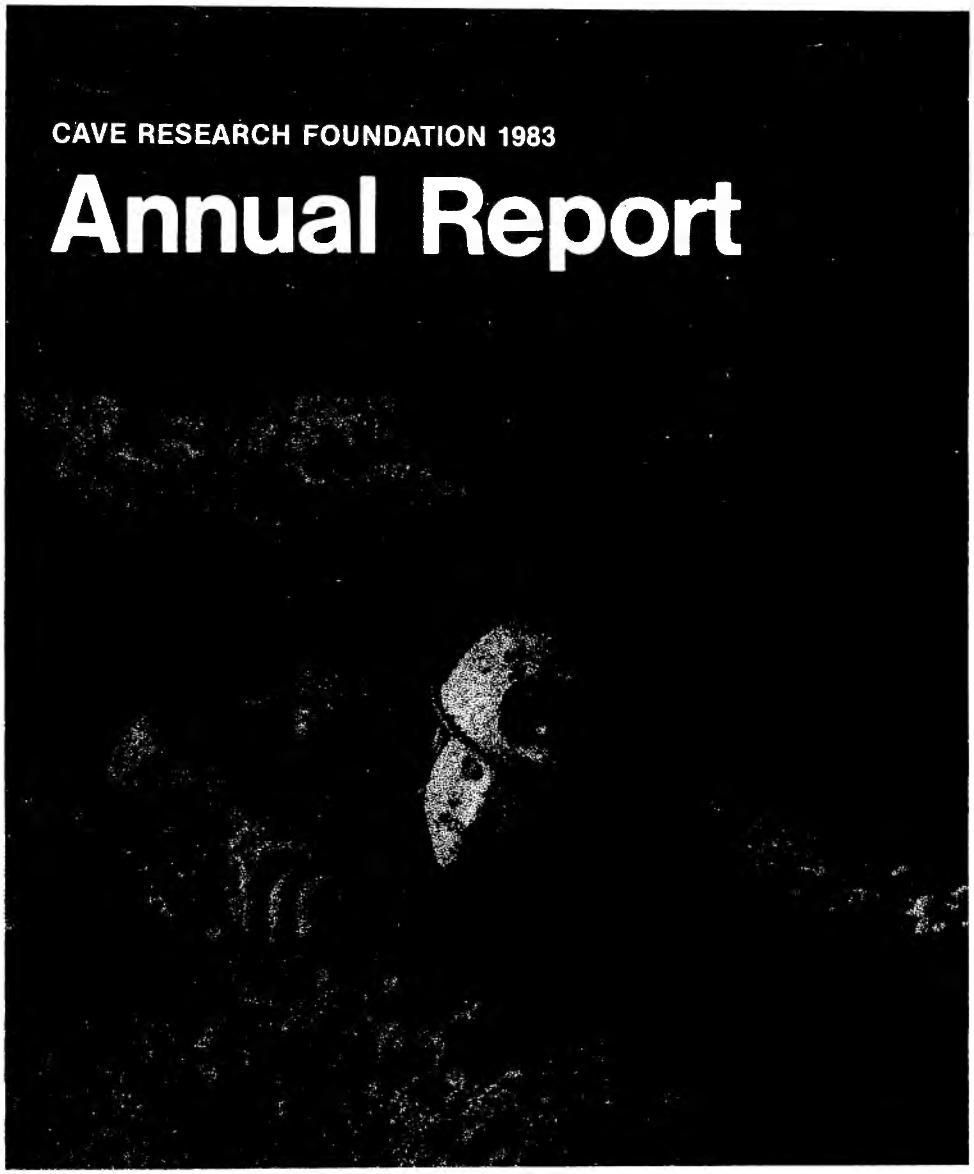
CAVE RESEARCH FOUNDATION 1983

Annual Report



Cave Research Foundation 1983 Annual Report

Cave Research Foundation
4916 Butterworth Place NW
Washington, DC 20016

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

Cover: Great Onyx Cave, Mammoth Cave National Park, Kentucky. Photo by K. Lavoie

ISBN 0-939748-15-0

Printed by

ADOBE PRESS, INC.

Albuquerque, New Mexico
USA

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CAVE CONSERVATION

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

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 And many of the processes that formed the cave passages that we travel are no longer active in the same places.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

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

Acknowledgments

Many of the projects outlined in this Report have been conducted within the boundaries of public lands. The support and encouragement of the Superintendents and staffs at Mammoth Cave National Park, Carlsbad Caverns National Park, Guadalupe Mountains National Park, Sequoia-Kings Canyon National Park, Grand Canyon National Park, Lincoln National Forest, Buffalo National River, and Ozark-St. Francis National Forests have greatly contributed to the success of these projects. Their assistance is greatly appreciated.

The Editor wishes to thank all of the Contributors to the 1983 Annual Report for their efforts. Janet Edwards printed all of the photographs taken by K. Lavoie that were used in this issue. Special thanks to Jim Lavoie, John Tinsley, Tom Poulson, Doug Rhodes, Art Palmer, and Peg Palmer for their extra efforts and advice in editing this Report.

Other acknowledgements appear at the end of some reports.

President's Report: Highlights of 1983

There were several newsworthy events for the Cave Research Foundation in 1983: another big connection in Mammoth Cave, a major change in commitment in our publishing program, an astonishing assessment of the value of our volunteer efforts, and some precedent-setting discussions with senior administrators in the Park Service, including the Director, Russell E. Dickenson. These events and other activities are summarized here and presented in greater detail in the reports that follow.

Exploration and Cartography

Mammoth Cave Region—On September 10, 1983, Roppel Cave, which was almost 50 miles long, was connected to Mammoth Cave. The resulting cave is 294.4 miles long, three times longer than the next longest cave in the world. The connection was a joint effort among the Cave Research Foundation, the Central Kentucky Karst Coalition, and a group of researchers working for Dr. James Quinlan, an NPS scientist. Two new "map factories" have started up and products such as a base-level map of Mammoth Cave, major revisions to the Salts Cave map, and a detailed presentation of Brucker Breakdown have begun to emerge.

Projects in Arkansas—CRF published a superb set of maps of caves in the Ozark-St. Francis National Forests to accompany a report on the second phase of a contract with the United States Forest Service. Work on a third phase is underway.

Lilburn Cave—More than a mile of cave was surveyed in 1983 bringing to the halfway point the enterprise of accurately surveying all the known passages in the cave. The 100 survey loops have been checked on a computer and errors corrected.

Guadalupe Area—Although more effort supported research than mapping projects, a unique project to map Carlsbad Caverns in vertical profile was begun. To date profiles have been completed for the commercial part of the cave from the Natural Entrance across the Mystery Room and for the Guadalupe and New Mexico Rooms.

Computers are playing an increasingly important role in the Foundation's cartography programs. A large enough portion of the data base from Mammoth Cave surveys is in machine-readable form that research questions, such as, "where can I find an example of such and such," may be answered. Twenty-five percent of the data collected in Carlsbad Caverns is now stored in CRF computers. A next important step is to make the exchange of information possible among a myriad of computers available to us.

Scientific Studies and Conservation

Work in the areas of geosciences, ecology, and archeology, anthropology, and paleontology progressed during the year. Specific projects are noted in several states and mainland China. Studies begun several years ago on the Mammoth Cave Blind Shrimp (*P. ganteri*) revealed so small a community that the species was declared endangered by the Department of Interior in October. The shrimp's preferred breeding habitat and susceptibility to changes in water quality are candidates for further study.

The Karst Field Studies at Mammoth Cave National Park attracted dozens of students during June. Foundation scientists presented one-week intensive seminars in karst geology, speleology, cave archeology, karst hydrology, and cave ecology. Academic credit for these courses is offered by Western Kentucky University.

The Foundation awarded grants to Kenneth B. Tankersley and Sheila Grow in support of graduate studies in karst related subjects.

Plans for a regional sewage system for the Mammoth Cave area began to take final shape. Because funds are available to complete the Cave City/Horse Cave segment now, construction on that part of the system will likely begin soon. Work on outflow from the drainage basin of major concern to the park, the Park City and route 70 corridor, will not begin until funding problems are solved. Foundation researchers have provided assistance to Park Service and local officials in their efforts to develop the sewage system.

Publications Program

Early in the year, CRF took steps to become a major publisher of cave books. Cave Books is now listed in *Books in Print* as a publisher, and has obtained the rights to the Johnson Reprint Series. Our goals are to publish new cave books as well as revised editions of classics in the field. A primary impetus to the Foundation to assume greater publishing responsibilities was that profits from the few cave books that have been published recently were not being used to publish other cave books. Income from Cave Books will be used strictly for this purpose.

The first new book to be financed and published by Cave Books will be *The Grand Kentucky Junction*, the memoirs of the joint venturers who connected the Flint Ridge Cave System to Mammoth Cave in 1972. A limited number of hard and soft-bound, hand typeset copies will be signed by the seven authors.

Finances

Foundation income comes from contributions, expedition fees, sales of publications, services and royalties. In addition to the general fund, the archeology, library, Cave Books publishing, and endowment funds have been established to support CRF activities. However, these accounts do not tell the whole story. As a volunteer organization our greatest assets are the people who contribute their time and energy to our projects. The value of this contribution, probably greater than $1,000,000 per year, we can estimate fairly well based on the number of hours spent. We spend an average of 12 work years per year on surveying and cartography for the Mammoth Cave project alone (2 work years surveying and 10 work years working up the data and drafting the maps). Research support at Mammoth Cave National Park and survey, cartography, and research support at our other field areas in New Mexico, California and Arkansas account for numerous additional work years of effort. The National Park Service has recognized our efforts and expressed its gratitude for our contributions.

Administration

Facilities—Research facilities at MCNP were improved with living and working space being set aside for resident researchers. CRF volunteers assisted the Park Service in completing maintenance tasks on the facilities we rent at Carlsbad Caverns. Construction of the Lilburn field station was completed in the fall and a solar charging system to power the cave telephone and emergency radio was put in place.

National Cave Rescue Seminar—Sixty participants in the 1983 National Cave Rescue Seminar, including CRF JVs and several MCNP employees spent a week in MCNP receiving training in underground medical care, search, communication, and patient evacuation. A final rescue field problem was successfully resolved with all "victims" safely brought to the surface. MCNP staff and CRF JVs participating renewed their awareness that cooperation among competent and trained volunteers and staff can multiply the effectiveness of rescue capability.

Beauty Cave Projects—In December 1982, CRF sent an unsolicited proposal for various scientific projects, including surveying, to be performed in Beauty Cave, Arkansas to Alec Gould, Superintendent of Buffalo National River. Although NPS had an agreement with another individual to survey the cave, toward the end of 1983 CRF was invited to resubmit its proposal to support at least two scientific projects. Earlier in the year, the Foundation advised NPS on the construction of a gate for one entrance to the cave.

Long Range Planning

In 1983 the National Park Service Director announced a service-wide initiative that included the effective use of volunteers. As a volunteer organization that had worked in National Parks for 25 years, we saw a challenge to make our efforts and accomplishments better known. We also saw an opportunity to align our own long-term planning process for karst research with efforts NPS might be making in this area. To bring the challenge and the opportunity together, we started drafting a 25-year agenda for the Foundation. At the same time we took the record of our successes to NPS and asked them to participate in planning our agenda. These two processes came together at the annual meeting of the Board of Directors in November.

In June the planning process began. Phil Smith, the Executive Secretary of the National Academy of Science and the founding President of CRF, made the following observation about our long-term view: "Although I do not believe that 25-year goal setting can be exceptionally realistic, I do believe that it is a worthwhile effort in the case of science, and it might be carried out in the cave systems within the national parks. ...One of the unique ways in which CRF can help in the cave sciences, particularly the physical and biological sciences, is to initiate and then provide the institutional base for some longer term studies." Others had some more specific suggestions: 1) CRF should articulate some research questions and then find researchers interested in answering them; 2) the Foundation should be involved more in resource evaluations; 3) we need to become more involved in interpretation; 4) we could advise NPS managers on how to get research done in cave parks where CRF could not support a project.

In meetings with NPS Washington officials the CRF President reviewed the history of the Park Service and Foundation 25-year partnership. As part of the scientific establishment, CRF has done credible work in national parks in large part because of NPS support. We owe a large portion of our success to the continuity—of which a 20-year agreement with the NPS assured us—we provided the talented volunteers who have contributed so much to the achievement of Foundation programs. The partnership should be strengthened, perhaps redefined, and we wanted the close participation of NPS managers as we developed our long term agenda. Director Dickenson and Associate Directors Briceland and Albright praised the Foundation for its contributions to research and resource management and encouraged us to play a more active role in interpretation and to publish reports of our work in Park Service publications. They also encouraged us to look at individual park resource management plans to identify research opportunities. As a first step toward making our capabilities better known within the Park Service, Chief Scientist Briceland invited the CRF President and the Head of the Science Committee to meet with the Regional Chief Scientists.

The Foundation has field areas in parks in three of the NPS regions. Meeting with all of the chief scientists gave us an opportunity to learn about research issues in parks with caves in regions where we had not worked before. The group of scientists were eager to learn about our research and how results from it had assisted park administrators resolve cave management issues. They encouraged us to publish articles in Park Service journals and participate in their professional conferences.

The groundwork was laid. We had presented our capabilities to Park Service managers at the national and regional levels and had been enthusiastically received. The next step was to develop our own 25-year agenda and invite park level managers to compare it with their planning efforts. Where there was a match, we should coordinate our plans. Where our interests diverged from their needs, perhaps a little further exploration would make the results of our work more valuable to them. As independent researchers, we would continue to be free to pursue our own interests. At the same time we were ready to try to direct our research to producing results that were more influential in such areas as resource management and interpretation.

Board of Directors Meeting

The 45th meeting of the Board of Directors of the Cave Research Foundation was held in Louisville, KY, November 17-19, 1983. In a precedent setting session, current and former Directors met with NPS managers to begin thinking about a 5- to 25-year research agenda for CRF. The planning process continues and is currently focused on the upcoming negotiation of a new long-term agreement with the National Park Service. During the annual members meeting, Board members and others reported on activities and accomplishments of the previous year. Superintendent Deskins of Mammoth Cave National Park, and John Palmer, Chief Park Interpreter, Sequoia and Kings Canyon National Parks, talked about goals for their parks and how CRF could help achieve those goals. Prior to the meeting several map drafters and project directors displayed and discussed their work with meeting attendees. Perhaps the most intriguing was Bill Wilson's three dimensional model of the vertical profile map he and others have done at Carlsbad.

The Board of Directors accepted with regret the resignations of Rondal R. Bridgemon and W. Calvin Welbourn. Both were elected to the Board in 1975. Cal served as Secretary from 1975 to 1977 when he became President and served until 1979. Ron served as Secretary from 1977 until his resignation from the Board. Sarah G. Bishop was re-elected President, Roger E. McClure was re-elected Treasurer, and R. Pete Lindsley was elected Secretary. New area managers are as follows: Richard Zopf, MCNP; John Tinsley, S/KCNP; and Rich Wolfert, Guadalupe area.

The Cave Research Foundation awards membership to individuals who have made and will continue to make substantial contributions to the Foundation, or who have made particularly noteworthy contributions to the world of speleology. The following individuals were elected members of the Foundation in November: Susan Lee Bridgemon, David Cowan, Peter Wilson Crecelius, W. Gerry Estes, Howard A. Hurtt, Ron Lipinski, Roger L. Miller, Robert R. Stitt, and Rich Wolfert.

Sarah Bishop
President, 1984

Cartography and Exploration

Cartography provides a central framework for all other areas of underground study. Exploration expands the limits of the underground and maps allow others to use these areas or estimate their usefullness for a particular study.

The reports in this section detail explorations done in 1983 as reported by Zopf for the Mammoh Cave Area, by Bosted for Lilburn, Buecher for the Guadalupes, and Welbourn for Arkansas. These reports also emphasize the development of new techniques and the increasing use of computers in managing data, checking accuracy, and producing maps.

Radionavigation is the subject of two reports by Reid. He summarizes tests of different types of radionavigation equipment, and the use of these techniques in radiolocating the eastern extremity of Mammoth Cave (prior to the Roppel connection).

Exploration and cartography are hard work and a good field facility goes a long way in contributing to the success of an expedition. Spiess chronicles the decision to build a new field station at Lilburn through its' successful completion in 1983. The design and implementation of a solar-powered electricity system at the new Lilburn station is poetically reported by Hurtt and Tinsley.

Figure 1. Relaxing at the old Austin House, MCNP, after a hard, but satisfying, cave trip. (Photo by K. Lavoie)

Cartography and Exploration in the Mammoth Cave Region—1983

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Like 1972, 1983 was a year with very low water levels in the Mammoth System and consequently allowed major low level discoveries. What had been a siphon at the eastern end of the river system discovered in 1979 was found to be passable this year and led to an immediate connection with the Roppel Cave System. About seven and one quarter kilometers were surveyed by both CRF teams and teams working under James Quinlan's research for the NPS discovery in the river area included a dry route from Morrison Cave to the river level. About one and a half kilometers were surveyed in Mammoth Cave's Mystic River. This work and several other surveys were made in conjunction with A. T. Leithauser's biological research. Another four and a quarter kilometers were surveyed throughout Mammoth and three and a half kilometers came from Flint Ridge. A significant segment of Salts Trunk was found to the east of the entrance and a long, unbranching passage was discovered between Turner Avenue and Grund Trail. This year's survey of new passage totaled over 16 kilometers and when added with Roppel cave, brought the length of the Mammoth System to over 474 kilometers.

The cartography program continued to expand this year with new outposts in Bowling Green and Cave City, Kentucky. A base level map of Mammoth is being compiled to support research in those areas and a map of the river system has been assembled for general use. Excellent progress is being made on a revised map of Salts with special emphasis on the complicated 'S' survey area. The Ferguson Entrance area map has been drafted and a working copy of the revised Crystal map has been unveiled. Finally, a detailed map of the Brucker Breakdown area is emerging.

Computer-related developments in the cartography program are proceeding on several fronts. All of this year's numerical survey data is in machine-readable format and we are beginning to eat away at our backlog. The general plan of our data base has been designed and will begin to be written this year. Slowly the data and programs from CRF's former computer operation are being converted to forms we can use today.

The coming year should be one of change in the cartography program. Although computer systems are easing the data reduction tasks, demand for maps continues to overwhelm volunteer effort. Consequently, both an overall strategy for a complete set of maps of the system is being developed and consideration is being given to obtaining funding to support more intense efforts. A revised map card is in the works and efforts to incorporate more draftsmen in the program continue.

Lilburn Cave Cartography Project—1983

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The resurveying of Lilburn Cave showed good progress in 1983. A total of 1828m (5997 feet) and 465 stations were surveyed. Twenty survey trips were accomplished during five expeditions in April, May, July, August, and October. The cartography trips were chiefly devoted to resurveying passages from previous surveys that never were drawn up as a map. Parts of two trips and one entire trip covered passages that had never been surveyed previously. The 1983 surveys emphasized five areas in the cave: the West Stream, the Kleinbottle Complex, Pandora's Passage, the area around South Seas Junction, and the eastern part of the East Stream. Some work was also done in the Schreiber Complex and a second route from the Hex Room to the White Rapids was surveyed. The total length of passage now surveyed by the CRF (excluding survey shots which traverse the same passage more than once), is 6,167 meters (20,233 feet) in 1,245 survey stations. Approximately 20,000 feet of known passage remains to be surveyed.

The Lilburn survey data are input into a computer: a FORTRAN program then simultaneously closes all the survey loops (there are presently more than 100 of them!) resulting in the least total disturbance to the array of survey shots. Several erroneous readings were found by looking for loops that had poor closure (total change needed greater than 2% of the length of survey leg). Most of these errors have been corrected by parties returning to the site in question. The computer then produces plots at a scale of one inch equals twenty feet showing the corrected survey station positions. The plots have been sent to the six people who kept book so that they can produce drawings which will be compiled onto the master map by the end of February. We plan to make copies of the map available to our cartographers to take them with them into the cave to better identify passages which still need to be surveyed. The project is now at the stage where most of the principal trunk passages have been surveyed. Seldom-visited passages remain to be surveyed and explored.

Guadalupe Area Cartography Report —1983

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During the last year emphasis in the Carlsbad area has shifted away from surveying to support for other forms of research. Many of last year's projects did little to add to the length of the cave but, nevertheless, served to help portray and understand the Caverns. The majority of Carlsbad Caverns has been mapped and much of the remaining work is adding greater detail or correcting errors made in earlier surveys from many parts of the cave.

A major discovery in 1982 was the Remarkable Crack, which connected Bat Cave to New Section. Since the initial connection, over 1000m (3400 feet) of passage has been surveyed in an area which parallels the north wall of Bat Cave, but on a lower level. Another connection route has been found off the east end of this section, and more connections surely exist. A number of signatures and trash from the 1930's indicate that portions of this area were known. These earlier explorers came very close to discovering the New Section!

A major portion of last year's cartographic work involved making profiles along several of the main passages and rooms in Carlsbad Caverns. Bill Wilson enthusiastically directed the efforts and compiled the maps, completing a section from the Natural Entrance down along Main Corridor, through the Scenic Rooms and across the Mystery Room. Wilson also completed profiles and cross sections of the Guadalupe Room and the New

Mexico Room. Considering the amount of relief in the cave (over 1000 feet) and the size of the main passages (175 feet high by 100 feet wide), the profiles make an impressive set of maps! The maps will help to accurately portray the relation among the various sections of the cave and to form a basis for further work on the cave's geology. We hope to extend this work next year to Lower Cave and the Big Room.

The profile work showed several vertical errors in New Section. To correct these errors, a number of water level surveys were done to extend the precise level network into New Section.

We have continued in our efforts to computerize survey data for Carlsbad Caverns and other caves in the area. The emphasis has shifted from using the computer merely for computing coordinates to that of storing the original data for future uses. This system lends itself to easy duplication of data with no loss in quality and allows many people to have access to "original" data. Copies of the data have been sent to other individuals within CRF for their use, and to serve as backup copies. Progress has been hampered by the great variety of computers within CRF, with the resulting lack of systems compatibility. These incompatibilites can be reduced by the use of modems. At present, only 25% of the Carlsbad Caverns survey books have been entered. We plan on expanding efforts next year in automating production of the actual maps. Two plotters, mine and Elbert Bassham's, will plot 24' by 36' sheets with a resolution of 0.001'.

The computer is also being used to organize the data. At present the Guadalupe Area Cartography files contain over 680 survey books from more than 65 caves. A data base has been created which contains information on each survey book including cave name, area, survey date, designation, survey totals and other information concerning the survey. Sorting the information by different headings allows rapid retrieval of the appropriate survey data. To date, all of the survey books for Carlsbad Caverns (380 books) and Dry Cave have been entered. We also plan on creating a data base containing information from the trip reports.

The computer revolution has not only caught up with CRF, but also with the National Park Service at Carlsbad. The NPS has recently acquired their own computer and are anxious to gain access to the data that we have on the Caverns. So far, the problem of incompatible computers has prevented the free exchange of information, but both sides are working on ways around the problem.

Cartography and Exploration in Arkansas

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The second phase of the cave inventory project under contract with the U.S. Forest Service in the Ozark-St. Francis National Forests, Sylamore District, Arkansas, was completed in January of 1984. A 126 page final summary report was submitted with over 90 square feet of cave maps representing 11.6 km (7.2 miles or 38,001 feet) of survey from 12 caves. Seven caves were less than 1000 feet long, two were less than 2500 feet, two (Bonanza and Hidden Springs Cave) were just over 5000 feet, and one, Rowland Cave, was 6.17 km (20,201 feet) long. Bob Buecher, Debbie Buecher, and Ron Bridgemon have been recognized for their superb efforts in drafting maps for this project.

Major field work on the third phase of the Sylamore Cave Inventory Project was completed in September, 1983, with the survey of the last of six caves. Tom Brucker is supervising this contract with Doug Baker assisting with the cartography. Most of the caves on this contract are small (less than 1000 feet long) and will require only minor additional fieldwork to complete. The final report and maps are due by June, 1984.

Radionavigation For Cavers

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Dense vegetation at Mammoth Cave National Park and other cave areas often causes difficulty in mapping and returning to small karst features. Conventional survey methods are prohibitively time-consuming. At the request of MCNP Geologist Jim Quinlan, I investigated ways of using radio waves to define surface locations and evaluated existing radionavigation systems against stringent requirements for high resolution and repeatability, ease of operation, portability and, of course, low cost.

A simple receiver with a directional antenna and magnetic compass can be used to "sight" two or more fixed transmitters, and determine position by crossed bearings. An ordinary transistor radio tuned to the MCNP tourist-information transmitter was not fully evaluated when the transmitter was discontinued, but preliminary results were disappointing. Geometric constraints limit direction-finding systems to a small area where accuracy is acceptable. The only improvised system which showed promise was a radio-controlled car horn, which is useful for finding one's way back to the road at night.

None of the commonly-used radionavigation systems for aircraft are adaptable to caving. Experiments with car-mounted equipment in the Garrison Chapel Valley cave area near the Bloomington, Indiana, airport confirmed that the VHF omnirange distance-measuring-equipment (VOK/DME) system is unusable on the ground at ranges greater than two miles from a station. (The VOR station nearest MCNP is at Bowling Green.)

An aircraft-type automatic-direction-finder (ADF) receiver works well on the ground because it uses low frequencies not subject to line-of-sight limitations. ADF's receive AM broadcast stations in addition to low-frequency nondirectional beacons, and are an interesting aid to navigation while driving cross-country, but they have the same limitations as the manually-operated systems mentioned above.

The Omega navigation system provides worldwide coverage with a network of powerful, very-low frequency (10 to 14 kHz), stations. Although the signals are detectable underground, the Omega system only has a resolution of approximately 2 nautical miles; hardly suitable for caving applications. Omega receiver/computers can be home-built; commercial models are prohibitively expensive.

Loran-C navigation receivers for boats have recently become small and almost affordable, due to the development of 16-bit microprocessors. Loran is an acronym for "Long Range Navigation." The government-operated Loran-C system covers most of the continental U.S. with strong signals. (Coverage in the Carlsbad, NM, area is however, very poor. Planned new transmitting stations are expected to fill the gap.) Loran receivers indicate latitude and longitude to the nearest 0.01 minute (50 to 60 feet), range and bearing to desired destinations, and other useful navigation functions. Repeatability varies with position relative to transmitting stations, and is approximately 115 feet in the MCNP area. The 100-kHz Loran signals follow the curvature of the Earth, and are fully receivable at ground level.

Tests of a pack-frame-mounted Loran receiver at MCNP and other cave areas confirm its ability to navigate to within sight of cave-entrance-sized features in dense woods, but there were unexplained errors at the features themselves, manifested as absolute errors of up to 300 feet, apart from the area correction factor. There appear to be propagation anomalies near sinkholes and vertical bedrock joints, perhaps caused by changes in ground-conductivity. Signals sometimes became unusably weak in the centers of sinkholes. There also seem to be anomalies near sandstone escarpments. Errors can be partially recovered by walking around the point of interest and averaging several latitude-longitude readings.

We tested Loran underground, on a hike from the Historic entrance to the Violet City entrance. Mammoth Cave was an ideal place for the test; the cave contains U.S. Geological Survey benchmarks of know lat/lon, ranging from 100 to 300 feet below the surface. In most places, signals from New York and Florida were unusably weak, but the signal-to-noise ratio from Dana, Indiana, (about 100 nautical miles away) stayed almost as good as it had been on the surface. (Three stations must be received to compute a position.) Adding 50 feet of wire to the short whip antenna improved reception, but usually not to usable levels. At benchmark TT6W, near where water enters the cave through the ceiling, all signals were good and the position error was about 1/4 mile. Presence or absence of power lines in the cave had no noticable effect. The cave lights were not turned on.

The tests on the surface and in the cave suggest that a Loran receiver, or a simplified 100-kHz receiver with a directional antenna, could be used to detect certain geological features by methods analogous to those of resistivity-survey but eliminating the cumbersome wires.

Earth-satellite-based navigation systems will eventually replace Loran-C, and will eliminate many of its limitations. Satellite equipment may be more expensive and some systems may entail user fees. Loran-C is presently a useful cavers' tool for quickly determining and recovering geographic positions, and has potential application in cave rescue.

Eastern Extremity of Mammoth System Radiolocated

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On September 10, 1983, the same day that the Roppel and Mammoth Cave systems were officially connected, a joint operation involving CRF, Central Kentucky Karst Coalition and Fisher Ridge Cave Survey personnel established cave-radio locations in the Eastern end of Roppel, and the Remington Sink area of Fisher Ridge Cave System. The presence of Indian artifacts in cave passage under Remington Sink suggested that the sink had once been a cave entrance.FRCS people have subsequently re-opened the sink.

The "Kahn" area of Roppel Cave extends under the Northwest end of Fisher Ridge. Organic debris inside the cave indicated that the passage was near the surface. The radio depth indication was only 38 feet! The surface party found a small opening nearby, with cold air coming out, and moved a few loose rocks. The cavers inside could hear the noise of rocks being moved, but there was no voice connection, nor was there one-way radio conversation. (Due to the length of the cave trip, we had elected to omit the extra equipment required for two-way contact.) Two complete sets of underground transmitting equipment allowed us to radiolocate both caves during a single afternoon.

The surface radiolocating party carried a Loran-C navigation receiver mounted on a pack-frame, in an experiment to evaluate its usefulness for finding cave-entrance-sized karst features in dense woods, for guidance to expected cave-radio locations, and for recording the latitudes and longtitudes of those locations. It was very successful in all three applications. Topographic maps and magnetic compasses are entirely adequate, much smaller and much less expensive, but the Loran "saved the day" in one instance by guiding us directly to Remington Sink, which we might otherwise have been unable to find in time for the scheduled radio transmission.

The Loran computer indicated about 2300 feet distance between the Fisher Ridge and Roppel radiolocations. No connection attempt was made, nor were the two locations at the closest known distance between caves.

Special thanks go to Dan Crowl and the Fisher Ridge Cave Survey, Dwight Hazen, Tom Brucker, Pete Crecelius, and the owners of Fisher Ridge.

REFERENCES

Crowl, Dan, 1983, Report on Surface Radiolocating Activity—9/10/83: *Dug Scoops,* 1:12, (Newsletter of the Detroit Urban Grotto).

Mergens, D. (ed), 1981, Use of the Cave Radio in Mapping: *CRF Personnel Manual,* Third Edition, p. 102.

Lilburn Field Station Completed

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Construction of the Lilburn Field Station drew to a close following the October, 1983, expedition. The year's principal achievements included construction of the chimney and hearth, plus the installation of a solar electrical system to power the cave telephone and the emergency radio. This was the culmination of an effort initiated during the autumn of 1980 with a decision to build a new field station, rather than shore up a rapidly deteriorating prospector's cabin built in 1923. Planning was catalyzed by Park Management's decision to manage the Redwood Canyon area as wilderness and to terminate vehicular use of the Redwood Canyon jeep road. Victor Ulfeldt, who is Stan Ulfeldt's father and a retired architect, designed the cabin. The National Park Service gave their prompt approval of the plans, and as the snow began to fall in December, 1980, Stan Ulfeldt and Howard Hurtt hauled the construction materials to the site and stored them inside the prospector's cabin.

Early in May of 1981, a willing crew hiked to the site carrying demolition tools. The old cabin was razed in less than three hours, the lumber for the new cabin was stacked, and the site was leveled prior to construction of the new cabin on the site of the old. The initial construction efforts materialized the week prior to Memorial Day Weekend, as the Ulfeldts accompanied a NPS mule train bringing the remaining construction materials to the site. The floor piers were set in concrete and the foundation and subfloor were in place by the time that the rest of the construction forces arrived.

The 1981 Memorial Day Expedition was very impressive; by the time the sun set on Sunday evening, the new field station was framed, the sheeting was installed, and the roof was prepared to receive shingles. During the remainder of 1981 and taking time out only to attend the 8th International Congress of Speleology in Bowling Green, Kentucky, all hands became very accomplished at tacking on cedar shingles to the roof and sides of the cabin. The final shingles were applied to the ridge as a driving sleet storm forced all personnel to retreat from the canyon for the winter.

The 1982 construction year was devoted to making the interior of the cabin fully operational. This involved the permanent installation of a wood-burning stove, the construction of primitive furniture, and the installation of tables, shelves, storage cubicles, and the communications module. The upper 2/3 of the original chimney that has stood without complaining excessively since 1923 was deemed to be unsound. Work crews removed the crumbling masonry and shielded the site against the winter's snows, as reconstruction was not complete.

The 1983 season saw the completion of the field station—a 16 x 20 foot cabin, with a loft for sleeping. The credit for this achievement is shared among the many who donated money, time, talent, strong backs and materials. Special recognition is reserved for those several overloaded human mules who selflessly backpacked loads including not only their camping and caving gear, but also 30 lb. aliquots of cement from the roadhead at Redwood Saddle along five miles of rough trail to the field station. JV's also packed-in the re-bar and quarried the sand and the stones from nearby creeks. Without these extraordinary efforts, the year's ambitious plans and goals would have been unfulfilled.

As a result of the 1983 season, we can point proudly to a fine hearth and a 7-meter high chimney constructed of native stone built upon the remains of the original chimney. In recognition of the earthquake history of the eastern Sierra Nevada region and the recent activity in the Mammoth Lakes area, we incorporated many feet of steel reinforcing rod into the masonry. Everyone anticipates a cheery hearth with a roaring fire next season.

Many small jobs were completed during the season; most of these efforts were devoted to housekeeping and landscaping. A fire perimeter was established by clearing brush from around the cabin. The construction litter was gathered and burned and the ashes scattered in the forest. Surplus construction materials were stacked out of sight. Provisions, equipment, and supplies were inventoried and reorganized. The telephone line was repaired. The water-level recorder at Big Spring was repaired and recalibrated. Vents were installed in the attic of the field station to forestall the build-up of moisture during winter expeditions and the station's front door was coated with linseed oil.

The major construction of the field station is completed; however, we plan improvements to the interior for 1984, as well as repair of the gate at the Lilburn Entrance, improvement of the campsite areas and the cooking facility.

Solar Power Comes To Redwood Canyon

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The recently completed Lilburn Field Station is a 16 x 20- foot cabin designed to encourage and facilitate research. The principal amenities are eating and sleeping space for twelve researchers, a wood burning stove, running water, a picturesque fireplace, a radio for communication with the National Park Service (NPS), and a telephone and telemetry system. A significant achievement of 1983 was the solar-powered electrical generating system installed to satisfy a growing need for electricity and a growing reluctance to backpack the storage batteries formerly used to power the communications facilities.

The most important need for electricity is the radio communication with NPS authorities due to the potentially hazardous nature of working in cave systems, plus the desirability of having an extra fire look-out in this remote area. A second requirement for electricity is an underground communication system. A telephone line which traverses some 4.5 kilometers of the Lilburn Cave system was installed in 1974 to relay water level data to recording equipment. This line also served as a phone system between cave and field station. Additional power requirements include charging batteries for headlamps and operating scientific equipment.

In 1980, the NPS withdrew vehicular access to the field station area, an action consistent with managing the area as wilderness. In previous years, cave-related research had flourished here, due in part to the ease of transport to the site of scientific equipment and support supplies, notably batteries. The need to have electricity for research and safety at the station, together with the mandate to manage the area as wilderness, precipitated a search for a new power system which would not require heavy batteries to be packed five miles to the field station and back during each expedition. The challenge was to devise a power source for the station that was scaled to the system's needs yet was easy to maintain and was fully compatible with the wilderness setting.

Howard Hurtt, a biologist and former solar system evaluator for an independent testing laboratory, had been associated with field station activities for fifteen years and accepted the challenge. First, the power-hungry modified taxi cab radios that had provided vital communications during the years of vehicular access were now useless. The radios were too heavy to pack and their power demands would have gladdened the heart of the most dour marketing agent for any utility you might care to name. Hurtt began to modify a donated solid-state transceiver and CRF researchers borrowed walkie-talkies from NPS for use during expeditions. The new radio would incorporate circuitry for the cave telephone as well, enabling both systems to use the same power supply. There was a further advantage in that a "patch" could be designed to connect the cave telephone to the NPS radio in case of emergency. At the beginning of this field season, all communications were powered by a single 12-volt motorcyle battery, which could be backpacked out to civilization after each expedition for recharging.

The breakthrough for the power system came when Hurtt contacted Mr. Gabe Amaro, telecommunications applications specialist with ARCO SOLAR, INC. ARCO donated two M-81 photovoltaic panels along with abundant and valuable advice on system design.

Because the field station is located in a dense, shady mature forest, the photovoltaic panels were installed 130 feet up in a white fir. As this part of the Sierra receives numerous summer thunderstorms, the power system is extensively protected against lightning. A lightning rod in the tree above the collector forms a bypass to the ground. Western Electric-style circuit protectors are installed on the photovoltaic array lead-ins and phone lines to short to ground any line that passes excessive current. Inside the power system distribution panel are gas-discharge arrestors and metal-oxide varistors which instantaneously short any line to ground that exceeds about 130 volts. There are also time-constant-sensitive inductor-capacitor networks which counteract any fast-rising voltage. Finally, every circuit is liberally protected by fuses.

Power requirements for scientific equipment can vary considerably, so a general purpose outlet was provided in the distribution panel fused at 10 amperes. A second outlet was fused at two amperes and was given extra surge protection.

The two 1/2 ampere photovoltaic panels are harnessed to two 12-volt deep-cycle storage batteries having 139 total ampere-hours capacity.

Testing has shown that power production is more than adequate to charge the batteries in 2-4 weeks during the summer. Storage is adequate to power the communications equipment, to run a 30-watt fluorescent light, and to recharge headlamp batteries.

The complete system was installed by Mike Spiess and Dave Zoldoske during July and August of 1983, using mounting hardware designed and built by Spiess. The batteries, the photovoltaic panels, the mounting hardware, wire, and the distribution panel were backpacked to the station. On July 24, the switch was thrown connecting the photovoltaics to the storage batteries. On August 21, 1983, sunlight captured in a tree-top shone again 400 feet underground.

Geosciences

The Geosciences deal with processes that both create and destroy caves, the often unique mineralogy associated with caves, and paleoclimatic conditions. The reports in this section reflect the diversity found in the area of Geosciences.

Hill reports on the mineralogy of Hell Below Cave in the Guadalupes.

Perry discusses preliminary findings about the fluvial hydrology of Lilburn Cave, and presents the long-term goals of the study.

Initial findings of a study by Tinsley to determine sedimentation rates using sinkholes and deposits of volcanic ash as markers are optimistically reported.

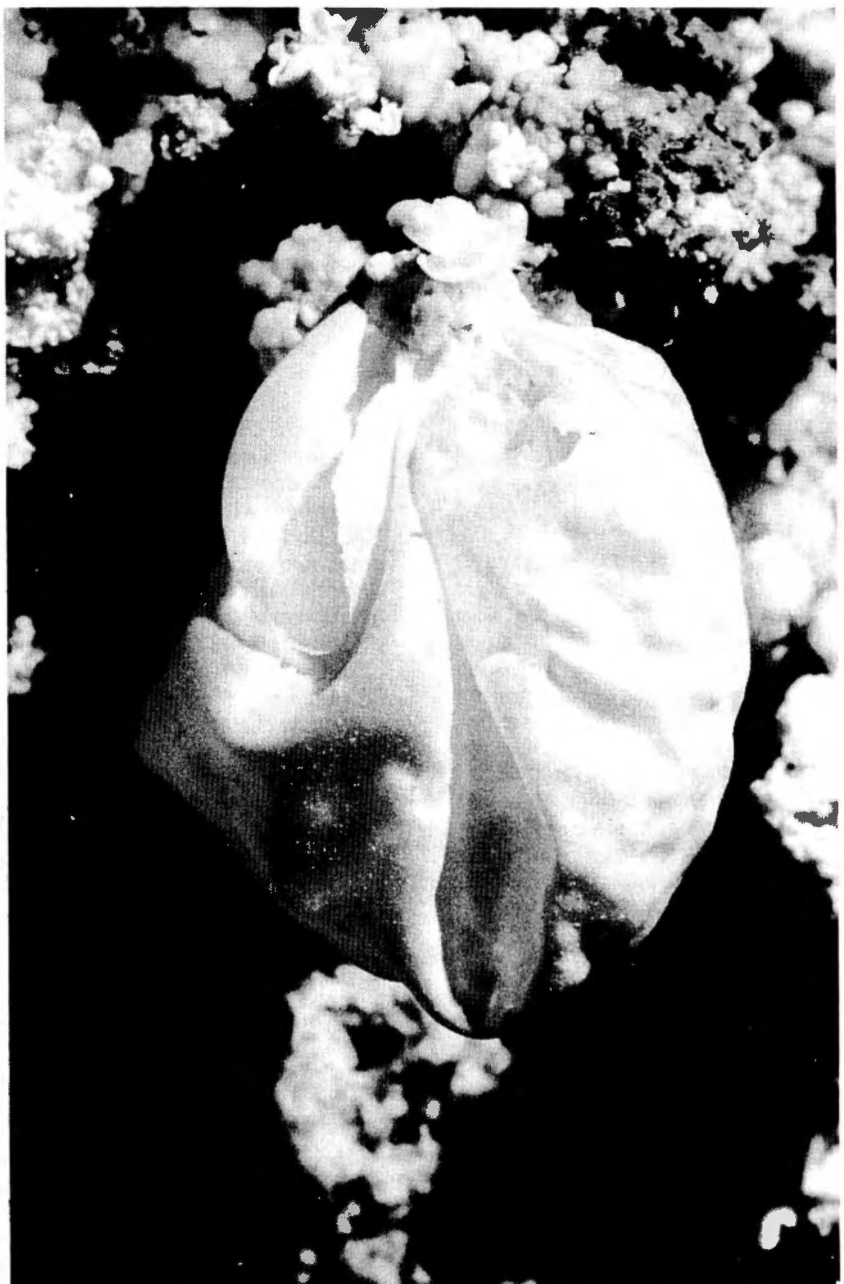

Figure 2. Hydromagnesite balloon, Jewel Cave, South Dakota. Length, 3 cm. (Photo by A.N. Palmer)

Preliminary Notes On Flute Reed Cave and the Tower Karst of Guilin, China

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Guilin, China: "land of magnificent views, crystal clear waters, fantastic caves, and elegant rocks," and "every hill has its own cave," or so our guide for the Li River tour from Guilin to Yangshuo repeatedly told us. The Guilin area is the world's classic location for tower karst landforms.

Hua (1981) described the karst hydrological terrain of the Guizhou Plateau, Guizhou Province, as being controlled by lithology (calcite verses dolomite), structure (folds, faults), and baselevel. While east of Guizhou Province by 160 km, the Guilin tower karst is geologically related to the plateau and is similar to it in that its caves are developed in tilted and folded rock. Guilin is situated at latitude 25 degrees 15 minutes N, with an altitude of 155 m above sea level (Dehau and Pengjia, 1981). It has a humid, subtropical climate with mean annual temperature of 19 degrees C and average annual precipitation of 190 cm. The total thickness of carbonate rocks in the Guilin district reaches 3000 m and are mostly upper Paleozoic in age. Maximum height of the tower karst in the Guilin area is approximately 100 m—perhaps the relatively flat summit tops of the karst reflect a former peneplain level at this elevation prior to a regional uplift. Erosion has lowered the height of tower pinnacles adjacent to flat valley floors where red soils are derived from the red clay residue of the limestone itself.

The Guilin caves are not extensive, the tower karst dissection having divided once-connected hydrologic avenues into discreet, separate sections. Some of the caves and also some of the tower karst itself seem visibly aligned along major joint trends; a few caves are developed along fault zones (in what looks like paleokarst breccias?). Most caves are found along tilted or folded bedding planes with cave entrances most often exposed on the updip side of the tilted beds of a truncated tower. Masses of exposed travertine are evident where there has been collapse of cave passages by downward erosion along structurally weak points, or by meanders of the Li River channel. Sheets of flowstone, oddly weathered into sharp-fingered points and columnades of disintegrating dripstone, adorn overhanging side cliffs all along the course of the river.

Flute Reed Cave, located in the northwestern suburbs of Guilin, is approximately 240 m long and has a mean annual temperature of 19-20 degrees C. Speleothems along its 500 -m long tourist route includes: stalactites, stalagmites, columns, flowstone, draperies, shields, welts, boxwork, rimstone dams, and popcorn. Most of the stalagmites and columns have undulating shapes due to alternating wet and dry periods. For the most part the speleothems are "dead;" however, some of them towards the interior of the cave are wet, and a few even have a glistening surface texture, with crystal faces that reflect light like so many grains of sugar.

The most unusual aspect of Flute Reed Cave's speleothems are its well-developed shields which relate to the generally fractured nature of the limestone. One hanging shield near the cave entrance is approximately 4 m in diameter; another free-standing one further back into the cave is 1 m in diameter. In the Crystal Palace "Shuiquinggong," a large room touted as being capable of holding up to 100 people, seams of white powder (gypsum?) encrust fractures in the ceiling limestone.

As our guide said, "every cave is a palace of Natures art."

REFERENCES

Dehau, Zhu, and Pengjia, Tan, 1981, The geomorphological feature of the karst in Guilin district: *Proc. 8th International Congress of Speleology, Bowling Green, Kentucky,* 1:145.

Hua, Song Lin, 1981, Some characteristics of karst hydrology in Guizhou Plateau, China: *Proc. 8th International Congress of Speleology, Bowling Green, Kentucky,* 1:139-142.

Mineralogy of Hell Below Cave, Lincoln National Forest, Guadalupe Mountains

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Hell Below Cave on the Guadalupe Mountains is developed in the Seven Rivers Formation, just below its contact with the Yates Formation. Its speleothems seem to be far more active than those in most Guadalupe caves. Secondary speleothem types noted were stalactites, stalagmites, helictites, flowstone, draperies, rimstone, cave pearls, moonmilk, and—most outstanding of all—a massive display of popcorn coralloids. Also of note is the primary gypsum in the cave, located along sections of the Main Corridor and in a side passage off the Main Corridor called Gypsum Alley.

Popcorn: The walls of Hell Below Cave are adorned everywhere with popcorn, from the entrance drop all along the Main Corridor to the end of the cave. The popcorn ranges from grape and knob shapes to acicular protuberances of aragonite, or moonmilk globs on the tips of popcorn (probably hydromagnesite, although no samples were collected). The popcorn appears to be actively forming by seeping water and by splash. New growth on the tips of popcorn were observed in the lake area.

Jagnow (1979) noted a "popcorn water line" in Hell Below, the only other cave in the Guadalupes beside Carlsbad Caverns known to posses such a feature. The "popcorn line"was noted in two places—near (17m from) the entrance drop (not well developed here), and further on where the start of the large pits. The "water line" in this second area is more prominent along the left wall than on the right, and only goes for about 30 m or so and then dies out.

In my opinion the so-called "water line" of Hell Below Cave is *not* a water line defined by a reflooding of the cave, but instead is defined by stratigraphy. The line corresponds to a bedding plane in the Seven Rivers Formation; where the bedding plane jogs up slightly on the right wall towards the pit area, the popcorn "water line" also similarly jogs upward. The "water line" in Hell Below Cave differs from the line in Left Hand Tunnel, Carlsbad Caverns, in that:

(1) it consists of chalk-white moonmilk popcorn rather than calcite and aragonite nodular popcorn.

(2) it does not correspond to the maximum width of the passage.

(3) it is not extensive, but peters out quickly.

(4) it seems to be developed at two different levels, a higher level nearer to the entrance, and a lower level farther back into the cave.

I think that the line in Hell Below Cave may indicate a change of limestone type — perhaps it is more dolomitic or porous than the above-lying limestone which is not adorned with popcorn.

Primary Gysum: As is typical of most Guadalupe caves, Hell Below has primary gypsum blocks and rinds in it. These are equivalent in character and origin to the gypsum blocks of the Big Room in Carlsbad Caverns; that is, they formed as a precipitate at the time of cavern dissolution by sulfuric acid. In Gypsum Alley, the primary gypsum coats the walls, ceilings, and floors in protected places where water is not dripping in along a ceiling joint. The gypsum coats the *ceilings* of Gypsum Alley as well as its walls and floors—this is unusual in Guadalupe caves, as most primary gypsum occurs either as floor blocks or wall rinds. It appears that Gypsum Alley was once completely filled with gypsum, and subsequent resolution carved a streamlined passage through the gypsum. Later, the gypsum dried, compacted, and dislocated from the ceilings to form gypsum archways.

Secondary gypsum flowers of fibrous structure are associated with the primary gypsum in Gypsum Alley—this is another rare occurrence for Guadalupe caves. In all other places where gypsum flowers are known to form, they are extruded out of the wall limestone, but in Hell Below they appear to be growing directly from the primary gypsum. Perhaps this anomoly can be explained by the fact that most of the primary gypsum has dislocated from the walls and in doing so has separated the flowers from their previous point of attachment to the limestone.

Much of the primary gypsum in Gypsum Alley is recrystallized and has developed an almost "snowball"- like surface texture. No laminations or other features such as native sulfur were observed in the gypsum. At the beginning of Gypsum Alley, one small (15 cm in diameter) "commode" was noted.

REFERENCES

Jagnow, D. H., 1979, Cavern development in the Guadalupe Mountains, New Mexico: University of New Mexico (unpublished master's thesis), appendix.

Investigation of the Hydrology of Redwood Canyon Karst

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

Specific objectives are:

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

Three sets of samples were collected in 1983 in May, July and October. Samples were collected for stable isotope and chemical analysis from surface streams, cave streams, drips and Big Spring. At the time of collection, temperature, pH and electrical conductivity were measured. Seventy-nine samples were collected at 24 different sites during the year. The stable isotope analyses are presently being performed. Preliminary results from oxygen-18 indicates an isotopic shift during a flush cycle. This needs to be verified upon the completion of the isotope analyses. At least four sets of samples will be collected during 1984, including a winter set. An attempt will also be made to collect precipitation samples.

Fluvial Hydrology At Lilburn Cave, Sequoia and Kings Canyon National Parks, California

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Measurements of the time required for a pulse of fluorescein dye to appear at several successive points along the Lilburn Cave Stream were collected and compiled during the October, 1983 expedition. The discharge of the cave stream was at a seasonal low stage, and Big Spring was not exhibiting the ebb-and-flow phenomenon that is characteristic of discharges above 12 to 15 cubic feet per second (cfs), according to Sara (1977, p. 56). The presence of the dye was observed by several CRF parties and the times of observation were reported to the surface personnel via the cave telephone. Limits can be placed on transit times during non-ebb-and-flow conditions as shown in Table 1. The limits are approximate because the arrival and the departure of the dye pulse was not noted in every instance. Points of observation are separated by siphons. The places named are shown on the map, Figure 3.

Table 1. 1983 Dye Traces in Lilburn Cave.

Interval	*Linear Distance (m)*	*Transit Time (hr)*
White Rapids to Lake Room	170	1.25 ± .25
White Rapids to Big Spring	1650	< 11
Z-Room: clear of visible dye	780	< 11
Big Spring: dye visibly present	1650	<11 to >13

During the 1984 field season, two dye traces are planned. One trace will determine where the hydrologic connection of a major tributary stream (Pebble Pile Creek) and the Lilburn Cave Stream occurs; either (a) at a point upstream of the Z-Room, or (b) between the Z-Room and Big Spring. Siphons preclude direct observations in both instances. The second trace will endeavor to measure the transit time from a surface tributary, May's Creek, to the White Rapids area, which is the known junction of the May's Creek tributary with the Lilburn Cave Stream.

The discharges of principal tributary streams will be measured using a flow velocity meter and V-weirs. As we seek a more

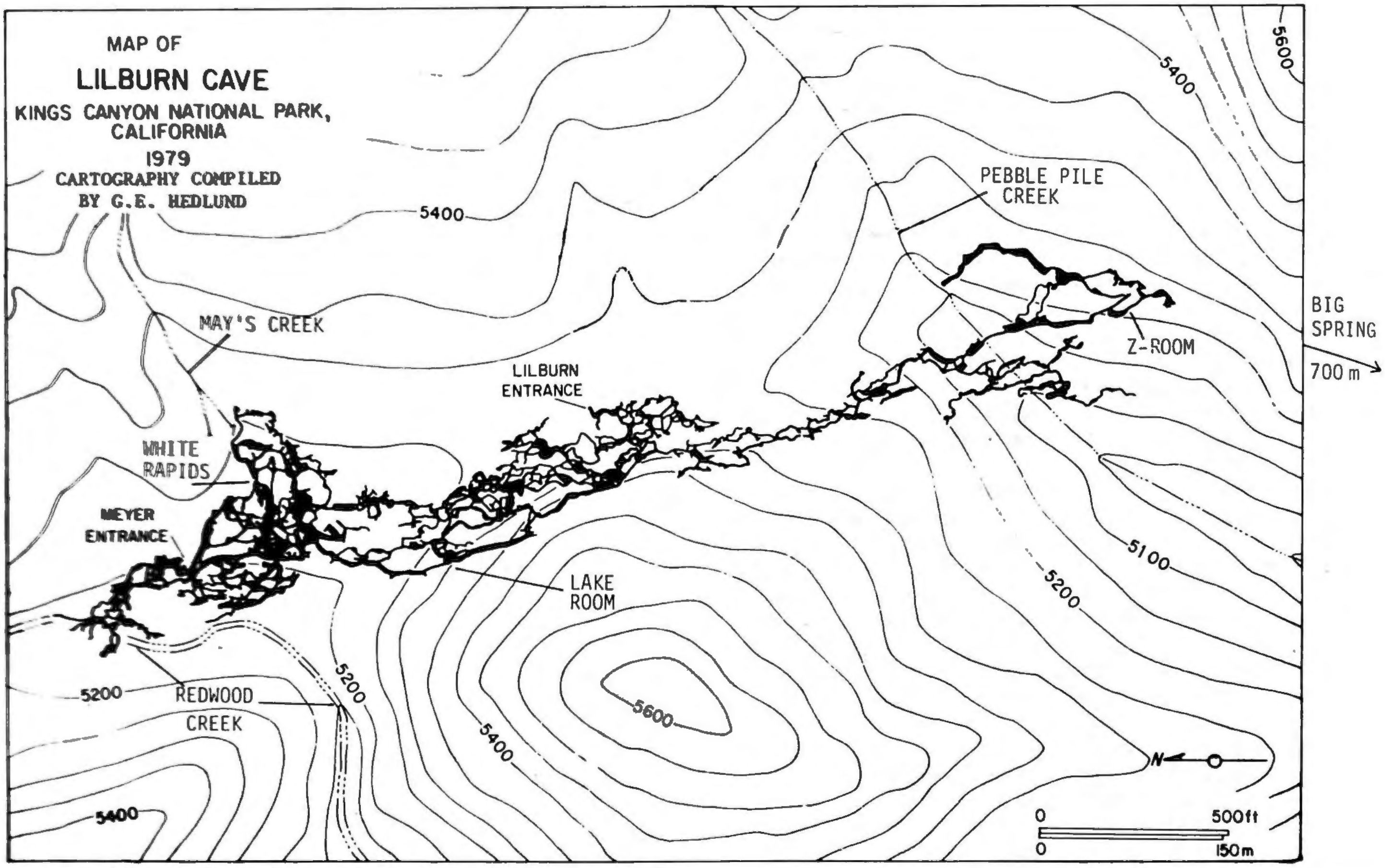

Figure 3. Map of Lilburn Cave and near environs.

comprehensive understanding of this dynamic karst system, it is desirable to learn what proportion of the total discharge at Big Spring is represented by the discharges of tributaries.

REFERENCE

Sara, M.N., 1977, *Hydrogeology of Redwood Canyon, Tulare County, California:* Unpublished Master of Science Thesis, University of Southern California, Department of Geology, 129 p.

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

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Introduction

Initial indications are promising, although results are highly preliminary, as studies continue to derive rates of sedimentation in sinkholes using volcanic ash (tephra) beds as stratigraphic markers within the Redwood Canyon karst. The tephra deposit being studied was erupted about 720 ^{14}C years ago from the Deadman Creek Domes area in the Inyo Craters volcanic field, near Mammoth Lakes and the Long Valley caldera in the eastern Sierra Nevada, California. The age and the identity of the tephra found in Redwood Canyon is based on a chemical "fingerprint," a comparison of the relative abundances of a suite of trace elements contained in the volcanic glass ejected from the vent.

Following the eruption of the tephra, winds carried the eruptives south and west where parts of the plume settled within Redwood Canyon. The powdery ash was washed rapidly from the forest floor and vegetation into the more than 60 sinkholes that dot the central reach of Redwood Canyon. During the 700 or so years since the tephra was deposited, erosion of the land has continued, and undetermined volumes of sand, silt, and clay have been washed into the sinkholes, resulting in burial of the ash layer. Thus, the tephra deposit is a distinctive and therefore readily indentifiable datum, the result of a short-lived geologic event preserved in small sedimentary basins of Redwood Canyon. The ash is a datum against which both the volume and the approximate rate of deposition of sediment can be measured.

Field Technique

A hand-powered soil auger, a Brunton transit, a tape, a notebook, and a planimeter are the tools required for this study. As many as 30 holes are augered within each sinkhole. The cuttings are logged and the subsurface distribution and thickness of the tephra and of the non-tephra-bearing sediment are noted. A compass-and-tape survey is made to map the sinkhole, the auger holes, the floor of the sinkhole, and the perimeter of the entire basin draining into the sinkhole.

Depending on the magnitude of the sinkhole, and the depth to the volcanic ash layer (1 to 2 meters), a party of 3 or 4 persons can core and map one basin (sinkhole) per day.

Reduction of Data

The survey data are reduced in the conventional manner. Base maps are prepared showing the auger holes within each sinkhole, the respective thicknesses of the tephra and the post-tephra sediment encountered by each boring, the limits of the sinkhole, and the limits of the drainage basin of each sinkhole. Using overlays, the thickness data are contoured and the resulting two isopachous maps show the distribution and the thickness of the tephra and the post-tephra sediment, respectively. To calculate the estimated volume of tephra or post-tephra sediment, one first measures the area within each isopach line using a planimeter. Multiplying the area within each isopach line by the isopach contour interval yields one increment of sediment volume for each isopach line shown on the map. These increments of volume are summed to obtain the total volume of sediment represented on the isopach map.

Proposed Analysis

An analysis of sediment yield always depends upon one or more assumptions or inferences concerning the depositional system. Greater credence may be accorded the findings of the study provided the governing assumptions are reasonable and that the study included checks for internal consistency. In the present instance, a primary area of concern is the efficiency of the sinkhole as traps for sediment. Sinkholes are known to open and close without much regard for the wishes or the presumptions of a geologist, and this irascible tendency among sinkholes must be considered if the sediment volumes being measured are to have any significance.

For example, studies of the distribution of ashfall during historic eruptions (Mt. St. Helens, to name one) indicate that at a distance of a few tens of kilometers and over a small area the thickness of the blanketing ash does not vary much. Thus, it is not unreasonable to assume that the ashfall was uniformly thick in Redwood Canyon 700 years ago. If this assumption is approximately correct, then the volume of ash or tephra available to the sinkholes is determined directly by the size of the respective drainage basin feeding the sinkhole. If the sinkhole was plugged effectively when the tephra was deposited, the *volume* of the trapped tephra divided by the *area* of the drainage basin yields a figure approximating the thickness of the ashfall that blanketed the canyon (ignoring minor complications such as post-depositional compaction, for the moment). If this computed thickness varies widely among the population of basins that was sampled, then (1) something is very wrong with the assumption of uniform thickness, or (2) the drainage basin may have changed in size during the past 700 years, or (3) the sinkhole failed to trap the silt-sized tephra, or (4) the sinkhole may have opened one or more times during the past 700 years and all or parts of its tephra-bearing fill may have been lost to the cave below, or (5) the sinkhole may be a feature less than 700 years old and may not have been exposed to the ashfall event. The ratio of sediment *volume* to drainage basin area, when computed for basins of various sizes, serves as a check to ensure that many factors are behaving in a uniform fashion. If the ratio varies widely, then the investigator is alerted to the need to seek additional information to interpret the data.

Results

As I have studied only two sinkholes, to comment on the results would be imprudent. It is safe to state that for the "non-leaky" population of sinkholes considered to date, the initial results are encouraging and are supporting the assumption of uniform thickness of tephra. I expect the volume of non-tephra-bearing sediment to be characterized by greater variations compared to the tephra volumes, because other factors are very important in determining the sediment supply in a sedimentry basin. A steep basin may have higher yields of sediment per unit area than a basin characterized by gentler slopes. The orientation of the basin correlates strongly with the amount of sunlight received and the type of vegetation. The latter factors affect the available moisture and the efficiency with which soil is retained on slopes following fires and other perturbances to the ecosystem. Parts of Redwood Canyon were logged prior to the area's being added into the National Park System. From studies of an additional 15 to 30 sinkholes, I anticipate discerning trends in the data that will disclose how rapidly the karst mantle is evolving beneath the white fir forest in Redwood Canyon during the past 700 years.

Ecology

The cave presents a unique natural laboratory for the ecologist and the biologist. Culver (1982), in his book *Cave Life* (Harvard University Press), stresses that the cave is a useful place to study, not because the biology is extreme, but because it is simple. This simplification, without many of the environmental rigors associated with most simplified ecosystems, lends itself to understanding more complex systems and provides a good place to test hypotheses.

The reports in this section are concerned with testing some hypotheses and investigating some areas that would be too complex to study outside the cave.

Poulson reports on a series of experiments to show biotic and abiotic effects of very subtle moisture and food gradients, particularly on invertebrate distribution.

Seasonal distribution of obligately cold-adapted bacteria in cave and forest soil is reported by Lavoie and Crossnoe. They found little difference in cold-adapted bacteria from either soil type, but report on evidence for seasonal surface effects on cave soil.

Lavoie and Hatcher report on the adaptations of bacteria in the cave to rigors of nutritional limitation. Although food is usually considered to be limiting in the cave environment, the limitation does not appear to extend to the level of the individual bacterial species, but the total population is reduced in the cave compared to surface controls.

Feldhake and Vestal discuss the distribution of microorganisms in caves. Correlations of microbial populations with soil organic content and moisture level were noted. Invertebrate activity and substrate recalcitrance may also affect microbial access to nutrients.

Wares has determined that water stress, in terms of osmotic pressure, faced by cave-dwelling Actinomycetes is extreme, and may help to explain their distribution.

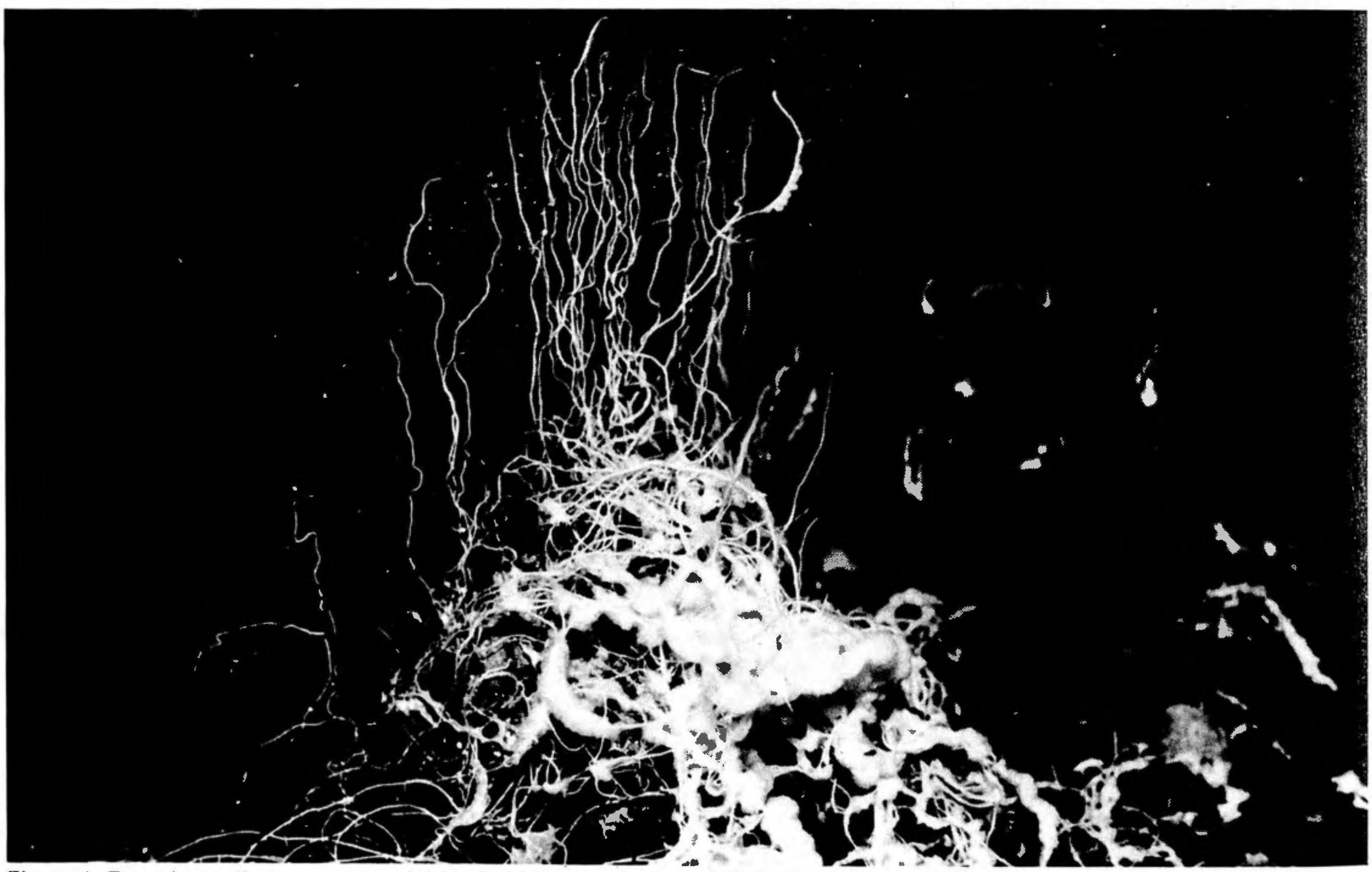

Figure 4. Fungal growth on a cave rat latrine in Little Beauty Cave, MCNP. The fungi recycle nutrients in the feces, making energy available to other organisms in the form of microbial biomass. An example of natural recycling. (Photo by K. Lavoie)

Distribution of Oligotrophic Bacteria in Cave Soil vs Forest Soil

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Most microbiological studies are concerned with the growth and activities of chemoheterotrophic bacteria. These bacteria are able to use organic nutrients for energy and as a source of carbon for biosynthesis. Most bacteria are chemoheterotrophic, including all pathogenic bacteria as well as all animals and fungi. Chemoheterotrophic bacteria are cultured on routine bacteriologic media containing an abundance of nutrients, including organic carbon at concentrations usually in excess of 5000 mg C/liter. Many natural habitats outside of a host animal typically have much lower concentrations of carbon; for example, a eutrophic freshwater lake might have a flux of organic carbon of at least 5 mg C/liter per day while in an oligotrophic lake the flux is less than 0.1 mg C/liter per day (Poindexter, 1982).

There has recently been a trend in microbiology to divide chemoheterotrophic bacteria into two groups, copiotrophs and oligotrophs, based on the level of organic carbon which will support the growth of each group. Copiotrophs are capable of growth only in rich media (5000 mg C/l) while Oligotrophs can only grow in very dilute media (0.5 mg C/l) (Poindexter, 1982). According to Koch, (Poindexter, 1982) many bacteria, including copiotrophic species like *E. coli*, have evolved an alternating 'feast or famine' strategy, feasting when there are high inputs of nutrients into their environment and starving during transient periods of low nutrient input. Oligotrophic bacteria, according to Poindexter, (1982) have never been invited to a feast. They must be adapted to dealing with permanently low nutrient conditions.

Since caves are characterized as being rigorous because of low nutrients, we decided to see if this nutrient rigor extended to the bacteria. If the cave soil is an oligotrophic habitat for bacteria, we would expect a higher proportion of the chemoheterotrophic bacteria to be oligotrophic in comparison to a less rigorous environment, such as forest soil, which has higher levels of nutrient input.

We prepared a medium containing 5000 mg C/liter using tryptone, glucose and yeast extract as nutrient sources. This medium was called the copiotrophic medium. The medium was then diluted to a level of 0.5 mg C/l which we designated as the oligotrophic medium. Both media were solidified with 1.5% agar and poured into Petri plates.

Cave mud from Columbia Avenue, Flint Ridge, and forest soil from the sinkhole around the Historic Entrance to Mammoth Cave were brought to the lab. The two samples were diluted in sterile distilled water and dilutions plated on both copiotrophic and oligotrophic media. The plates were incubated at 15 C and colonies of chemoheterotrophic bacteria were counted after 2 days on the copiotroph medium and after 5 days on the oligotrophic medium.

Total counts were lower for the cave soil, but the ratio of oligotrophs to copiotrophs was approximately the same in both environments. Results were variable, but the total number of colonies which grew on both types of media were within one log order of magnitude. In a few cases, oligotrophs outnumbered copiotrophs in both environments.

Oligotrophs typically cannot grow on copiotroph medium, but some colonies develop the ability to grow on rich medium after several transfers. Once the oligotrophic colony develops the ability to grow on rich medium it loses the ability to grow on the dilute medium. Attempts to grow oligotrophs on the copiotrophic medium were unsuccessful after two transfers. Poindexter (1982) has reported that the reverse switch, copiotroph to oligotroph, has not been observed. Transfers of our isolated copiotroph colonies to oligotrophic medium were also not successful.

While preliminary in extent, this study indicates that the cave environment may not be any more rigorous to bacteria for nutrients than forest soil, although the total microbial biomass in the cave soil is lower. The similarities between the two environments may also support an earlier observation with regard to the distribution of psychrophilic bacteria (Lavoie, 1979, and Lavoie and Crossnoe, elsewhere in this Report), that the cave environment may have a constant input of microbes and nutrients from the surface. Further studies will be needed to support or refute this interpretation, and to determine the extent of surface input to different areas of the cave. A search for obligate oligotrophs *vs* facultative oligotrophs may be a better way to determine the absolute nutrient stress for microbes in a cave environment.

Acknowledgement: This work was supported by a Faculty Development grant to the senior author from the University of Michigan-Flint.

REFERENCE

Lavoie, K.H., 1979, Psychrophilic (cold-adapted) bacteria from caves: *CRF Annual Report*, pp. 26-27.

Poindexter, J.S., 1982, Oligotrtophy: Feast and Famine Existance: *Advances in Microbial Ecology*, Volume 5.

Subtle Microspatial Gradients in Moisture and Food Supply

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There is no doubt that cave organisms are adversely affected by drying conditions which do not compromise their non-cave relatives, but it is not clear whether differences in moisture in the 90% + R.H. range have any influence on obligate cave species (troglobites). The desiccating effect of cool-cold and dry air is known to affect the distribution and abundance of troglobites near entrances whether on a seasonal basis, in temperate caves, or on a diurnal basis, in lava tube caves or tropical Hawaii (Howarth, 1980). Two kinds of experiments show that amelioration of desiccating effects increases the diversity and abundance or cavernicoles. Natural experiments are provided by horizontal passages no longer connected to a large cave system; thus White and Little Beauty Caves in MCNP are *the* only entrance areas of the huge Mammoth Cave System not subject to winter cold-dry conditions and both are biologically rich. Howarth used a manipulative experiment, by using a tent to block air currents, to enrich the biota of shallow lava tube cave entrances in Hawaii (pers. communication). Such increases in troglobite diversity with microclimate stability are not surprising in light of the generality that terrestrial troglobites have thinner cuticles than their non-cave relatives and the recent demonstration that the thinner cuticle, and its lower amount of epicuticular wax, *does* result in higher rates of evaporative water loss even at subsaturated humidities (Hadley, Ahearn and Howarth, 1981). It remains to be seen, however, if the slight rates of water loss at the highest humidity tested (90%) would translate into limitations in the deep cave environment. At 95% R.H. the troglobitic spider would lose about 4% of its body weight per day and this would be easily replenished by a moderate sized prey. Also one wonders whether the humidity at the substrate might not be 100%. Troglobites of 1-100 mg are well within the boundary layer and so experience the microclimate of the substrate and are not limited by conditions 1-5 cm off the substrate where we usually measure humidity and evaporation rates. The only study to measure conditions with the boundary layer showed that troglobitic beetles were experiencing no air movement or temperature fluctuation on rock walls at an entrance in winter where conditions a centimeter or so off the wall were still windy, cold, and dry enough to cause high rates of evaporation (Juberthie, 1969). Of course this logic presumes that the substrate is wet enough to be at 100% R.H. and we know of some conditions where this may not be the case (Poulson, Keith and Lavoie, 1981). However, on most sand and rock substrates the microclimate *is* less rigorous than outside the boundary layer and this report deals with these more usual situations. Thus if troglobites can so readily avoid desiccation stress near entrances in winter then it seems unlikely that they are so sensitive to slightly subsaturated humidities deep in the cave that they become restricted to wall recesses and solution pockets.

Logic to the contrary, observations on the sand beetle (*Neaphaenops*) have led us to reconsider the hypothesis of wall pocket refuges from microclimatic problems. Our problem is how to account for the rarity of immature beetles, the larvae, when the adults are so abundant. If the species were long-lived then the rarity of larvae could be real but *Neaphaenops* only lives about 1.2 years (Kane, Norton and Poulson, 1975). Data from one of its best habitates illustrates the numerical seriousness of our dilemma. Over a period from June to September the 700 adults die and are replaced by newly hatched beetles. Yet, while the larvae are growing and maturing we catch a maximum of 3 larvae in pitfall traps and census only 7 prepupal larvae or pupae under rocks. Where are the other 690 immatures needed to account for the approximate year to year stability of beetle population size? We have sifted through the sand looking for immatures and find none despite finding many 100s of cricket eggs on which the adult beetles (and larvae?) prey. We are left with considering the possibility that larvae are restricted to the stable microclimates with 100% R.H. in wall recesses, solution pockets, bedding plane anastomoses, and microcaverns among loosely piled limestone scree. This scenario can be called the "microclimate refuge" hypothesis. To be realistic it has the corollaries that food for larvae (i.e. other troglobites like springtails and scavenger beetle larvae) and adult beetles should also be more common in the refuges than in the open cave passage. Thus the animals that we census in the open passages would be only the "overflow" from the main populations in the wall refuges.

We chose to examine the microclimate refuge hypothesis in Great Onyx Cave in one of the best habitats for the sand beetle-cricket egg, predator-prey interaction (*Kane and Poulson, 1976*). The passage at the end of Edwards Avenue in Great Onyx Cave is 9-12 M wide, 2-3 m high (in areas more than 2 m from the walls), and has a uniform sand substrate with occasional flat rocks on the substrate surface. And, both walls and ceilings are continually moist with a paste-like coating 5-15 mm thick (moonmilk?).

Table 2. Abiotic and Biotic Response To Tree Branches Placed Across Edwards Avenue in Great Onyx Cave.

	Distance from Wall (m)		
	0.2	*4*	*4*
Response	*open*	*among rocks*	*open*
ABIOTIC			
touch/visual	damp	damp/dry	dry
BIOTIC:			
springtails	9	1	0
mold colonies	0	13	0

Table 2 shows that there are subtle gradients of moisture across the Edwards Avenue passage despite apparently uniform sand a measured R.H. of 97-99% throughout (at 2-3 cm off the substrate). Three sets of four 25 cm x 1 cm wet and dead branches were placed in three spots at the end of March. When checked in mid June there were abiotic differences in apparent moisture for the branches and associated biotic differences in organisms on the branches. Because of the differences at 4 m we suspect that the cause of moisture and organism differences is air movement. Among the rocks, air movement would be interrupted so the boundary layer would be greater and so there would be less evaporation.

The baiting results of Table 2 show a subtle microclimate effect but it is complicated by food so we chose to see if there was also an effect on animals caught in unbaited pitfall traps. We used straight-sided plastic vials 8 cm deep with a 7.9 cm perimeter since they could even be buried at the wall-substrate interface where limestone shards were mixed with the sand substrate. These traps catch the more abundant and mobile species.

Key to species trapped:

Nt = *Neaphaenops tellkampfii* = sand beetle, predator on Hs eggs
HS = *Hadenoecus subterraneus* = cave cricket, 1st-2nd instars
Ph = *Ptomaphagus hirtus* = scavenger beetle, adults and larvae
Pa = *Pseudosinella argentea* = Springtail

There are also other species but they were not trapped in this study. The bristletail *Litocampa cookei* is more common than Ph in visual censuses but avoids or does not fall into the traps. The predatory ascid mite and the pseudoscorpion *Kleptochtonius packardi* are both rarer than any of the other species and are found mainly under rocks and so are seldom trapped.

The first trapping results are for a 2 m section of lawn edging set in the middle of the passage as a control for wall-edge effects. We set it in the sand as an "L" with a trap at the inside angle and another trap 0.5 m out each arm of the "L." As a more natural control we placed two traps adjacent to two of five large rocks, in a group near the center of the passage, but too deeply buried to have organisms beneath. The data are presented in Table 3.

Table 3. Pitfall Trapping Results Along A Simulated "L"-shaped Cave Wall Set Up In Mid-passage.

	"L" Fence			*Rock Sides*	
Species	*arm*	*angle*	*arm*	*a*	*b*
Nt	10(5)*	17(12)	29(6)	14(7)	8(3)
Ph	—	—	—	9(2) +	10(0)
Hs	—	—	—	2(2)*	—

* total individuals (dead individuals)
\+ total individuals (larvae)

Nt are caught in the open as expected from visual censuses of 3-4 per m^2 in the open (Kane and Poulson, *op cit*). So why are Ph and Hs caught, in addition to Nt, in open areas by rocks? We suggest that the rocks have ameliorated the microclimate as shown by the rock effect in Table 2. Thus the "L" drift fence captures are the better control for edge effect uncomplicated by microclimate, but if microclimate is more stable at the wall, as suggested by Table 2, then the "Rock Side" captures are a better control for assessing the microclimate refuge effect by the walls.

The second trap arranagement was designed to directly assess the microclimate refuge hypothesis, i.e. troglobites have their primary habitat in wall pockets and recesses and spill out into the adjacent cave passage. Two meters of lawn edging were set into the sand so that two "wall side" traps could sample visible wall pockets which were blocked by sand at either end of the 2 m of edging (we judged that the wall side included 3-4 m^2 of pockets; there could well have been more not visible to us). We also set two traps adjacent to the edging on the "passage side." Table 4 shows no trend for higher numbers or kinds of organisms trapped on the "wall side" of the edging.

Table 4. Pitfall Trapping Results Along A Simulated Cave Wall Near Naturally-occurring Wall Pockets

	Wall Side		*Passage Side*	
Species	*a*	*b*	*a*	*b*
Nt	16(11)	25(7)	19(11)	27(18)
Hs	—	1(1)	—	—
Ph	2(2)	—	14(7)	1(0)
Pa	2	—	—	1

Unfortunately, we cannot unequivocally reject the microclimate refuge hypothesis with these data. On the one hand the area available on the wall side would seem to be less and so the similar number trapped on each side would argue for a denser population in the wall pockets. On the other hand the chance of every individual being trapped would be greater in the restricted area on the wall side where each individual would pass a trap many times over a 3-month period.

The third trapping regime was not designed to assess the wall pocket microclimate refuge hypothesis, but turns out to have given us the most insight by suggesting how microclimate and food interact to control the microspatial distribution and abundance of troglobites. We set a four-trap transect starting at the wall and then 0.2, 0.5, and 1.0 m away from the wall at a spot with no apparent wall pockets. Contrary to expectations based on an edge effect (cf Table 3), the fewest organisms were caught at the wall with most caught 0.2 m away (Table 5).

We suggest that this pattern is a reflection of food rather than of microclimatic differences. Specifically, we think that the

Table 5. Pitfall Trapping Results Along A Transect Away From A Cave Wall.

Species	*Wall*	*+ 0.2m*	*+ 0.5m*	*+ 1.0m*
Nt	1(0)	20(15)	15(3)	8(1)
Ph	—	8(7)	3(0)	—
Pa	—	4	—	—

detritivores (Ph and Pa) are responding to a sparse peppering of feces from the crickets (Hs) that roost on the walls and that predatory Nt are attracted to the detritivore prey. Nt are known to switch to alternative prey as cricket eggs become less available when the crickets hatch from May to July (Kane and Poulson, *op cit*). Within 1.0 m of the wall the moisture differences shown in Table 2 are nonexistent, thus making food the most likely variable. An alternative interpretation is that Ph and Pa are attracted by the smell of dead Nt in the crowded traps, but this seems unlikely for several reasons. Reviewing the Tables there is no consistent trend for more Ph and Pa with more dead Nt or dead Hs. Eliminating sites with no detritivores there is still no trend. There *is* a clear trend for more larval Ph with more dead Nt, but this is an effect that could result from differential egg laying by adult Ph after being trapped since there is no trend of more adult Ph (total larvae) in traps with more dead Nt. We know that larvae forage widely when they run low on food and one of the wall side traps of Table 4 caught 2 larvae and no adults. In the final analysis the Nt should not have been most abundant at the 0.2 and 0.5 m positions (Table 5) unless there were more prey to begin with.

A number of earlier observations are consistent with the importance of subtle gradients in cricket feces and these are cases where there is little or no confounding effect of dead Nt that might attract detritivores. In Edwards Avenue itself all species are most dense under rocks with uneven enough bottoms to form a labyrinth of micro-openings at the rock-sand interface. Of course, the humidity should be 100% in such restricted spaces, but there will also be the most food available for detritivores. In addition to occasional dead Nt, the feces of live beetles will be dense. Live beetles find widely dispersed cricket eggs and each carries its "prize" under a rock to avoid competition with other beetles for the egg. Each eats its egg under the rock and defecates. The feces of adult crickets are a less important contribution to the local food web. After the first few days in the mating egg laying area of Edwards Avenue, the adult cricket guts are empty and so the "rain" of their feces, from the wall roosts to the sand 0.2-0.5 m away from the wall base, stops. We know little of what the 1st-3rd instar crickets eat, other than being cannibalistic, before they find their way to a cave entrance, but the contribution of their feces must also be minimal compared to the cricket egg/beetle feces source for detritivores. Unlike these sand areas, subadult and immature crickets *do* defecate a lot, while in transit from cave roosts to foraging sites outside. Upper Columbian Avenue in Flint Ridge is one such site where the feces microgradient out from the wall is obvious due both to the dark feces on the smooth mud floor and to the colored molds that often grow on the fecal splotches. Both visual censuses and pitfall trapping show that most organisms are out from the wall base and under the areas where transient crickets move along the wall and roost. Numbers of troglobites drop to zero 2m + from the wall base even though the substrate is a continually moist mud-clay where nothing ever dries out.

As a final insight, these deductions of the importance of microspatial availability of sparse cricket feces underscore the importance of the cricket as *the* key industry species in the cave.

We already knew that one of the community types is associated with cricket guano slopes under dense roosting crickets near entrances. And we knew that the cricket guano community species are characteristic of different fecal freshness and density (e.g. millipede species: Poulson, 1978). But we used to believe that organisms of the seasonally flooded mud-clay areas depended on the sparse dissolved organic matter left at the high water line. Now it appears that the sparse peppering of feces from transient crickets is the more important food base in areas like the upper reaches of Columbia Avenue.

REFERENCES

Hadley, Ahearn, and F. Howarth (1981). *J. Arachnology*, 9:215-222.

Howarth, F. (1980). *Evolution*, 34:384-406.

Juberthie, C. (1969). *Annales de Speleol.*, 24:75-104.

Kane, T.C., R.M. Norton, and T.L. Poulson (1975). The Ecology of a Predaceous Troglobitic Beetle, *Neaphaenops tellkampfii* (Coleoptera: Carabidae; Trechniae) I, *International J. Speleol.*, 7:45-64.

————, and T.L. Poulson (1976). Foraging by Cave Beetles: Spatial and Temporal Heterogenity of Prey, *Ecology*, 57(4):793-800.

Poulson, T.L. (1978), Community Organization, *CRF Annual Report.*

————, J. Keith, and K.H. Lavoie (1981, in press). Biological Deserts Under the Caprock, *CRF Annual Report.*

Seasonal Distribution of Psychrophilic Bacteria in Cave Soil vs Forest Soil

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The temperature of an environment plays a vital role in determining the distribution and activity of any species, and microorganisms are no exception. Bacteria may be loosely grouped according to their ability to grow and reproduce at various temperatures. Bacteria with an optimal growth temperature of 20-45 degrees C are called mesophiles; bacteria with lower temperature optima are called psychrophiles, and bacteria with higher optimal temperatures for growth are called thermophiles.

Much discussion has been given to the precise definition of a psychrophile. For the purposes of this report, psychrophilic bacteria will be defined as bacteria having an optimum temperature for growth at 15 degrees C or lower and a maximal temperature for growth of approximately 20 degrees C. Organisms with a mesophilic temperature optimum, but which can grow at temperatures less than their ideal, will be defined as facultative psychrophiles. It should be noted that although facultative psychrophiles are capable of growth in the psychrophilic range, their growth rate is usually slowed substantially, sometimes requiring many days or weeks for significant amounts of growth. True psychrophiles would show maximum growth at these same temperatures.

Psychrophiles have been readily isolated from such constantly cold environments as deep ocean water and regions in the Arctic and Antarctic. Given the constantly cool environment of Mammoth Cave with an average temperature of 13.5 $\pm$ 0.2 C (Barr and Kuehne, 1971), and the age of Mammoth Cave, it is reasonable to assume that psychrophilic bacteria have had sufficient time and opportunity to evolve. Adaptation, including the evolutionary loss or extreme reduction of useless features such as eyes and pigmentation, has occurred in higher cave-adapted organisms, including invertebrates, amphibians, and fishes. Bacteria, with their rapid rate of reproduction, should be prime candidates for specialized adaptations to cool temperatures. Assuming that having a faster growth rate is an evolutionary advantage in the cave, then the psychrophiles should be the predominant type of bacteria in the caves.

Methods used were identical to those reported in the 1979 Annual Report (Lavoie 1979). Soil samples were collected from different sites in the cave and returned to the lab for assay. Total moisture was determined, and a one gram sample of each soil type was diluted and plated on Tryptone Glucose Yeast Extract Agar. Three plates from each dilution were incubated at four temperatures: 5 C, 15 C, 20 C, and 37 C. Plates were incubated until colonies appeared and the number of colonies were counted to determine the total number of colony-forming units (CFU) per sample. Every colony which grew at 7 or 15 C was subcultured onto four replicate plates of medium and incubated at the four test temperatures. The amount of growth each colony type showed at the different temperatures after three days of incubation was subjectively determined (no growth, trace, 1+, 2+, 3+, 4+).

As reported in the 1979 Annual Report, Lavoie found higher absolute numbers of colony-forming units (CFU) at 20 C for all sites from the cave during the winter. Of the total isolates tested further, 2% were obligately psychrophilic, 90% were facultatively psychrophilic, while 8% were unable to grow at cave temperatures. This pattern suggested that few microorganisms found in the cave were uniquely adapted to the temperature conditions found in the cave. Lavoie hypothesized that we were seeing typical surface microorganisms being washed into the cave and not unique cave forms, as suggested by Gounot (1973). We decided to repeat the 1979 study and compare temperature distribution of cave *vs* surface (forest soil) microorganisms. We expected similar patterns of growth from both areas to support our surface imput hypothesis. We also thought that there might be seasonal effects, with a higher proportion of cells growing at 37 C in summer *vs* winter, if the migration was fast enough to reflect the seasonal variation expected on the surface.

Our results tend to support the surface input hypothesis. A comparison of Figure 5 and Figure 6 which show the distribution of cave micrconsole organisms at different temperatures in the winter and the summer, respectively, show the same overall pattern but with a much higher number of microbes able to grow at 37 C in the summer than in the winter. Figure 7 shows the temperature pattern found for forest soil microbes in the summer. The pattern of distribution of forest soil microorganisms is nearly identical to the pattern seen for cave microorganisms (Fig. 6), at the same time of year. Identification of the growth optima for the microbes isolated in the summer interestingly show the same proportion of obligate psychrophiles, about 2% of the total, for

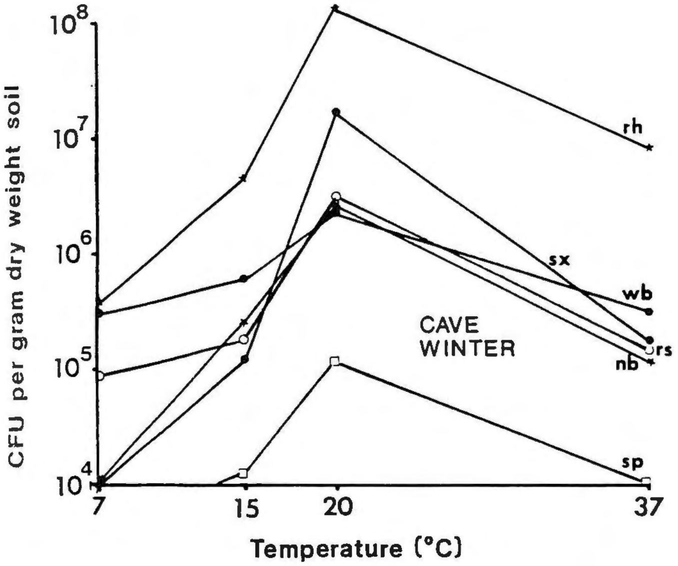

Figure 5. Sites in Historic Mammoth Cave; Winter. Colony forming units (CFU) of heterotrophic bacteria per gram dry weight of soil. Incubations of the same dilutions were done at 7C, 15C, 20C, and 37C.

nb	Natural Bridge	sx	River Styx mudband
rs	Richardson Springs	rn	Upper River Hall
sp	Rotunda; Saltpetre vats	wb	Wooden Bowl Room

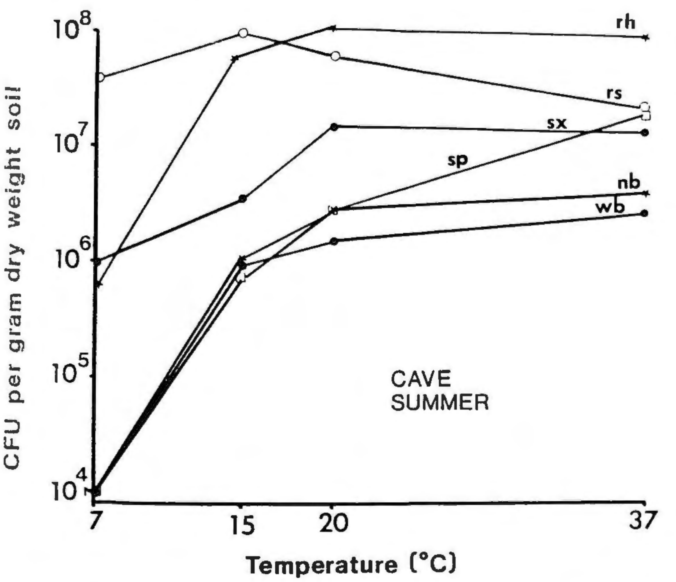

Figure 6. Sites in Historic Mammoth Cave; Summer. Legend and key identical to Figure 5.

both the surface and the cave isolates. Similar proportions of psychrophiles from surface soil and stream samples (approximately 2%) with no seasonal variation was reported by Holder-Franklin (1982).

Further evidence for surface input comes from a comparison of the CFU capable of growth at 15 C per gram dry weight of soil with the percent moisture in that soil sample (Figure 8). Both cave and surface samples collected in the summer (Figure 8) have a higher number of CFU and a higher moisture content per site than those samples collected in the winter (Figure 8). This

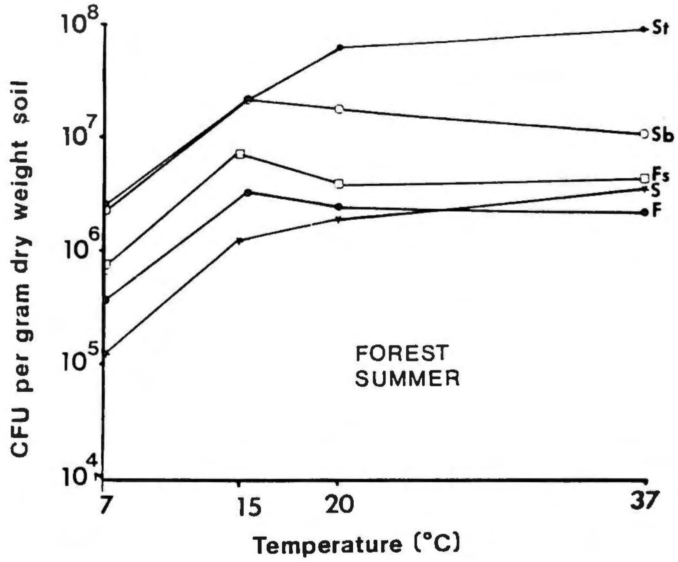

Figure 7. Forest and sinkhole sites around the Historic Entrance to Mammoth Cave; Summer. Legend is identical to Figure 5.

F	Forest sample from woods surrounding sinkhole
Fs	Forest sample from woods above sinkhole
St	Sample from rim of entrance sinkhole
S	Sample from midway point of entrance sinkhole slope
Sb	Sample from the bottom of the entrance sinkhole

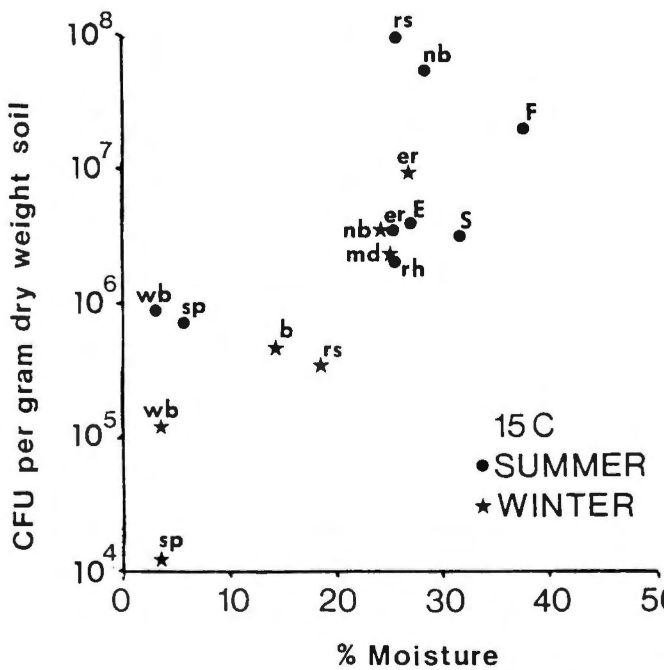

Figure 8. Relationship of Colony Forming Units to soil moisture from all sites grown at 15 C, summer and winter.

sp	Rotunda; Saltpetre vats	rh	River Hall (upper)
wb	Wooden Bowl Room	er	River Hall (lower)
b	Bottomless Pit		
rs	Richardson Springs	E	Historic Entrance
md	Mammoth Dome (bottom)	S	Sinkhole slope
nb	Natural Bridge	F	Forest sample

correlation of CFU with moisture may not be a reflection of reduced rigor with increased moisture, but probably reflects the fact that the moister areas have more direct surface inputs.

Our results support Lavoie's conclusions (1979). There seems to be a continual input of surface microbes into the cave which are able to grow and survive in the cave without needing to make any special adaptations to the temperature of the cave. Surface inputs are greater in the summer than in the winter, as suggested by Poulson and White (1969). Further studies might show a higher proportion of obligate psychrophiles in caves with more extreme selective pressures for temperature or among chemoautotrophic cave microbes. More work needs to be done on the surface input.

Acknowledgement: This work was supported by a Faculty Development grant to the senior author from the University of Michigan-Flint.

REFERENCES

Barr, T.C. and R.A. Kuehne, 1971, Ecological studies in the Mammoth Cave system of Kentucky. II. The ecosystem: *Annals de Speleologie*, 26:47-96.

Gounot, A.M., 1973, Importance of the temperature factor in the study of cold soils microbiology: *Bull. Ecological Research Comm.* (Stockholm), 17:172-173.

Holder-Franklin, M., 1982, The use of discriminant analysis on the evolution of tests in numerical taxonomy: Presented at the American Society for Microbiology: Michigan Branch Meeting, Windsor, Ontario, November.

Lavoie, K.H., 1979, Psychrophilic (Cold-adapted) bacteria from caves: *CRF Annual Report*, pp. 26-27.

Poulson, T.L., and W.B. White, 1969, The Cave Environment: *Science*, 165:971-981.

Cave Soil Microbial Communities: Evaluation of Biomass and Activity

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Introduction

Soil microorganisms fullfill important roles in the cycling of many nutrients commonly used by other organisms. The microbial communities found in caves may be particularly significant in converting organic materials into forms which higher trophic levels can utilize. The absence of light precludes photoautotrophic activity. Thus, the heterotrophic microbiota depend almost exclusively on sporatic imputs of detritus or animal wastes as sources of carbon. Because of the limited quantity and the nature of the organic nutrients available to cave soil microbiota, it is apparent that carbon availability may be an important factor in determining the size and activity of microbial communities in cave environments.

Previous cave microbiological research has depended largely on obtaining information concerning the microbiota by removing it from the cave environment. Dickson (1976) used standard plate counts to estimate the numbers of bacteria, actinomycetes, and microfungi in a variety of cave substrates. A positive correlation between troglobitic invertebrates and fungal populations was found, but no correlation between bacterial populations and invertebrates was observed. Dickson's study provides some insight into the types of microbes present in cave soils, as well as indicates a possible interaction between fungi and invertebrates in caves. However, the actual activity of the natural microbial community remains a relatively unexplored topic.

Lavoie (1979) performed a carbon and nitrogen enrichment of the cave substrate to determine if increased microbial biomass resulted in increased numbers of invertebrates at the enrichment site. Results indicated that there was a response by the invertebrates to the enrichment, but it was not possible to quantify the role of the soil microbiota in this phenomenon.

The purpose of our seasonal survey was to provide basic information concerning the biomass and activity of the natural microbial populations found in a variety of cave substrates. Soil moisture and the organic content of cave soils were also monitored as two environmental parameters which may significantly influence the cave microbiota.

Methods

Twelve sites were selected for a seasonal survey of diverse cave soil environments and the microbial communities associated with these environments. The sites are briefly described in Table 6. Little Beauty and Great Onyx caves are located within the Mammoth Cave National Park, whereas Parker's, Walnut Hill, and Bland's caves are in the general vicinity of the park.

Table 6. Brief Comparison of Cave Study Sites.

Caves	*Sites*	*Location*	*General Soil Type*
Little Beauty	1	Near Entrance	Loam
	2	Main Passage	Clay
	3	Main Passage	Clay
	4	Rear	Sand
Great Onyx	1	Rear	Sand
Parker's	1	Lower Passage	Clay
	2	Upper Passage	Loam
	3	Upper Passage	Cricket Guano
Walnut Hill	1	Rear	Clay
Bland's	1	Main Passage	Clay/Sand
	2	Main Passage	Worm Turnings
	3	Cave Wall	

Soil Characteristics

Moisture content of the soils was determined by heating samples overnight at 60 degrees C. Total organic matter at the various sites was determined by ashing samples at 500 degrees C for two hours, and then correcting for the loss of the water of hydration.

Microbial Community Characteristics

Microbial biomass was determined by the quantification of lipid phosphates in the soils (White *et al*, 1977). Since phospholipids are a primary constituent of cell membranes, they can be used to estimate the total number of microorganisms in a sample. Lipids were extracted immediately upon sampling in the field. Lipid phosphate values obtained were expressed as umole PO_4 per gram dry weight of soil (umol/g dw).

Microbial activity was assessed as the rate of (^{14}C) acetate incorporation into lipids (McKinley *et al*, 1982). The assay was performed in triplicate *in situ* for one hour. Acetate was chosen as the substrate because it is the immediate precursor for lipid biosynthesis, and is readily taken-up by most microorganisms. Results were expressed as the rate of incorporation of labeled acetate per gram dry weight of soil, or disintegrations per minute/hour/gram dry weight of soil (DPM/h/g dw).

Samples were obtained and experiments performed during the months of March, August, and November of 1983, and January of 1984.

Results and Discussion

A wide range of values were obtained for each of the characteristics which were monitored. Water content of the various substrates ranged from 6.0 to 36.9% of total weight, while organic matter at the different sites varied from 1.1 to 39.7% of dry weight. Microbial biomass and activity also showed great variation from site to site. Biomass determinations of 0.003 to 1.25 umol PO_4/g dw were obtained, and activity measures ranged from 898 to 27,307 DPM/h/g dw.

Correlation values determined from environmental and microbial community data during each of the field trips are presented in Tables 7-10. Table 11 contains correlations based on pooled values from all four sampling periods. Microbial biomass was significantly correlated with soil organic content in all cases, with the exception of August data. Microbial activity and soil organic content were also correlated in several instances. Microbial biomass correlated with soil moisture in November, while biomass and activity correlated with soil moisture when linear regressions were performed using pooled data.

It is apparent from these data that the organic content of cave soils, and possibly soil moisture, may play a major role in

Table 7. Correlation Matrix of Environmental and Microbial Community Characteristics. 22 March 1983.

	% H_2O	*% Organic*	*Biomass*
% Organic	0.6103		
Biomass	0.6129	0.9855***	
Activity	0.4989	0.8476***	0.7953*

***P< 0.01 *P< 0.05 N = 8

Table 8. Correlation Matrix of Environmental and Microbial Community Characteristics. 22 August 1983.

	% H_2O	*% Organic*	*Biomass*
% Organic	0.8761***		
Biomass	0.4450	0.4014	
Activity	0.5320	0.4696	0.1369

***P< 0.01 N = 12

Table 9. Correlation Matrix of Environmental and Microbial Community Characteristics. 27 November 1983.

	% H_2O	*% Organic*	*Biomass*
% Organic	0.7610***		
Biomass	0.7153*	0.9825***	
Activity	0.1069	0.1687	0.0822

***P< 0.01 *P< 0.05 N = 11

Table 10. Correlation Matrix of Environmental and Microbial Community Characteristics. 27 January 1984.

	% H_2O	*% Organic*	*Biomass*
% Organic	0.4125		
Biomass	0.3467	0.9895***	
Activity	0.4001	0.8975***	0.8739***

***P< 0.01 N = 12

Table 11. Correlation of Environmental and Microbial Community Characteristics. Summary of All Dates.

	% H_2O	*% Organic*	*Biomass*
% Organic	0.6587***		
Biomass	0.3414*	0.8014***	
Activity	0.3508*	0.6037***	0.7953***

***P< 0.01 *P< 0.05 N = 44

determining the size and activity of cave soil microbial communities. It is likely that other factors are also important. Invertebrate activity and other physical disturbances may affect microbial access to nutrients, and the recalcitrance of organic matter may limit microbial biomass and activity. Other paramenters such as soil redox potential and temperature differences (due to season or location within the caves) may also be significant factors influencing cave microbiota.

Future work includes a more detailed analysis of cave soil inorganic nutrients, soil particle size, and soil pH at each site. A statistical analysis of the data is currently being undertaken to determine if there are seasonal variations in microbial biomass and activity in caves.

REFERENCES

Dickson, G.W. and P.W. Kirk, Jr., 1976, Distribution of heterotrophic mircoorganisms in relation to detritivores in Virginia caves (with supplemental bibliography on cave mycology and microbiology): In B.C. Parker and M.K. Roane (eds.), The distributional history of the biota of the southern Appalachians. *Algae and Fungi*, IV.Charlottesville, VA; Univ. Press of Virginia, pp. 205-226.

Lavoie, K.H., 1979, Invertebrate response to inorganic enrichment of cave substrates: *1979 CRF Annual Report*, p. 22-23.

McKinley, V.L., T.W. Federle and J.R. Vestal, 1982, Effects of petroleum hydrocarbons on plant litter microbiota in an arctic lake: *Appl. Environ. Microbiol.*, 43:129-135.

White, D.C., R.J. Bobbie, S.J. Morrison, D.K. Oosterhof, C.W. Taylor and D.A. Meeter, 1977, Determination of microbial activity of estaurine detritus by relative rates of lipid biosynthesis: *Limnol. and Oceanogr.*, 22:1089-1099.

Water Tolerance of Cave-dwelling Bacteria

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Certain species of cave dwelling bacteria (Actinomycetes) appear to be more prevalent in cave settings not directly exposed to water. Visible colonies of these bacteria grow on cave mud and formations and probably derive enough moisture from cave humidity to meet their hydration requirements. Direct exposure to water might only prevent the bacteria from adhering to cave formations, or it is also possible that cave water may contain minerals in sufficient quantity to interfere with bacterial metabolism. One must also consider possible osmotic stresses placed on the bacteria by direct contact with water.

Preliminary attempts to explain distributions of Actinomycetes in the cave have been directed towards understanding osmotic stresses. Diffusion of water across a biological membrane from an area of high water concentration to an area of low water concentration is termed osmosis. The pressure required to halt such a movement is called the osmotic pressure. Molecules and ions in solution, because of electrical repulsions, are ideally as far removed from each other as possible. If such particles cannot cross a membrane (are non-diffusable) and water exists on the opposite side of the membrane and can cross the barrier, the water will move to it's area of lower concentration (many particles, little water). Water will continue to move (within certain limits) until it's concentration on each side of the membrane is equal. The osmotic pressure would need to be higher for a solution which had a greater particle concentration. The directional movement of water between two solutions separated by a membrane will give an indication of relative concentrations (and osmotic pressures) of the solutions. Pure distilled water has a concentration (osmotic pressure) of 0 mosmol/liter (milliosmoles/liter) while human red blood cells (RBC's), for example, have an approximate osmotic pressure of 300 mosmol/liter. If RBC's are placed in distilled water the water will move into the RBC's in an attempt to reach osmotic equilbrium, causing the RBC's to swell and ultimately burst.

It was not known whether cave water picks up molecules and ions as it passes into the cave from the surface or whether this water is more like distilled water. Cave water high in osmotic pressure would take water away from bacteria when in direct contact with the bacteria. Conversely, if cave water were essentially osmotically identical to distilled water, we would expect bacteria in contact with the water to swell almost to the point of bursting, preventing growth and metabolism. In either instance it would not be beneficial for the bacteria to be in contact with the water.

Water samples were collected from White Cave (Mammoth Cave National Park) in May of 1983. Samples were obtained from pools and dripping sources near Actinomycete colonies. Mean osmotic pressures were determined on both classes (pool and drip water) and compared to the osmotic pressure of distilled water. Statistical analysis (ANOVA) showed no difference between the osmotic pressure of pool water, drip water or distilled water ($P > 0.05$).

The danger associated with exposure to a solution of very low osmotic pressure (cave water) may be one of the possible explanations for Actinomycete avoidance of direct water contact. Work to test this and related areas is being done to understand the distributions of cave dwelling Actinomycetes.

Archeology, Anthropology and Paleontology

Caves frequently serve as natural refuges for man and animals, and often provide a record of their activities, distribution and paleoclimatic conditions.

The CRF Archeological Project, headed by Dr. Pattty Jo Watson, reports on several activities in and out of MCNP that are concerned with human prehistoric activities, diet, and cave utilization and exploration (Kennedy, Hensley-Martin, and Watson). Vandalism is an unfortunately common problem in any such work (see Figure 10).

Tankersley reports on several unique mineralogic properties of Wyandotte Chert which may allow tracing of prehistoric trade networks dealing with chert.

Emslie discusses the successful completion of Phase I of the paleontology of a newly-opened cave in Nevada (Labor of Love Cave). A collection and survey of all exposed bone deposits was done to protect them from vandalism and stream fluctuations. The most notable find was the most complete individual skeleton of an extinct giant short-faced bear.

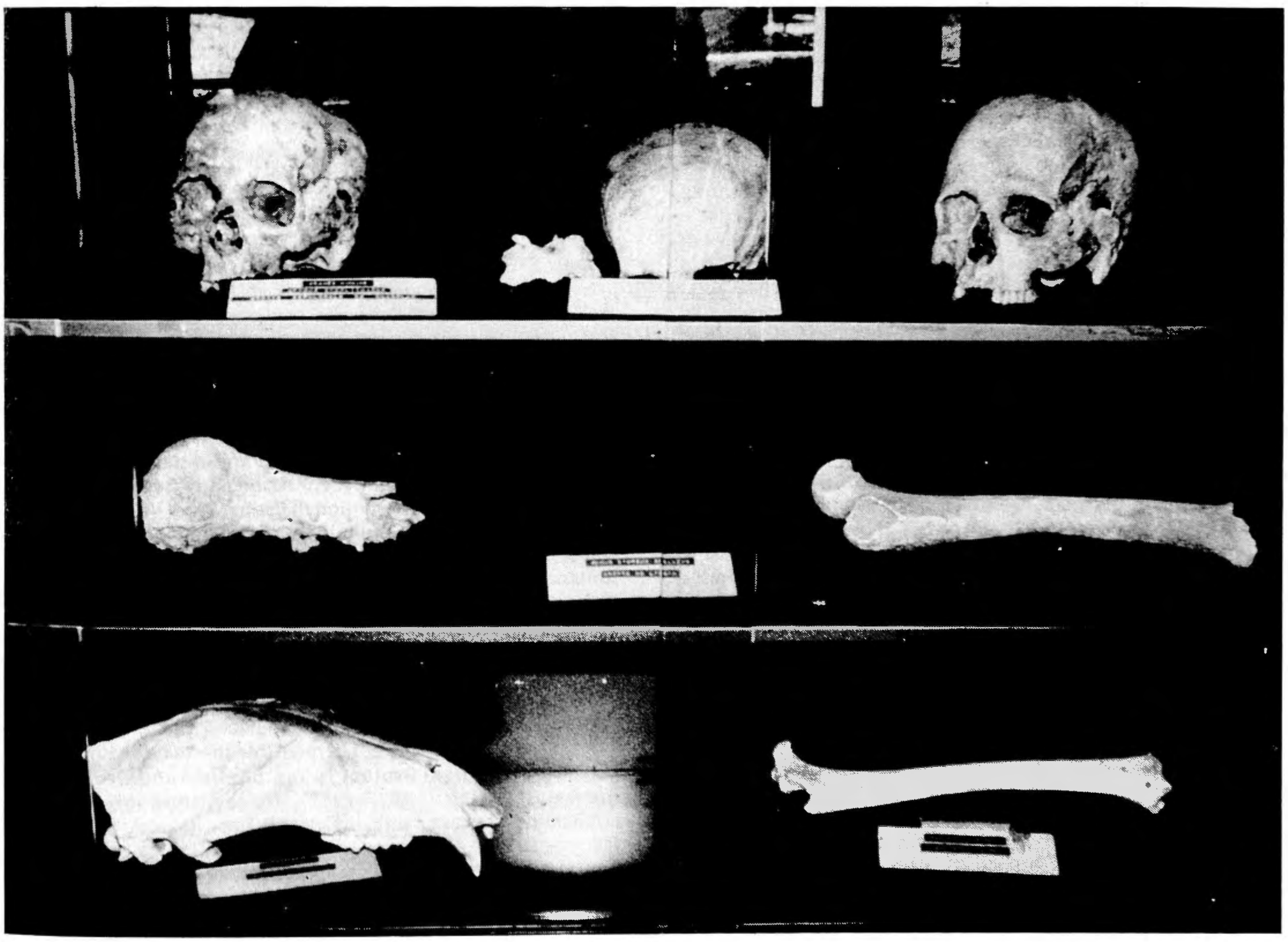

Figure 9. Human prehistory and cave utilization are topics of worldwide interest. This photo shows a collection of human and cave bear remains collected from caves in the French Pyrenees on display at the CNRS (Centre Nationale de Rescherches Speleologie), Moulis, France. (Photo by K. Lavoie)

CRF Archeological Project—1983

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Three archeological activities were carried out inside MCNP this past year. From June 5-11 Pat Watson taught Cave Archeology for WKU's Summer University in the Park; she was assisted by George Crothers, Mary Kennedy and Ron Wilson. The course included field trips to above- and below-ground sites within the Park as well as a two-day trip to Jaguar Cave, Tennessee, and to the University of Tennessee's archeological project at Columbia, Tennessee. On June 12, after the course was over, a CRF archeological crew surveyed the junction of the Nolin River and Second Creek in search of a shellmound rumored to be located there—no sign of it—but we did get a close look at some bluffline and rock shelters. Finally, on Labor Day weekend a crew consisting of Ken Carstens, Chris Hensley-Martin, and Mary Kennedy re-examined the Doyel Valley/Union City drill points for Jim Quinlan's hydrological monitoring studies. We had checked in this general area last year (see 1982 Annual Report), but locations had been changed so additional survey was required to determine whether drilling would disturb any archeological sites. Later the same day the crew also rechecked the Northtown Road as the bulldozing operation for road improvements had exceeded the limits of our original survey (see 1982 Annual Report). In addition to the fieldwork inside the Park, we conducted several projects that were outside the Park but relevant to our knowledge of regional prehistory (1 through 4 below).

1) Prewitts Knob is a karst feature just outside the Park's southeast boundary. Preliminary work was done there last year (see 1982 Annual Report) after human skeletal material was discovered in Pit of the Skulls. In May, Pat Watson, Valerie Haskins, Eve Anderson, Julie Katz, Mary Kennedy, and Ron Wilson spent two days doing fieldwork that will be the basis of Valerie's M.A. thesis (Washington U., St. Louis, — Anthropology) on the prehistory of Prewitts Knob. Valerie took up residence at Flint Ridge for several weeks in June and July and continued her documentation of the chert outcrops, lithic scatters, pits containing skeleton material, and other evidence of prehistoric human activity on the knob. With the enthusiastic support and expertise of numerous members of the CRF July expedition, the exploration and mapping of all 14 pits was accomplished.

2) Sinking Creek Cave is located near Bowling Green, Kentucky, on the property of Mr. and Mrs. Merle O'Bryan. The site is a piece of collapsed trunk passage with two large entrances directly opposite each other and a running stream in the center. With plenty of light, water, and a constant temperature this would have been an ideal prehistoric human habitation. Geary Schindel is responsible for bringing this site to the attention of the CRF/AP. In December 1982 Ron Wilson, Phil DiBlasi, Jan Hemberger, Geary and Sue Schindel evaluated the site and filed a Kentucky site report. At that time there was concern about vandalism as there had already been some damage by relic collectors. On June 13, Geary visited the site with Pat Watson, Chris Hensley-Martin, and Mary Kennedy to find that more destruction had occurred (Figure 10). We returned in July to begin excavation with Chris Hensley-Martin as field supervisor, but in the intervening weeks the vandalism had intensified to the extent that in the course of nine days' work in the cave we were unable to locate any undisturbed cultural deposit. However, some information was recovered from a passage off the vestibule where midden debris from the surface had accumulated. This material will provide data on prehistoric diet at Sinking Creek as it contained animal bone and charred plant remains. We know from artifacts discarded or missed by the looters that the site was occupied during Archaic and Woodland periods, probably continuously or nearly so for thousands of years, a time span that includes the period of intense utilization of the Mammoth Cave System. Unfortunately the wealth of comparative data this site once had to offer no longer exists, having been destroyed by the vandals.

3) On a more positive note, the documentation of 272 aboriginal footprints made 4500 years ago in Jaguar Cave, Tennessee, is now complete. Each print is recorded on a 10' x 3' map expertly drafted by Mike Voligny. A final mapping trip was made in August by Mike, Pat Watson, Ron Wilson, Alison Wylie, Sam Gerszonowicz, and Mary Kennedy.

4) Since the last Annual Report we've obtained radiocarbon dates on material from a Kentucky footprint cave, Fisher Ridge Cave, located east of MCNP. There are approximately 18 slippered footprints in a mud-floored passage of this cave. Dr. Robert Stuckenrath of the Smithsonian Radiation Biology Laboratory has provided dates on two samples collected near the footprints: 800 B.C. $\pm$ 85 on a piece of oak log and 1225 B.C. $\pm$ 80 on cane charcoal. Radiocarbon dates from Fisher Ridge, investigations at Prewitts Knob, Sinking Creek, and Jaguar Cave all contribute to a better understanding of aboriginal cave utilization and exploration in and around the Mammoth Cave system.

In July we had a chance to present some of that information to the larger caving community. An Archeology Session was held on July 1 at the NSS Convention in Elkins, West Virginia. George Crothers outlined his preliminary investigations in Big Bone Cave, Tennessee; Lee Ferguson described his recording of flintknapping debris in Salt-petre Cave, Tennessee; Valerie Haskins gave a preliminary report on Prewitts Knob; and Pat Watson discussed prehistoric footprints in U.S. caves. We finished up our trip to West Virginia with a tour of Organ Cave in Lewisburg, WV, led by John Rutherford of WVACS.

The other focus of our archeological work in western Kentucky, the Shellmound Archeological Project, was inactive in so far as fieldwork is concerned (for the relationship of the CRF Archeological Project to the Shellmound Project see Annual Reports for 1977-1982). We're still involved in the publication process, with the SMAP book (senior editor, Bill Marquardt) scheduled to go to the publisher in late Spring 1984. Fortunately for us, we did get to Logansport over the Labor Day weekend so we don't feel totally out of touch with our friends in the Big Bend. We set up the flotation system and processed several bags of deposit from Sinking Creek Cave, Toolshed Cave (a paleontological site near Louisville where Ron Wilson has been working), and from a Mississippian site under investigation by Ken Carstens near Murray, Kentucky. We are indebted to

Figure 10. Vandalized deposits in Sinking Creek Cave (15 519), July, 1983. (Photo by G. Schindel)

Lena Gray Annis for letting us set up the SMAP machine on her property along the Green River, and—as always—we are grateful to Ethie and Waldemar Annis, and to John L. Thomas for assisting us in every way, and putting up with us so cheerfully.

Acknowledgements

As in previous years, we are grateful to Superintendent Robert Deskins, to Management Assistant James Wiggins, and to the other officials and staff of Mammoth Cave National Park who facilitate and support our research in the Park. We are also grateful to Mr. Reynold and Mr. Kline for allowing us access to Pit of the Skulls on Prewitts Knob. Special thanks go to Tom Black, Tom Brucker, Roger Brucker, and Lynn Weller Brucker and all the JVs who assisted with the work on the Knob during the July expedition. Mr. and Mrs. Wesley Odle were generous and hospitable to Valerie Haskins and the CRF crews working in and around Crystal Onyx Cave, also on Prewitts Knob. Our salvage work at Sinking Creek Cave could not have been done without the permission of Mrs. O'Bryan, and the enthusiastic support of Geary and Sue Schindel, and of Michael and Lee Ann Hennion. Geary's photographic expertise as well as his speleological knowledge are much appreciated.

Once again Dr. Robert Stuckenrath of the Smithsonian Radiation Biology Laboratory generously provided us with radiocarbon determinations to help make the chronological framework of Mammoth Cave area prehistory more secure.

We are grateful to Walter Klippel and the other members of the University of Tennessee's Columbia project for being such generous hosts when we visited their fieldwork area.

Finally, we are pleased to acknowledge once more our great debt to the kind and hospitable people of Logansport, Kentucky, in the Big Bend of Green River. Over the period of our work there, they have accepted us into their community and have in turn become colleagues and good friends.

The Diagnostic Properties of Wyandotte Chert

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Wyandotte chert is one of the highest quality cherts in the midwestern United States and was heavily utilized throughout 12,000 years of prehistory. It outcrops in the karst landforms of eastern Harrison County and western Crawford County, Indiana, and adjacent northern Kentucky. Stratigraphically, this chert occurs in the upper part of the Fredonia Member of the Ste. Genevieve Limestone (Bassett and Powell, 1982), and Wyandotte Cave is the type site. Chert artifacts that are microscopically identical to Wyandotte chert occur on archaeological sites hundreds of miles from this karst area (Seaman, 1975). If diagnostic properties of Wyandotte chert exist and can be determined, then prehistoric procurement strategies and trade networks for this important raw material may be determined.

Previous archaeological work on Wyandotte chert has concentrated on identifying prehistoric mining and workshop activities, investigating the cultural context to those activities, and establishing a detailed lithologic description of the chert's stratigraphic position and geographic distribution. However, there has been little or no attempt to identify the diagnostic properties or "fingerprints" of Wyandotte chert. Munson *et al.* (1983) have described Wyandotte chert as being high quality, microcrystalline in structure, bluish gray in color and nodular or tabular in form. Unfortunately, this description applies to cherts that occur in many karst areas of the Eastern United States.

If Wyandotte chert is a distinctly identifiable variety of chert, then its mineralogical properties should be distinguishable when compared to "look-a-like" cherts from various stratigraphic and geographic locations in the karst areas of Indiana, Kentucky, Tennessee, Illinois, and Ohio. Any distinct mineralogical properties can be searched for in the laboratory using high magnification microscopy.

Using petrographic thin section analysis and scanning electron microscopy, the presence of distinctive microstructures and non-silica mineral inclusions were recognized. Wyandotte chert's microstructure consists of isotropic and anisotropic silica with an occasional occurrence of spicular silic forms (see Figure 11-1). Large rhombohedrons of dolomite are abundant throughout the silica matrix (see Figure 11-2). Pyrite crystals and grains often co-occur with spherical bodies of anthraxolite. Geode-like inclusions of opaline and crystalline quartz or calcite are common. Joint fractures in chert from the argillaceous and shaly limestone horizons of the Wyandotte chert zone are filled with calcite and fluorite. Chert from these horizons often does not contain ooliths, although most Wyandotte chert is oolithic to some degree. Ooliths may be isolated or banded in a cryptocrystalline matrix, or massive with limited intergranular area (see Figure 11-3). Wyandotte chert ooliths usually have a quartz nuclei and are well defined. Glauconite, if present in Wyandotte chert, only occurs in minute quantities. Glauconite (see Figure 11-4) is abundant in look-a-like cherts from the St. Louis Limestone Formation. Fossils, common in many look-a-like cherts, are very rare in Wyandotte chert.

The knapping qualities of many cherts can improved upon heating. Experimentation has demonstrated that the knapping

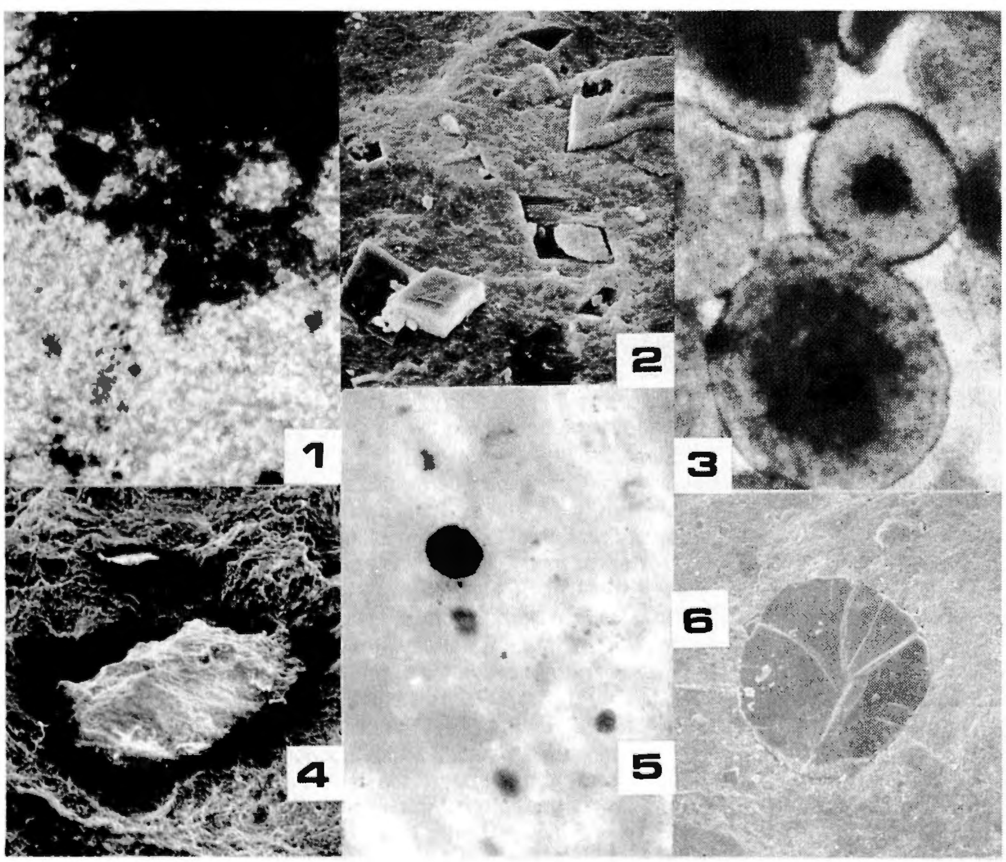

Figure 11. Photomicrographs of petrographic thin sections of Wyandotte and other cherts showing distinctive mineralogic features. Magnifications in parentheses, SEM = Scanning Electron Microscope.

11-1. Wyandotte chert (100X), crossed nicols.

11-2. Wyandotte chert and dolomite inclusions (400X), SEM.

11-3. Oolithic Wyandotte chert (100x), crossed nicols.

11-4. St. Louis (Dongolla) chert and glauconite inclusions (400X), SEM

11-5. Wyandotte chert and anthraxolite inclusions (100X), crossed nicols.

11-6. Wyandotte chert and an anthraxolite inclusion (400X), SEM.

qualities of Wyandotte chert can be destroyed at a very low temperature (at or below 588 degrees C) because of the decomposition of anthraxolite (see Figures 11-5 and 11- 6), the crystal inversion of quartz, and the dehydration of the silica matrix.

Continuing research on the mineralogical properties of this chert will provide the archaeological community with the best means of correctly identifying artifactual material made of Wyandotte chert. It is very possible that some or all cherts might have diagnostic mineralogical properties which can be microscopically identified (e.g. Ste. Genevieve cherts of Lower Mammoth Cave, Kentucky or Xarathustra Cave, Tennessee which were both prehistorically mined).

REFERENCES

Bassett J.L., and R.L. Powell, 1982, Stratigraphic distribution of cherts in limestones of the Blue River group in southern Indiana: A paper presented at the Conference on Prehistoric Chert Exploitation, Southern Illinois University, Carbondale.

Munson P.J., J. Bassett, and C. Munson, 1983, Cherts and cave minerals of the Mississippian carbonate rocks of southcentral Indiana and their uses by prehistoric Indians: *1983 GSA Field Trips in Midwestern Geology,* 2:189-198.

Seaman M.F., 1975, The prehistoric chert quarries and workshops of Harrison County, Indiana: *Indiana Archaeological Bulletin,* 2(3):47-61.

The Paleontology of Labor-of-Love Cave

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In December of 1981, members of the High Desert Grotto, Ely, Nevada, discovered the opening to a previously unrecorded cave in east-central Nevada on U.S. Forest Service land. The cave, named Labor-of-Love Cave by the High Desert Grotto, is located at the base of a limestone cliff at an elevation of 2050 m and faces east. The cave extends over 137 m into the mountain and consists of one main passage. A small stream flows through the entire length of the cave and emerges at the base of a talus slope 30 m below the cave entrance. Air and water temperatures in the cave remain constant at 10 degrees C. When the cave was first discovered, two deposits of bone were found in two side pools along the stream edge. Members of the speleological society immediately recognized the significance and value of these bones and protected the find by refusing to reveal its location to potential vandals.

When this find came to my attention, I applied for a special use permit from the U.S. Forest Service, to collect vertebrate fossils from Labor-of-Love Cave for the Los Angeles County Museum (Page Museum). A research design was prepared which outlined two phases of work. Phase I presented procedures for collecting all exposed bones in the two pools which were in immediate danger of being either washed away by fluctuations in stream flow, or stolen by vandals entering the cave. This phase included a photographic survey of the cave, and maps of the two pools giving the relative position of each bone within the pools.

Phase II of the research design, to be completed at a later date, will include detailed studies of the history and geology of the cave, stratigraphic studies of silt deposits in the cave, and taphonomic interpretations of bone deposited in the strata.

Results

The two bone localities in the cave were designated Bone Concentration #1 (BC-1) and Bone Concentration #2 (BC-2). BC-1 lies approximately 122 m into the cave in an area where the stream has been diverted creating a pool in a quiet backwater area where the bones were located. The pool is approximately 2 m wide, 3 m long and 70-90 cm deep. The bottom of the pool has deep mud and silt deposits on which the bones were lying. Bones recovered here included the scattered remains of a partial skeleton of an immature black bear (*Ursus americanus*), one bone of another black bear, one bone of a giant short-faced bear (*Arctodus simus*), and one bone that has been tentatively identified as grizzly bear (*Ursus arctos*). The partial skeleton of the black bear included all long bones, fragments of the skull, both mandibles, several vertebrae, and several metapodia and phalanges. All these bones probably were eroded by the stream from a mud bank adjacent to this pool.

BC-2 is another quiet backwater pool located approximately 20 m upstream from BC-1, towards the back of the cave. Bone was located in the pool and also lying on a gravel bar at the pool edge. Bones on the gravel bar appeared to be eroding from their original place of deposition, and were being washed into the pool. Bones recovered here included the scattered remains of a partial skeleton of an adult giant short-faced bear (*Arctodus simus*), three bones of a black bear (*Ursus americanus*), and one bone of an unidentified artiodactyl. The partial skeleton of the short-faced bear included all long bones, fragments of the skull, both mandibles, an atlas vertebrae, two metapodia, and one phalanx.

Conclusions

Preliminary investigations at Labor-of-Love Cave have demonstrated the paleontological importance of this site. The partial skeleton of the short-faced bear recovered at BC-2 is the most complete skeleton of one individual of this species yet recovered from North America. Although no radiocarbon dates have been obtained on the material, this species became extinct at the close of the Pleistocene, 12,000 years ago. The cave has probably been closed since that time and now contains a valuable record of fauna which lived in the Great Basin during the Pleistocene. Future studies will concentrate on evaluating the full importance of these remains, and the history and circumstances of their deposition.

Acknowledgements

Phase I was completed on 1 August 1982 with the assistance of Frank Johnson of the U.S. Forest Service, the High Desert Grotto from Ely, Nevada, several Bureau of Land Management personnel, and George Jefferson and Les Marcus from the L.A. County Museum. A grant from the Cave Research Foundation provided funds for this phase of the project. The U.S. Forest Service provided funds for two C14 dates.

Interpretation and Education

Knowledge gathered about caves is only useful if it can be shared. The Foundation encourages professional presentation of findings and talks to increase awareness of caves for the general public.

This section summarizes publications and presentations made in 1983, service in cave-related areas, and reports on the 1983 CRF Fellowship.

Figure 12. Cave conservation is a continual concern of everyone who uses caves. Caves and cave organisms are deceptively fragile. Conservation and management of limited cave resources depends on an understanding provided by studies in all areas of speleology.

Dan Fong removes an "Accidental"—a frog found deep in Columbia Avenue of the Flint Ridge System. Is this well-intentioned case an example of conservation by saving the doomed frog, or an example of vandalism by removing a potentially valuable source of food for cave organisms? Conservation and Management must often tread a very fine line! (Photo by K. Lavoie)

CRF Fellowship and Grant Support

Each year, the Foundation may award up to $3000 as a fellowship or as one or more grants for research in karst-related fields. The truly exceptional proposal may receive a Karst Research Fellowship (limit $2000); meritorious proposals may receive one or more Karst Research Grants, in amounts less than $2000, awarded to qualified students in graduate programs of the natural or social sciences. Applications are screened by a committee of scientists. The judges seek promising or innovative topics, supported by evidence that the student has command of the literature and the methodology. A detailed announcement is mailed in the late Autumn, and the deadline for the receipt of the proposal, supporting documents, and letters of reference is 15 February. Awards are announced by 15 April. Send inquiries to:

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

In 1982, four proposals were received and the following Grants were awarded:

1. A CRF Karst Research Grant ($700) awarded to Mr. Kenneth B. Tankersley, Department of Anthropology, Indiana University, Bloomington, IN, for his proposal entitled "The Diagnostic Properties of Wyandotte Cave Chert: An Archeological Investigation."
2. A CRF Karst Research Grant ($300) awarded to Ms. Sheila Grow, Department of Geology and Geophysics, University of Minnesota, Minneapolis, MN, for her proposal entitled "Water Chemistry Variations of a Southeast Minnesota Karst Basin."

A Summary of Tankersley's research appears elsewhere in the report.

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

Abstracts of Published Papers

Lisowski, E.A., 1983, Distribution, habitat, and behavior of the Kentucky Cave Shrimp *Palaemonias ganteri* Hay: *Journal of Crustacean Biology,* 3(1):88-92.

The Kentucky cave shrimp *Palaemonias ganteri* is known only from base level cave passages in the Mammoth Cave System, Kentucky. Since the shrimp was not seen between 1967 and 1979, it was assumed to be extinct. Between May 1979 and February 1981, I looked for shrimp in the base level pools by searching visually or by seining and dip netting once a month. SCUBA divers on four occasions searched deep pools and submerged cave passages. No live shrimp were found in residual pools, where they were readily observed before 1967. A few shrimp were found in deep pools of streams and in submerged passages. Foraging at the water surface was observed.

Tankersley, K.B., P.J. Munson, and C.A. Munson, 1983, Physical and chemical properties of Wyandotte Cave aragonite and their archaeological implications: *GEO2, The Journal of the NSS Section of Cave Geology and Geography,* 11(1):2-5.

Analysis of prehistorically quarried speleothems in Wyandotte Cave, Indiana, have demonstrated that they are of aragonite with diagnostic crystal structure, mineralogy, and chemical constituents. These data have important implications for the determination of source areas for archaeological artifacts of aragonite in eastern North America.

Tankersley, K.B., 1983, Tracing recharge water to porous colluvium in archaeological sites: *NSS Bulletin,* (in press).

Fluorescein dye tracing can be used to demonstrate or negate a hydrological connection between a coal strata and a porous rockshelter colluvium. This method provides the archeologist with a method that can recognize a hydrological process that can transport radiocarbon contaminants to a charcoal sample.

Western Kentucky University Karst Field Studies at Mammoth Cave National Park—1983

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

These intensive field courses combine formal lectures with field observation and techniques held for one-week sessions at Mammoth Cave National Park. Courses offered in 1983 were:

Karst Geology: A study of the origin, hydrology, and morphology of caves and other karst features from the standpoint of rock characteristics and geologic structure. Dr. Arthur N. Palmer, Associate Professor of Hydrology, Geology, and Geophysics, SUNY at Oneonta. May 29—June 4.

Speleology: An introductory course which emphasizes the basic processes in speleology. Roger W. Brucker, Adjunct Professor, Wright State University, Dayton, Ohio. June 5-11.

Cave Archeology: An introduction to the study of archeological remains in caves and rock shelters, and of prehistoric subsistence patterns. Dr. Patty Jo Watson, Professor of Anthropology, Washington University, St. Louis, MO. June 5-11.

Cave Ecology: Caves are simple models of complex ecosystems with few species and obvious selective pressures. This course emphasizes the use of observation and experimentation to study ecological interactions and evolution. Dr. Thomas L. Poulson, Professor of Biological Sciences, University of Illinois, Chicago. June 12-18.

Karst Hydrogeology: Influence of stratigraphy, structure, and hydrologic setting on groundwater in karst, including water chemistry, pollution, and resource management in karst. Dr. William B. White, Professor of Geochemistry, Pennsylvania State University. June 12-18.

THESES

Lavoie, K.H., 1982, The effect of abiotic and biotic factors on the successional decomposition of cave rat dung. PhD Dissertation. University of Illinois—Chicago.

PUBLICATIONS AND PROFESSIONAL REPORTS

Carothers, G. M., 1983, Archaeological investigations in Sand Cave, Kentucky: *NSS Bulletin* **45**:19-33.
Carstens, K.C. and P.J. Watson, 1983, An archeological reconnaissance and testing of the Union City/Doyel Valley drilling areas, Mammoth Cave National Park: *MCNP Report,* 7 pp.
——— 1983, Northtown Road Survey, Mammoth Cave National Park: *MCNP Report,* 1p.
Hill, C.A., P.G. Eller, C.B. Fliermans, and P.M. Hauer, 1983, Saltpeter conversion and the origin of cave nitrates: *National Geographic Society Research Reports,* **15**:295-309.
Kane, T.C. and T. (VanZant) Ryan, 1983, Population ecology of carabid cave beetles: *Oecologia,* **60**:46-55.
Kennedy, M.C. and P.J. Watson, 1983, An archeological reconnaissance and testing of the Cedar Sink drilling and turn areas, Mammoth Cave National Park: *MCNP Report,* 6 pp.
Lisowski, Edward A., 1983, Distribution, habitat, and behavior of the Kentucky Cave Shrimp *Palaemonias ganteri* Hay: *J. Crustacean Biology,* **3**(1):88-92.
Marquardt, W.H. and P.J. Watson, 1983, The Shell Mound Archaic of Western Kentucky: **In** *Archaic Hunters and Gatherers in the American Midwest,* J. Philips and J. Brown, eds., Academic Press, New York, pp. 323-339.
Palmer, A.N., 1983, Chapters on Carlsbad Caverns National Park and Mammoth Cave National Park: **In** A. Harris and E. Tuttle, *Geology of National Parks:* Kendall-Hunt, Dubuque, Iowa. pp. 474-483; 484-495.
——— 1983, Karst research in North America: *Karstologia* (France), **1**(1):39-46.
——— 1983, Geomorphic interpretation of karst features, **In** *Groundwater as a Geomorphic Agent:* R. LaFleur, ed., Allen and Unwin, (in press).
Stein, J. K., 1983, Earthworm Activity: A Source of Potential Disturbance of Archaeological Sediments: *American Antiquity* **48**:277-339.
Tankersley, K.B., 1983, Tracing recharge water to porous colluvium in archaeological sites: *Bull. Natl. Speleol. Soc.*, (In press).
——— P.J. Munson, and C.A. Munson, 1983, Physical and chemical properties of Wyandotte Cave aragonite and their archaeological implications: *GEO2, The Journal of the National Speleological Society, Section of Cave Geology and Geography,* **11**(1):2-5.
Watson, R., 1983 The Philosophy of the Cave: Instant Cave: *NSS News,* **41** (11): 305.
——— 1983, A critique of Chronostratigraphy: *American Journal of Science,* **283**:173-177.
——— 1982, Absence as evidence in geology: *Journal of Geological Education,* **30**:300-301.
Yarnell, Richard A., 1982, Problems of Interpretation of Archaeological plant remains of the Eastern Woodlands: *Southeastern Archaeology,* **1**:1-7.

PRESENTATIONS AT PROFESSIONAL MEETINGS AND ABSTRACTS

Carothers, G.M., 1983, Preliminary report on the prehistoric archaeological remains in Big Bone Cave, Van Buren County, Tennessee: NSS Convention, Elkins, WV, July.
Ferguson, L.G., 1983, An archaeological investigation of TCS#FE60: A cave in north central Tennessee: NSS Convention, Elkins, WV, July.
Haskins, V.A., 1983, The archaeology of Prewitts Knob, Kentucky: NSS Convention, Elkins, WV, June.
Lavoie, K.H., 1983, Microbial involvement in bat scent production (with E.H. Studier): American Association for the Advancement of Science, Annual Meeting, Detroit, MI, May.
——— I983, Competitive interactions among fungi and invertebrates; A manipulative study of dung decomposition: American Association for the Advancement of Science, Annual Meeting, Detroit, May.
——— 1983, Microbial involvement in bat scent production (with E.H. Studier): Third International Symposium on Microbial Ecology, MSU, Lansing, MI, August.
——— I983, Competitive interaction among fungi and invertebrates; A manipulative study of dung decomposition: Third International Symposium on Microbial Ecology, Lansing, MI, August.
Palmer, A.N., 1983, Rates of Limestone Solution and Karst Development: Symposium on Alpine and Arctic Karst, University of Oslo, Norway, August.
——— 1983, Recent trends in Karst Geomorphology. Symposium on Recent Advances in Geomorphology: Geological Society of America Annual Meeting, Indianapolis, IN, November.
Studier, E.H., 1983, Microbial involvement in bat scent production (with K.H. Lavoie): Annual Meeting, American Association for the Advancement of Science, Detroit, May.
——— 1983, Microbial involvement in bat scent production (with K.H. Lavoie): Third International Symposium on Microbial Ecology, Lansing, MI, August.
Tankersley, Kenneth B., 1983, Coal, radiocarbon, and rockshelters of the eastern United States: 59Th Annual Meeting of the Central States Anthropological Society, Cleveland, OH, March.

——— 1983, Elements of Wyandotte Chert and their archaeological application: Midwestern Archaeological Conference, Iowa City, Iowa, October.
Tinsley, J.C., 1983, Studies of Lilburn Cave and the Redwood Canyon Karst: Oral presentation given at the NSS Western Region's Speleoeducational Seminar, La Canada, CA, February.
Watson, P.J., 1983, Prehistoric footprints in United States caves: NSS Convention, Elkins, WV, June.
——— 1983, Communication between Archaeologists and Botanists: Annual Meeting of the Southeastern Archeological Conference, Columbia, SC, November.
Yarnell, R.A., 1983, Prehistoric plant foods and husbandry in Eastern North America: Annual Meeting of the Southeastern Archaeological Conference, Columbia, SC, November.

TALKS

Hill, A.A., 1983, Cave Minerals: Presented to the Albuquerque Gem and Mineral Club, Albuquerque, N.M., December.
Lavoie, K.H., 1983, Microbial ecology and simplified ecosystems: Presented to 9th grade Pre-engineering and Science group, Central High School, Flint, MI, April.
——— 1983, Cave Organisms: Presented to students from an Honors Enrichment Program, Flint, MI, April.
Lisowski, E.A., 1983, Speleology at Mammoth Cave, Kentucky: Talk given to Speleology Class, Institute for Environmental Exploration, Urbana High School, Urbana, IL, March.
——— 1983, Interpretive tour of Great Onyx Cave, Mammoth Cave National Park: Speleology Class, Institute for Environmental Exploration, Urbana High School, Urbana, Il, March.
——— 1983, Interpretive tour of Salts Cave, Mammoth Cave National Park: Scout Troop 109, Robinson, IL, August.
Palmer, A.N., 1983, Origin of Limestone Caves: Department of Geology, University of Massachusetts, March.
——— Geologic interpretation of limestone caves: Department of Geology, Syracuse University, April.
——— 1983, Presentations for National Park Service Staff at each of the following parks and monuments:
A) Geology of Carlsbad Caverns, New Mexico, June.
B) Geology of Jewel Cave, South Dakota, July.
C) Geology of Wind Cave, South Dakota, July.
D) 'Walking Seminar' on geology of Wind Cave, on tourist routes, July.
E) 'Walking Seminar' on geology of Jewel Cave, on tourist routes, July.

Poulson, T.L., 1983, Ecology and Evolution of Cave Organisms: Presented as a Visiting Distinguished Ecologist, University of Michigan Biological Station, July.
Tinsley, J.C., 1983, The Lilburn Cave Project: Some recent findings, and the Paleoclimatology of the Great Basin and California: Presentation given at the monthly meeting of the Diablo Grotto, NSS, September.
——— 1983, Recent Developments in Karst Research and Implications for Cave Management: Presentation given to the Regional Scientists of the National Park Service, Albuquerque, NM, in behalf of the CRF Science Committee, October.
——— 1983, Introduction to How Caves Form: An illustrated lecture and "Mr. Wizard" presentation, given to 4th grade students, Los Gatos Lyceum, Los Gatos, CA, November.
Watson, P.J., 1983, Prehistoric exploration of the World's Longest Cave: Presented to:
Archaeological Institute of America, Memphis State University Chapter, Memphis, TN, March.
Department of Anthropology, Southern Illinois University, Carbondale, IL, April.
Archaeology Day, Museum of History and Science, Louisville, KY, July.
Mark Twain Summer Institute, Clayton, MI, July.

SERVICE

Cave Research Foundation Members serving on the National Speleological Society's Research Advisory Committee.
Rane L. Curl (Chair)
David Culver
Derek C. Ford
Russel Harmon
Jack Hess
Carol A. Hill
Arthur N. Palmer
Richard Watson

Kastning, Ernst, 1983, NSS Executive Vice President.
Poulson, T.L., 1983, Review of grants and manuscripts concerning caves for the following: National Science Foundation (2), *Science* (1), *NSS Bulletin* (2), NATO (1), and *J. Experimental Zoology* (1).

The Cave Research Foundation

Figure 13. Gypsum formation in Paradise, New Discovery Entrance, MCNP. (Photo by K. Lavoie, lighting by J. Lavoie)

Management Structure

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Computer Records Officer	William F. Mann
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Central Kentucky Area Management Personnel

Operations Manager	Ronald C. Wilson
Personnel Officer	Ronald C. Wilson
Chief Cartographer	Richard B. Zopf
Medical Officer	Stanley D. Sides
Safety Officer	Ken Sumner
Supply Officer	Roger Miller
Vertical Supplies Officer	Lynn Weller Brucker
Log Keeper	Ellen Levy
Field Station Maintenance	Robert O. Eggers

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Finance and Supply Coordinator	Linda Starr
Field Station	Ron Kerbo

California Area

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Chief Cartographers	Dave DesMarais, Peter Bosted, Lee Blackburn
Safety Officer	Howard Hurtt
Science Officer	John Tinsley
Field Station	Mike Spiess, Tom Mathey, Stan Ulfeldt

Arkansas Area

Project Director	W. Calvin Welbourn
Buffalo River Coordinator	Paul Blore
Sylamore Coordinator	Tom Brucker

STANDING COMMITTEES

The Foundation has established four permanent committees to help conduct its business. The Science Committee is of primary importance. All committees are chaired by a Director.

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

John C. Tinsley, PhD, Chairman
William P. Bishop, PhD
Nicholas Crawford, PhD
David J. DesMarais, PhD
Jack Hess, PhD
Carol A. Hill
Francis Howarth, PhD
Kathleen H. Lavoie, PhD
Arthur N. Palmer, PhD
Margaret V. Palmer
John D. Pickle
Thomas L. Poulson, PhD
Patty Jo Watson, PhD
W. Calvin Welbourne
Stephen G. Wells, PhD
Ronald C. Wilson

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

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

Finance Committee Report

The Cave Research Foundation is a non-profit, tax-exempt organization recognized by the Internal Revenue Service under IRS Code, Sec. 501(c)(3) and assigned Federal Number 31-6052842. The primary source of funds for operation of the Foundation are derived from gifts, bequests and other private contributions. Revenue from the Foundation Endowment Fund, established in 1974, is used to support a Grants/Fellowship Program to support research in karst-related disciplines. Other sources of income are obtained from the sale of publications and limited contract projects.

The Finance Committee charter is to draft Foundation Budgets, provide advice to the Treasurer, and seek sources of funds to support Foundation programs. Present members are:

Roger E. McClure, Chair
L. Kay Sides
Linda Starr
Roger W. Brucker
W. Calvin Welbourn

The Committee drafted, and the Board of Directors approved, a budget of $58,577 for FY 1983. Actual expenditures for the year were $44,786. The Endowment Fund increased during the year by $7,361 to $39,500.

The Foundation is maintaining good financial stability with the growth and subsequent increased revenue from our Publications Affiliate and the Endowment Fund. This stability allows us to offer increasing support to the CRF Fellowship/Grant Program. We invite your continued support and contributions in behalf of our efforts.

AD HOC COMMITTEES

Publications Committee: Roger E. McClure, Chairman. Publications activity has become a major force in CRF operations over the last 5-6 years. The effort here has been two-fold. First, to provide a service to CRF and the caving community, and second, to produce revenue to fund Foundation activities. We have moved from a small inventory with sales of about $1000 a year, to a large inventory ($100,000 retail value) with sales approaching $10,000 annually. We have moved from publishing one or two CRF items a year, to the current level of 3-5 major items and numerous minor items being published or reprinted each year. The magnitude of this effort resulted in a decision (late 1982) to formally establish a Publications Committee. Current members are:

Roger E. McClure, Chairman
Thomas A. Brucker
Roger W. Brucker
Richard A. Watson
Claire B. Wood

The purpose/charter of this committee is:
—to provide policy guidance and direction on all Foundation publication matters.
—propose publications initiatives.
—assist individuals/groups in accomplishing their publication goals.
—review/coordinate on all proposed publications.
—insure all publications meet desired quality/format standards and represent the Foundation in a favorable manner.

The Committee has been very active since its formation. One formal meeting, numerous minor meetings, and extensive continuing communication among the members. It is proving to be a very productive committee.

"Cave Books" is the operating publications affiliate of the Foundation and operates under the jurisdiction of the Publications Committee. It is further divided into a Sales/Distribution function and a newly-formed Publishing function.

"Cave Books Sales" handles the sales/distribution, wholesale and retail, of all publications materials. Sales function personnel are:

Claire B. Wood, Sales Manager and Retail Sales
Rich Wolfert, Retail Sales (West)
Thomas A. Brucker, Wholesale
Richard A. Watson, Used and Small Lot Remainders
Roger E. McClure, Business Manager

"Cave Books Publishing" is a new initiative established in 1983 with the goal of publishing one new cave book each year. Funding and management of this publishing effort will be handled independently of other internal publication efforts. Personnel managing publishing:

Roger E. McClure, Publisher
Richard A. Watson, Editor
Claire B. Wood, Sales Manager
Thomas A. Brucker, Wholesale Distributor

Initial funding for the publishing was provided by $10,000 in donations from thirty Foundation personnel. The first book in the series, ***The Grand Kentucky Junction***, will be released in the spring of 1984. Revenue from its sales will support the cost of a second book, and so on, thereby providing self-sustaining funding for each following publication. The manuscript for a second book is in hand and we project release in the spring of 1985.

Publications represents a major and growing effort in the Foundation. We continue to solicit manuscripts and add new items to our inventory. Revenue from this effort provides primary support for many Foundation programs, including the Annual Report.

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