan, J.F., 1980, Types of karst (unpublished Ph.D. thesis): Austin, Texas, University of Texas.

Stein, Julie, 1980, Geoarchaeology of the Green River shellmounds (unpublished Ph.D. thesis): Minneapolis, Minnesota, University of Minnesota, Center for Ancient Studies.

## ARTICLES

DePaepe, Duane, 1980, Saltpetre production from Indiana cave sediments: an important early regional industry: Indiana Military History Jour., v. 5, no. 3, p. 23-25.

Des Marais, D.J., 1979, Geology of limestone caves: Proceedings of the 1979 Far Western Cave Management Symposium, held in Redding, CA, October 23-25, 1979, Natl. Speleo. Soc.

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———, Tinsley, J.C., McCoy, Gail, Rogers, B.W., and Ulfeldt, S.R., 1980, The contribution of Lilburn Cave to the natural history of Sequoia and Kings Canyon National Parks: Proceedings of the Conference on Scientific Research in the National Parks (2nd), held in San Francisco, CA, National Park Service, Washington, D.C., v. 5, p. 347-364.

Hill, C.A., 1980, Speleogenesis of Carlsbad Caverns and other caves of the Guadalupe Mountains: unpublished report to the National Park, Forest Service, and Bureau of Land Management, 201 p.

Lavoie, K.H., 1980, Toxicity of carbide waste to heterotrophic microorganisms in caves: Microbial Ecol., v. 6, p. 173-181.

Lewis, J.J., 1980, A comparison of *Pseudobaicalasellus* and *Caecidotea*, with a description of *Caecidotea bowmani*, n. sp. (Crustacea: Isopoda: Asellidae): Proceedings of the Biological Society of Washington, v. 93, no. 2, p. 314-326.

Lindsley, Pete, 1980, Carlsbad Caverns: the CRF view: Natl. Speleol. Soc. News, v. 38, no. 11, p. 301-303.

Rogers, B.W., 1980, Survey and assessment of karst resources in Sequoia and Kings Canyon National Parks, California: CRF report of investigations, 328 p.

Watson, R.A., 1980, Comment a été topographiée la plus longue grotte du monde: Spelunca, v. 4, no. 2, p. 73-74.

Welbourn, W.C., 1976, Invertebrate fauna of the earth cracks of Wupatki National Monument, Arizona, *in* Linn, R.M., ed., Proceedings of the First Conference on Scientific Research in the National Parks, National Park Transaction and Proceedings Series: v. 1, no. 5, p. 387-391.

## MEETING PRESENTATIONS AND ABSTRACTS

Brucker, R.W., 1980, Current problems in cave management (abs.): Fifth National Cave Management Symposium, Mammoth Cave National Park, October.

Carstens, K.C., 1980, An historical overview of cultural resource management in the Mammoth Cave National Park area (abs.): Fifth National Cave Management Symposium, Mammoth Cave National Park.

Goodbar, J.R., 1980, Management techniques for wilderness caves (abs.): Fifth National Cave Management Symposium, Mammoth Cave National Park.

Hummel, J.B., 1980, Practicability of the underground wilderness concept (abs.) Fifth National Cave Management Symposium, Mammoth Cave National Park.

Lewis, J.J., 1980, Aquatic ecosystems and management problems in the Mammoth Cave region (abs.): Fifth National Cave Management Symposium, Mammoth Cave National Park.

Lisowski, E.A., 1980, The endangered Kentucky blind cave shrimp (abs.): Fifth National Cave Management Symposium, Mammoth Cave National Park.

Marquardt, W.H., and Watson, P.J., 1980, The Shell Mound Archaic of western Kentucky: Midwest Archaeological Conference, Chicago, Illinois, October.

Quinlan, J.F., 1980, Sinks, stinks, and springs: a summary of the hydrogeology of the Mammoth Cave region—with emphasis on techniques, results, and applications of National Park Service-sponsored research (abs.): Fifth National Cave Management Symposium, Mammoth Cave National Park.

Watson, P.J., 1980, The beginnings of horticulture in the Eastern Woodlands, Austin, Texas, Department of Anthropology, University of Texas, April.

Wilson, R.C., 1980, The recognition, evaluation, and management of cave bone deposits (abs.): Fifth National Cave Management Symposium, Mammoth Cave National Park.

## SEMINARS

Rogers, B.W., 1980, Speleology and geology of Sequoia and Kings Canyon National Parks: one-week seminar at Sequoia and Kings Canyon National Parks, August.

Lewis, J.J., 1980, The zoogeography and evolution of the subterranean invertebrates of Illinois and southeastern Missouri: seminar given to the Department of Biology, Louisville, Kentucky, University of Louisville, February.

————, 1980, Aquatic communities in the world's longest cave: seminar given to the Department of Biology, Louisville, Kentucky, University of Louisville, October.

Watson, P.J., 1980, The origins of horticulture in the upland drainages of the midwest-midsouth: Advanced seminar on "Origins of late husbandry in North America", Santa Fe, New Mexico, School of American Research, March.

## TALKS

DeMarais, D.J., 1979, Geology of limestone caves: 1979 Far Western Cave Management Symposium, Redding, CA, October.

————, 1979, Lilburn Cave—a resource for Park interpretation, talk given to National Park Service staff at Sequoia and Kings Canyon National Parks, Three Rivers, CA, November.

————, 1980, Caves of the southeastern United States, talk given to San Francisco Bay Chapter of the Natl. Speleol. Soc., May.

————, Tinsley, J.C., McCoy, Gail, Rogers, B.W., and Ulfeldt, S.R., 1980, The contribution of Lilburn Cave to the natural history of Sequoia and Kings Canyon National Parks: Conference on Scientific Research in the National Parks (2nd), San Francisco, CA.

Kerbo, Ron, 1980, Cave management at Carlsbad Caverns National Park, Fifth National Cave Management Symposium, Mammoth Cave National Park, Kentucky, October.

Lewis, J.J., 1980, Caves and cavernicoles in the eastern United States, slide presentation and talk given to the Louisville Natural History Soc., March.

Mylroie, J.E., 1980, the 1981 International Cave Management Symposium, Fifth National Cave Management Symposium, Mammoth Cave National Park, Kentucky, October.

Rogers, B.W., 1980, Sequoia and Kings Canyon National Parks karst inventory, San Francisco Bay Chapter Natl. Speleol. Soc., Sept.

## SERVICE

Rogers, B.W., 1980, Karst inventory planning, Sequoia National Park, consulting, October.

Field excursion in Mammoth Cave: "Historic" Tour led by National Park Service Personnel; archeological, biological and paleontological commentary provided by Julian Lewis and Ronald Wilson, during Fifth National Cave Management Symposium, Mammoth Cave National Park, Kentucky, October, 1980.

# CRF Fellowship and Grant Support

Each year the Foundation sponsors a karst-related Research Fellowship ($750) and/or Grant ($300) for 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 a command of the literature and methodology. A detailed announcement is mailed on 1 January, and the deadline for the receipt of the detailed proposal, supporting documents, and letters of reference is 15 February. Announcement of the award is 15 March. Send proposals in triplicate to Dr. David J. DesMarais, Mail Stop 239-12, NASA-Ames Research Center, Moffett Field, California, 94035.

In 1980 the following awards were given:

Meta Harker, Department of Biological Sciences, University of Kentucky, for her project entitled: Competitive exclusion and character displacement in *Pseudanophthalmus* of the southern Pennyroyal.

Robert Wykes, Washington University in St. Louis, Missouri, for his project: recording water sounds in the Flint-Mammoth Cave System.

# Field Operations

| AREA | Number of Expeditions | Number of Field Days | Frequency of JV Attendance |
|---|---|---|---|
| Mammoth Cave National Park | 48 | 209 | 438 |

# Management Structure

## DIRECTORS

R. Pete Lindsley, President
Sarah G. Bishop, Executive Director
Roger E. McClure, Treasurer
Rondal R. Bridgemon, Secretary
Thomas L. Poulson, Science Chairman
Charles F. Hildebolt, Operations Manager for the Central Kentucky Area
W. Calvin Welbourn, New Projects Operations Manager
Robert H. Buecher, Operations Manager of the Guadalupe Escarpment Area
David J. Des Marais
Kip K. Duchon
Roger W. Brucker

## OFFICERS AND MANAGEMENT PERSONNEL

General:

| | |
|---|---|
| Newsletter | Jennifer A. Anderson |
| Personnel Records | William F. Mann |
| Cave Books | Claire B. Weedman |

Central Kentucky Area Management Personnel:

| | |
|---|---|
| Manager | Charles F. Hildebolt |
| Personnel | Walter A. Lipton |
| Cartography | Richard B. Zopf |
| Medical | Stanley D. Sides |
| First Aid and Emergency Supplies | Ken Sumner |
| Supplies | Tomislav M. Gracanin |
| Vertical Supplies | Lynn M. Weller |
| Survey Gear | Tomislav M. Gracanin |
| Field Station | Robert O. Eggers, Roger L. McMillan |
| Log Keeper | Kathleen Dickerson |

Guadalupe Escarpment Area Management Personnel:

| | |
|---|---|
| Manager | Robert H. Buecher |
| Personnel | John S. McLean |
| Cartography | Joseph V. Repa |
| Safety | Don P. Morris |
| Finance and Supply Coordinator | Linda Starr |
| Field Station | Ron Kerbo |
| Log Keeper and Survey Book Coordinator | Diana Northup |

California Area Management Personnel:

| | |
|---|---|
| Manager | Stanley R. Ulfeldt |
| Personnel | Luther Perry |
| Cartography | Ellis Hedlund, Lee Blackburn |
| Safety | Howard Hurtt |
| Karst Inventory | Bruce W. Rogers |
| Science | David Des Marais, John C. Tinsley |

Arkansas Project Management Personnel:

| | |
|---|---|
| Manager | W. Calvin Welbourn |
| Area Coordinator | Paul Blore |
| Cartography | Ron Bridgemon, Bob Buecher, Debbie Buecher |

## Operating Committees

*Administration Committee*: Sets goals, identifies problems, and evaluates progress in the operation of the Foundation. Present membership is:

Robert H. Buecher, Chairman
R. Pete Lindsley
Roger W. Brucker
W. Calvin Welbourn
Rondal R. Bridgemon

*Finance Committee:* Drafts Foundation budgets provides advice to Treasurer, and seeks sources of funds to support Foundation programs. Present membership is:

Roger E. McClure, Chairman
Roger W. Brucker
William P. Bishop
David Des Marais
Charles F. Hildebolt
L. Kay Sides
Linda Starr
W. Calvin Welbourn

*Interpretation and Information*: Deals with the dispersal of information in a form suitable for the public. This includes the areas of training sessions for guides and naturalists, the preparation of interpretive materials and slide programs, and local library interface. Present membership is:

Ronald C. Wilson, Chairman
Thomas L. Poulson
Donald E. Coons
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*Conservation*: Acts as the Foundation's liaison with all aspects of the conservation movement, including Wilderness Hearings, and maintains contact with conservation organizations. Present membership is:

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R. Pete Lindsley
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*Initiatives*: Is a special committee charged with stimulating long range thought about "provocative and risk" future directions. Present membership is:

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

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