CAVE RESEARCH FOUNDATION 1981

Annual Report

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Cave Research Foundation
1981
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Cave Research Foundation
4916 Butterworth Place NW
Washington, DC 20016
USA

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: Diver standing near the First Arch in Echo River, Mammoth Cave, approximately 180 ft. (55 m) from the Echo River Spring Entrance. The January 15, 1981 dive was the first time that Echo River Spring, located on the Green River, had been successfully connected to the Echo River in Mammoth Cave thus becoming the 22nd entrance. Photo by Bob Cetera.

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CAVE CONSERVATION

Caves are fragile in many ways. Their features take hundreds of thousands of years to form. Cave animals such as blind fish are rare, and always live in precarious ecological balance in their underground environments. Cave features and cave life can be destroyed unknowingly by people who enter caves without informing themselves about cave conservation. Great, irreparable damage has been done by people who take stalactites and other flowstone features from caves, and who disturb cave life such as bats, particularly in the winter when they are hibernating. Caves are wonderful places for scientific research and recreational adventure, but before you enter a cave, we urge you first to learn about careful caving by contacting the National Speleological Society, Cave Avenue, Huntsville, AL 35810, USA.

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, Wind Cave National Park, Sylamore District of the Ozark-St. Francis National Forests, Lincoln National Forest and Buffalo National River have contributed greatly to the success of these projects, and their assistance is greatly appreciated.

Thomas C. Kane's research was partially supported by grants from the American Philosophical Society and the University of Cincinnati Research Council and George Brunner's research by a grant from the National Speleological Society.

Julian J. Lewis was the recipient of the 1980 Ralph Stone Award of the National Speleological Society (presented July, 1981) and also received a Grant in Aid of Research from the Graduate School of the University of Louisville.

The work of the CRF Archeological Project is partially supported by Washington University Faculty Research Grants. Shellmound Archeological Project activities were partly funded by a National Science Foundation grant.

A special thanks goes to the Superintendents and their staffs at Mammoth Cave National Park and Carlsbad Caverns National Park for their strong support of the International Congress of Speleology. In addition, representatives of the Job Corps at Mammoth Cave National Park are thanked for their support of the Flint Ridge Field Station prior to the Congress.

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

Highlights of 1981

The close of 1981 brings the Cave Research Foundation into its 25th year as an organization of dedicated scientists, working together and with others to improve our knowledge and understanding of the whole speleological process. This year's Annual Report summarizes many of the projects the Foundation has emphasized during 1981.

Mammoth Cave National Park was unanimously elected to the World Heritage list of the World's Most Outstanding Features. This should prove to be an important factor in the future of preserving Mammoth Cave National Park and its natural resources.

The major event of 1981 was the Eighth International Congress of Speleology which was held for the first time in the United States. Many of the Foundation's Joint Venturers contributed to the planning and organization of the Eighth Congress as well as actually helping with some of the field trips and expeditions. Our reward was that this International Congress was considered to be one of the best! The field trips to Flint Ridge and the Guadalupe Mountains were two of the favorites according to Congress participants. Speleologists from the world over met in Bowling Green, Kentucky to learn of the latest speleological theories and catch up on the most recent discoveries.

1981 saw numerous new publications by Foundation authors. *Origins and the First Twelve Years of the Foundation* describes the early years of the Foundation. *A Geological Guide to Mammoth Cave National Park,* by Dr. Arthur Palmer, is the result of over 16 years of study and analysis of the world's longest cave. Foundation cartographers produced two new Mammoth Cave maps that proved their popularity at the Congress. The Kaemper Map was the first multi-color reprint of the famous map by Max Kaemper. The Mammoth Cave Poster Map, showing five major color-coded levels of over 350 kilometers of cave passage, was an instant hit with the visiting speleologists at the International Congress.

Physical improvements to several field stations were completed during 1981. A major kitchen renovation at the Mammoth Cave Flint Ridge Research Station was completed and contributed to the smooth-running field camps enjoyed by speleologists from Belgium to Australia. The complete Lilburn Cave field station, with the exception of the stone fireplace and chimney, was first torn down and then rebuilt from the ground up, making a more permanent facility. At the Carlsbad Caverns Field Station numerous bunk beds were fabricated and facilities rearranged to handle a field camp tripled in size from the original plan.

R. Pete Lindsley
President

Scientific Programs

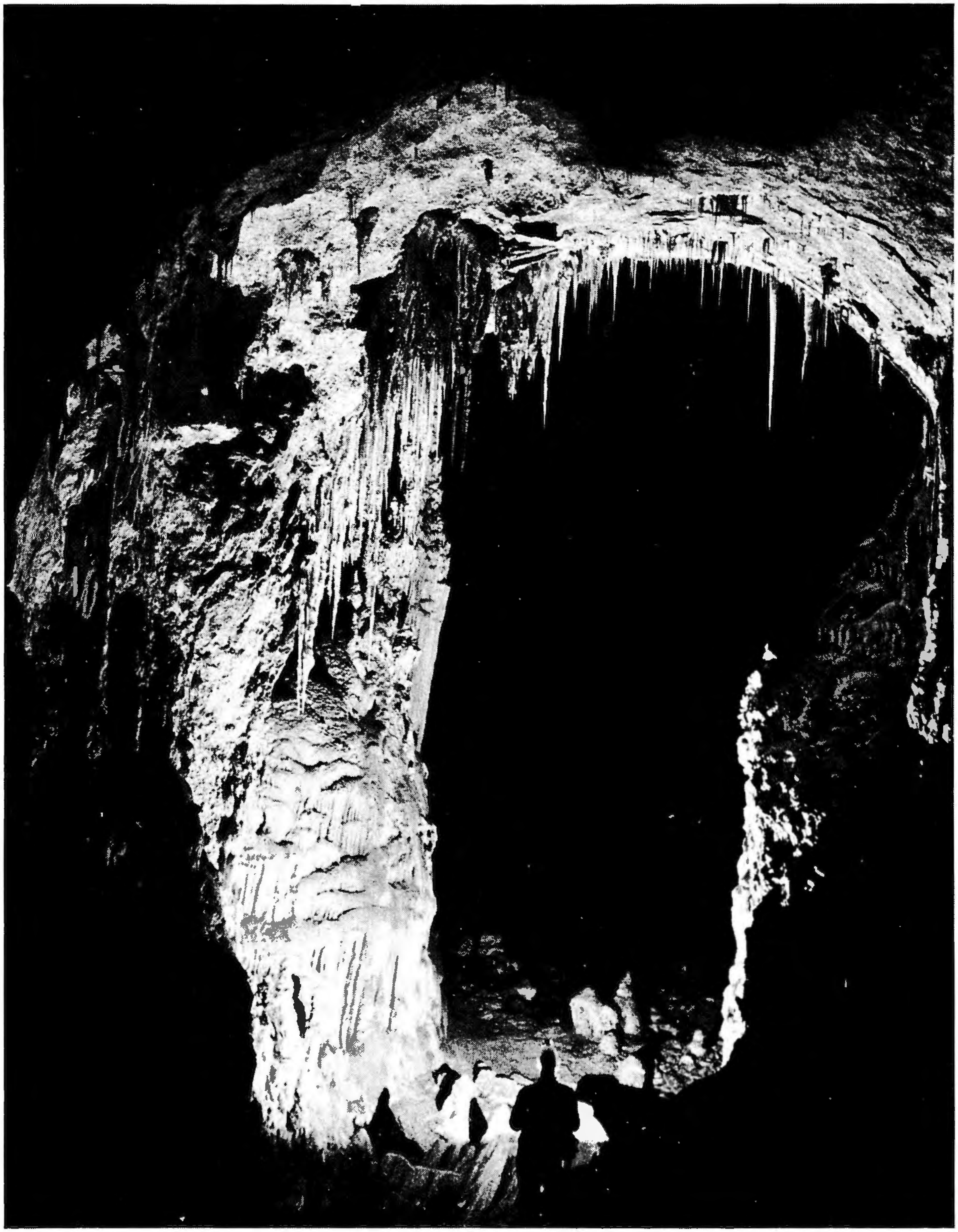

Figure 1. Large room containing many speleothems in Ogle Cave, New Mexico. (Photo by Pete Lindsley.)

Cartographic Program

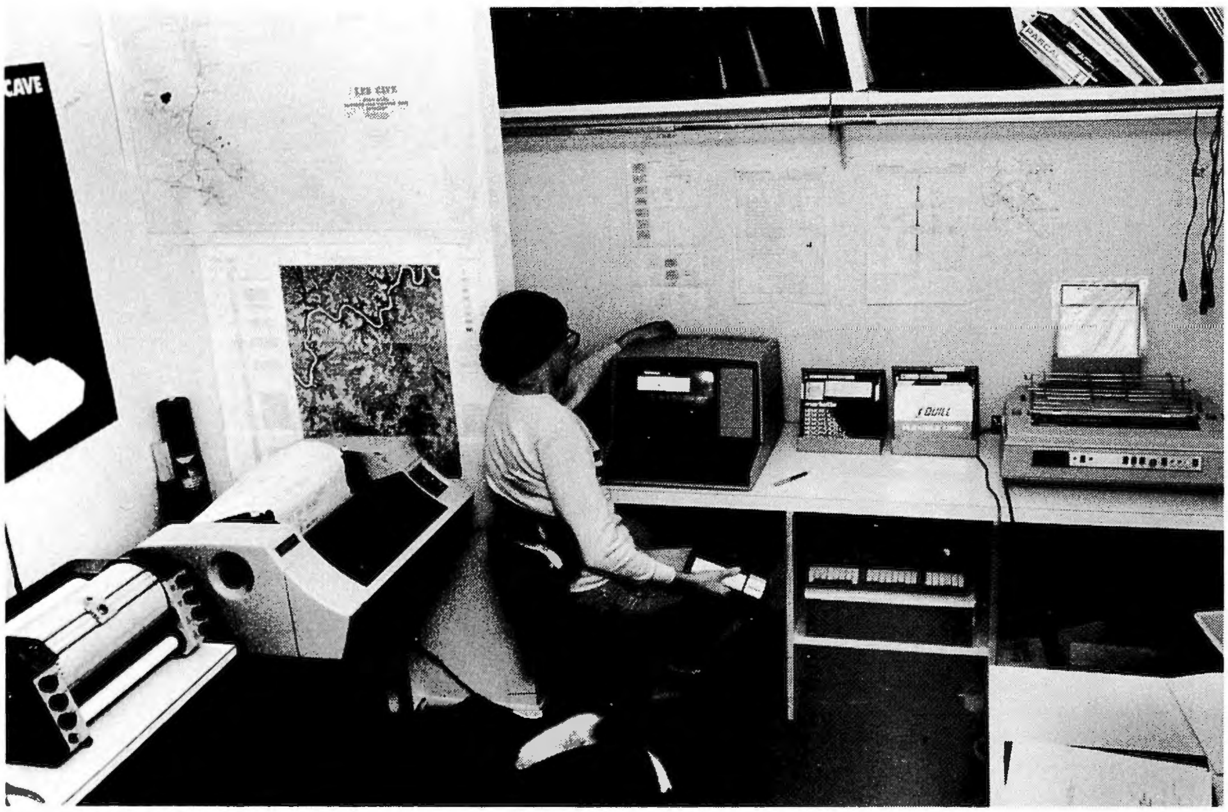

Figure 2. CRF's Mammoth Cave Area computer facilities in Fairborn, Ohio. Left to right is a Calcomp plotter, a Centronics line printer, a Heathkit terminal, an Ithaca Intersystems computer and a Qume daisy wheel printer. (Photo by Roger Brucker.)

Cartography Report: Guadalupe Area

Bob Buecher

Preparations for the International Congress Field Camp at Carlsbad Caverns diverted a great amount of energy from the cartographic program this year. Still, a large amount of progress was made on the preliminary 1" = 50' map of Carlsbad Caverns. A total of 5218.65 ft. (1590 m) was surveyed in Carlsbad Caverns. The majority of our work was in the New Section finishing up miscellaneous leads. Several parties made cross-sections and completed floor detail in the Guadalupe Room. Several small, decorated rooms along the north wall were mapped and leads off the northeast end of the room explored. Several teams finished the exploration and survey of leads at the east end of New Section. Attempts to find the source of the airflow into this area with smoke tracing were unsuccessful. The north edge of the New Section below the Pit Series was checked for new leads, but none were found. In other areas of the cave, small amounts of new passage were turned up. A new boneyard area in Left Hand Tunnel and a ladder climb into a lead in the Big Room both yielded 200 ft. (61 m) of new survey. The survey of the Scenic Rooms is complete with only field checking of the map remaining.

The new passage in Lower Cave that was discovered last year has been tied into Talcum Passage. This provides an important survey loop from the commercial portion of the cave, across Lower Cave into Talcum Passage.

In other caves in the Park:

The survey of Chimney Cave has been completed and work is in progress. Chimney is one of the caves that the Park plans to open to sport caving.

The trail up to New Cave was surveyed to establish the relationship with nearby Wen Cave. The proposed improvements to the trail may require blasting that could damage the cave if it were too close. Two new, small caves were discovered in the Park—Joint Effort Cave and Yucca God Cave.

This year we continued our work in the gypsum karst by surveying several of the caves that were discovered in last year's reconnaissance. Son-of-a-Gun Cave, discovered last year, was surveyed to an upstream and downstream sump. The length of this narrow, winding cave is 765.37 ft. (233 m). 3288.16 ft. (1002 m) of surface survey ties Son-of-a-Gun with nearby Yoda Cave, Chosa Draw Sink Cave and surface monumentation. Yoda Cave was discovered when the sound of running water could be heard in the bottom of a sinkhole. This cave was explored to a downstream and upstream sump. The length is now 879.58 feet with several leads still remaining. The downstream sumps of

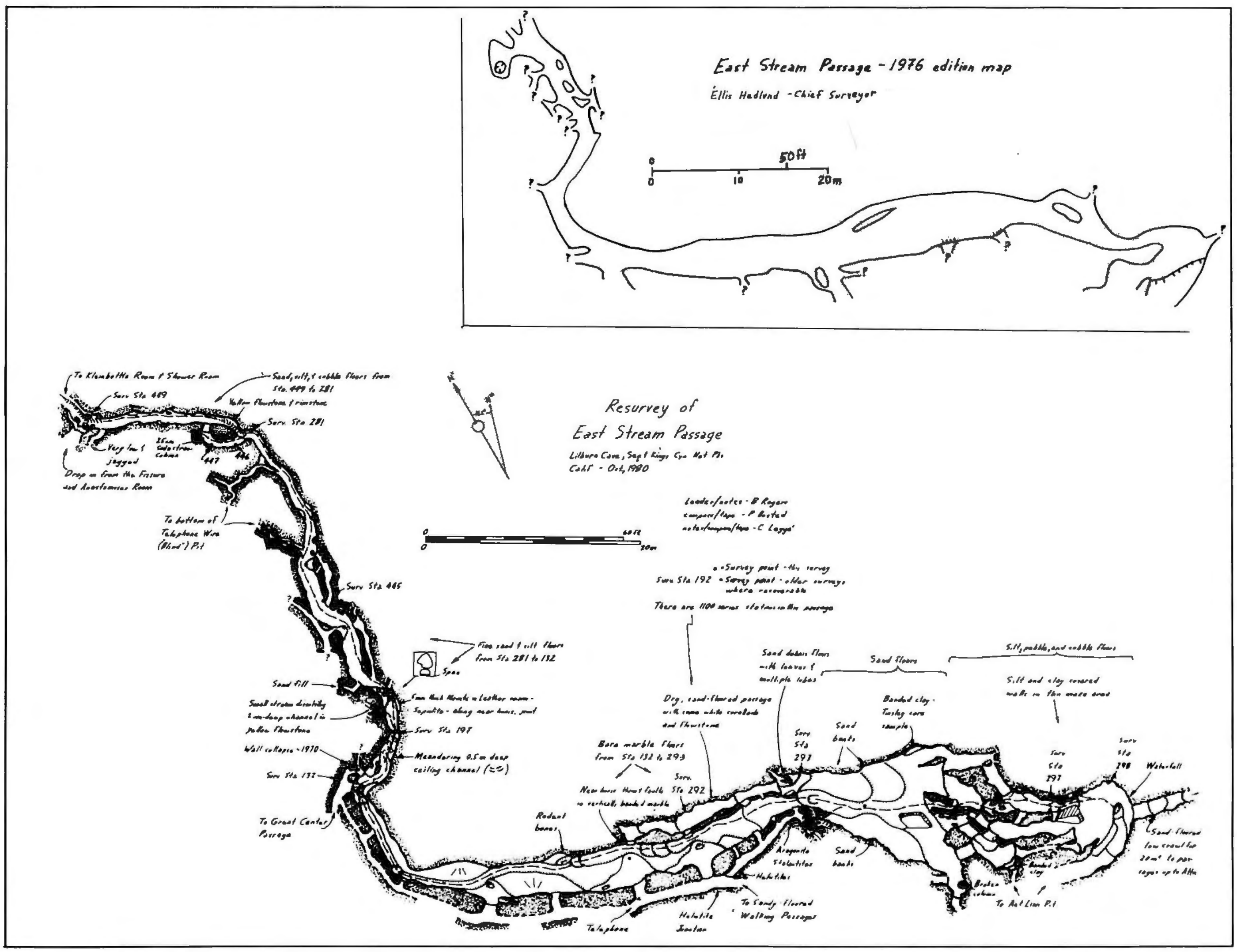

Figure 3. CRF Map showing part of the East Stream Passage in Lilburn Cave, Kings Canyon National Park, California. Inset depicts prior cartographic efforts in the same passage.

Son-of-a-Gun and Yoda are close together and appear to join before resurging in Chosa Draw. Another small gypsum cave, Killer Rabbit, was surveyed for 480.88 ft. (146.5 m).

In the central part of New Mexico, Jornada Lava Cave was surveyed for 1248.81 ft. (380.5 m). A map will be prepared for the Bureau of Land Management to aid in managing this cave.

Cartography at Lilburn Cave

David J. DesMarais

Work began in earnest on the new cartographic project in 1981. The Foundation inherited an accurate 37,000 ft. (11,280 m) line map of Lilburn Cave. However, the associated manuscript map of the cave depicted approximately 20,000 ft. (6000 m) of survey, and this map did not depict many features of the complex passages. The goal of producing a detailed and complete manuscript map was established, and this season a highly detailed resurvey of the cave was begun. The plan for the resurvey is as follows:

(1) Obtain new instrument data and sketches for the major avenues of the cave.
(2) Use the older instrument data for the secondary passages, but resketch these passages.
(3) Survey new passages.
(4) Provide the National Park Service with interim manuscript maps every two years.
(5 Devise plan views and cross-section views of the cave system. Final maps and sections will represent as clearly as possible the highly complex network of cave passages.

This season saw substantial progress towards realizing the first of the five objectives listed above. Fourteen parties surveyed approximately 5,700 ft. (1710 m) of main passageways, averaging perhaps 20 ft. (6 m) per survey station. An example of the new cartography compared to the existing cartography is shown in Figure 3 depicting part of the East Stream Passage in Lilburn Cave. We hope to provide the National Park Service with our first interim manuscript map during the spring of 1982, and look forward to maintaining a similar rate of progress in the 1982 field season.

Cartography and Exploration in the Mammoth Cave Region

Richard Zopf, Lynn Weller, Roger Brucker, and Diana Daunt

This year was one of both transition and change. The International Congress of Speleology was a significant directing force for the cartography and exploration program while at the same time a geographical and technological expansion of the cartography program was beginning to materialize. Survey of new cave was hampered by some of this activity, but still added 4.13 mi (6.65 km) to extend the length of the world's longest cave to 228.60 mi (4.68 km) of resurvey. The above total does not include the underwater work in Echo Spring which included survey of about 0.6 mi (.97 m) of passage not yet connected with the rest of the system.

Work in Mammoth Cave was not concentrated in any area. Survey continued in passages at the east end of Mammoth explored years ago while clean-up survey was done in the Historic Section in support of the Historic manuscript map. Silliman Avenue was carefully resurveyed. The lower level off Franklin Avenue continues to yield passage with new passage found off Jessup Avenue. On Flint Ridge the most work was in Salts Cave where survey teams continue to find significant sections of passage overlooked in previous years. Rigdon Pit appears to be finished. There were various trips throughout the Ridge, but without on-going success. Work in the Hawkins River System continued early in the year, but stopped in late summer when our access lease to the Morrison Cave entrance terminated. Several radio locations were completed in the area in order to tie those remote cave regions to the surface.

On the other hand there was a flurry of activity in the cartography program. A 1:12000 poster map of the Mammoth Cave System, colors denoting relative levels, was produced. The Kaemper Map was also reprinted in color.

Outside the Dayton area the Louisville map factory came to life, published the latest version of the Kaemper Map, and now is working on a map of the Historic Section of Mammoth. The microfiche of our survey books was updated in Columbus. The surface reconnaissance program is operating out of Lexington and continues the systematic ridge walking operation started some years ago. Both the Louisville and Lexington operations are computer-assisted. In the Dayton area work on the east end Cathedral Domes and New Discovery manuscripts continued. Rough drafts of schematics for all of Mammoth and much of the rest of the System have been completed.

We look forward to the firm establishment of the cartography programs mentioned above as well as expanded use of the new computer. We also hope to expand our techniques as a result of all we learned during the congress. Not only are there a variety of worthwhile exploration/survey techniques, there are also many ways to chart the cave.

Computer Cartography in the Mammoth Cave Area

Michael Banther, Richard B. Zopf, Roger W. Brucker, Lynn Weller, Chip Weller, Curtis Weedman

The Cave Research Foundation has been exploring and surveying the Mammoth Cave System for more than 20 years. During this time the size of this cave system has grown to over 226 miles (364 km). In addition to cartographic information, a large amount of scientific data has been collected. The purpose of the Cave Survey Information System is to manage this vast amount of information, to make it available to scientists and cartographers in a concise and timely manner, and to provide computerized assistance to the Mammoth Cave Area cartography program. These goals will be attained in the following way:

(a) Management of information is attained through the use of a CODASYL-oriented Data Base Management System. This DBMA allows the computer to be used as an efficient filing system for the survey data.
(b) Availability of information to both scientists and cartographers is provided by the generation of reports containing stored information in a wide variety of report formats. Selection of information based on any data field within the data base allows true ad hoc reporting without programmer intervention.
(c) Computerized assistance to the cartography program consists of using the computer to eliminate bottlenecks in the map-making process. Currently, the major bottleneck is in producing survey line plots.

A Brief Description of the CRF Mammoth Cave Computer Facilities

Hardware includes:
—Ithaca Intersystems DPS-1 20-slot motherboard with a 30-amp power supply and a full front panel.
—Ithaca Intersystems Z-80 based microcomputer with 64k RAM, 2 serial and 2 parallel I/O ports, a disk controller capable of accommodating 4 disk drives and a vectored interrupt system.
—2 Shugart 801 8" floppy disk drives capable of a total of 1 megabyte of on-line storage.
—A Heathkit H-19 Video Display Terminal with limited graphics and a 80 col x 24 line screen with an independent 25th status line.
—A Centronics 101 300 lpm Line Printer.
—A Qume Sprint 5 Daisywheel printer, 45 ch/sec.
—A Calcomp 565 Plotter
—Plans call for the inclusion of a Pertec Magnetic Tape Drive into the system.
Operating System: CP/M Version 2.0
Language Compilers:
Microsoft Fortran-80
Microsoft Cobol-80
Microsoft Basic-80
Pascal/Z
PL/I
C
Forth
Assembler: Mac-80 plus several others

Progress

The Mammoth Cave Area Computer Cartography Project has been characterized this year by its rapid growth. Although hardware assembly has dominated the project, software development has gone forward. All of the equipment listed in the hardware description has been acquired including the tape drive and plotter needed for the next enhancement. Currently, we are interfacing the Calcomp 565 plotter (Figure 4) with the computer. In the future we will add the Pertec magnetic tape unit and a Winchester hard disk unit which will have a capacity of 10-20 megabytes. While the principle software development has centered around long term, high level system design, a balanced short-term approach to system utilization is being pursued in the form of a data base entry and editing program. This program, although not yet complete, is well on its way to providing user interaction with the Computerized Cartography System. Completion is expected during 1982. Figure 5 shows a typical survey page mask used for data entry. It is significant that all of the equipment and software is owned by CRF, made possible by generous donations to the CRF Computer Fund. All software documentation is being made portable so that the CRF computer will be usable as a dedicated machine. This is in marked contrast to a dependence on computers owned by other organizations, whose availability may be withdrawn.

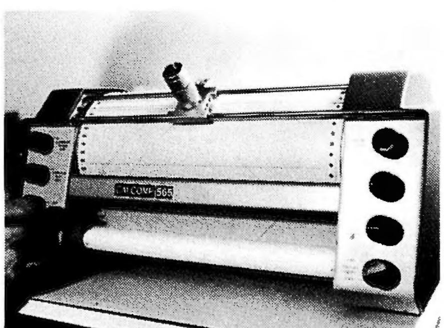

Figure 4. CRF's Calcomp drum plotter for computer-aided cave map drafting. (Photo by Lynn Weller.)

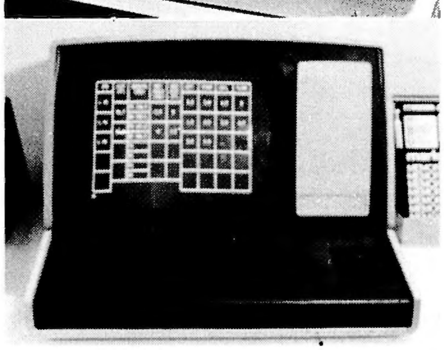

Figure 5. The data base system being designed permits typing survey data into a terminal display that simulates the survey page layout. (Photo by Lynn Weller.)

Mapping and Measuring Caves—A Conceptual Analysis

Claude Chabert and Richard A. Watson

A *cave* is an enclosed space in three dimensions. *Cartography* is the basic science essential to all of speleology. *Caves should be mapped* during their exploration. *International standards* of mapping and measurement should be established. Scientists should choose *systems of mapping and measurement* that best facilitate answering the questions and solving the problems they set themselves; sport cavers should choose systems of mapping and measurement that best show the distances they must travel to set the records they are interested in.

Map length is distance measured along the projection onto a horizontal plane of all the horizontal components of all cave passages and shafts. *Depth* is distance from highest to lowest points inside a cave measured along the projection onto a vertical plane of only the vertical components of all cave passages and shafts. A *genetically continuous* passage or shaft is one whose origin was temporarily and processually the same throughout its length. *Linear development* is distance measured along axes oriented parallel to the trends or longitudinal directions of all genetically continuous passages and shafts whatever their inclinations. For *continuous linear development*, the longitudinal axis of each passage or shaft is extended until it reaches a bedrock or debris termination or connects with the longitudinal axis of another shaft or passage. For *discontinuous linear development*, the longitudinal axis of each passage or shaft is extended until it intersects another genetically continuous shaft or passage. *Volume* is the cubic measure of the enclosed space of a cave.

Sylamore Project Summary

Calvin W. Welbourn

Seven expeditions were fielded to the Sylamore District of the Ozark-St. Francis National Forests. More than 60 JVs from a wide area participated in the field work. As of September 1981, 8 of the 12 caves to be surveyed and inventoried were complete, with the remaining four at least 50% complete.

Total survey was 5.16 miles (8.3 km). Another part of the contract calls for installation of brass caps at entrances of 35 inventoried caves (23 in the first contract and 12 in the current contract). As of September 1981 we have completed 26 installations.

At Buffalo National River, field work has been limited to 4 expeditions to complete surveys in Len House and Ice Box Caves.

Geoscience Program

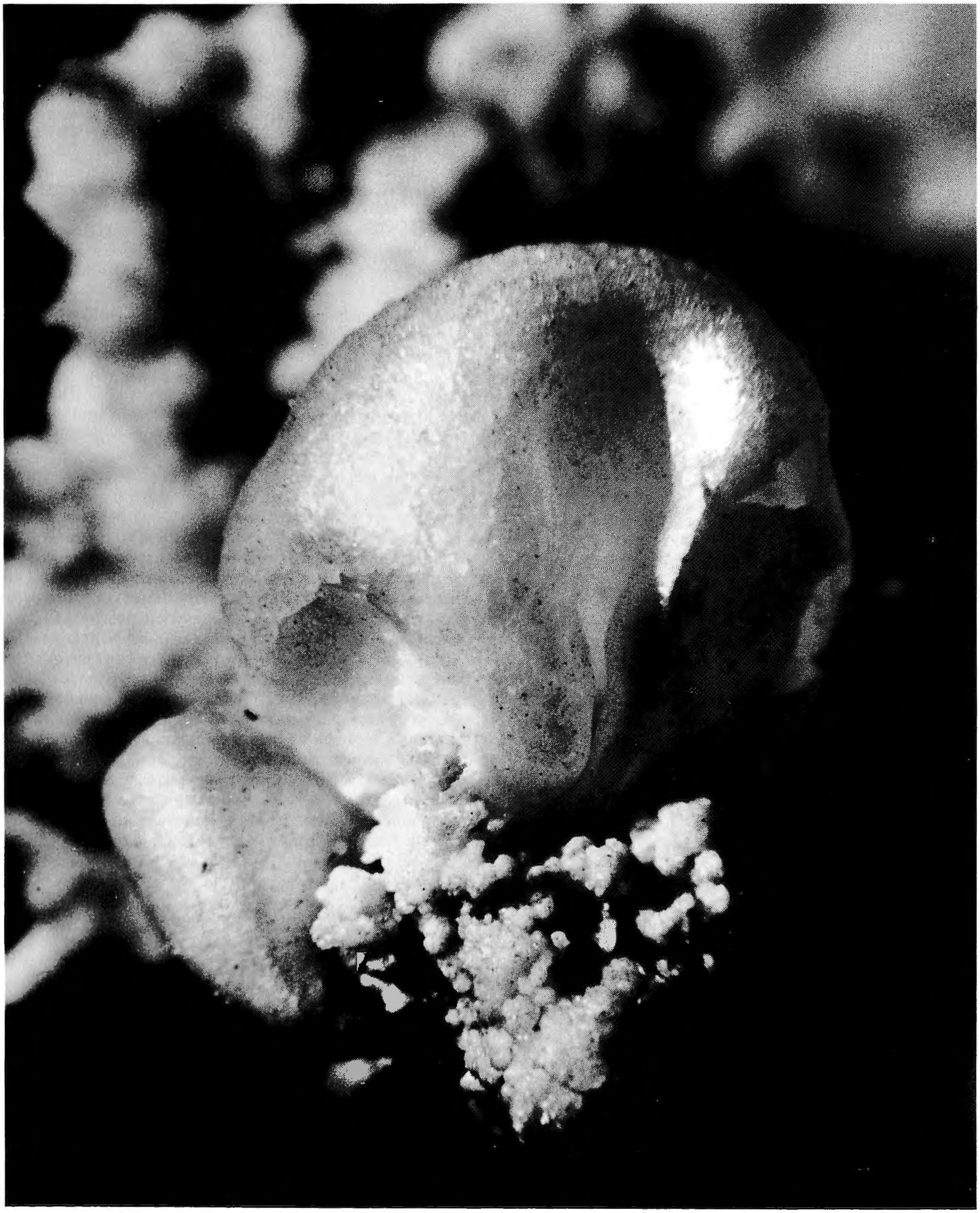

Figure 6. Hydromagnesite balloon approximately 2.5 cm in size found in the Left Hand Tunnel, Carlsbad Caverns, New Mexico. (Photo by Pete Lindsley.)

Load Reduction Banks as Cave Sediments

Joseph W. Saunders and Arthur N. Palmer

One of the fundamental steps in determining the evolutionary history of a cave is to ascertain the direction and quantity of the water flow that formed each of its passages. However, the most frequently used indicator of flow direction and velocity, solutional scallops, may be absent or ambiguous. Sedimentary deposits in a cave passage provide additional clues to the paleohydrology. For instance, the distribution of grain sizes and the presence of depositional structures such as cross beds and ripple marks provide excellent evidence for past water velocity, direction, and depth. This report concentrates on a sedimentary feature that has seldom been discussed in the literature and which seems to have no widely accepted name. We choose to call this feature a "load reduction."

Load reduction banks are elongate mounds consisting mostly of well-sorted coarse sediment such as sand or gravel, located at an abrupt change of cross-sectional area and/or rise in passage elevation. This change in passage shape decreases the sediment-carrying competence of the water flow, causing the heavier particles to be deposited. The origin of a load reduction bank requires two conditions: (1) a source of sediment upstream from the site, and (2) a decrease in the erosional force of the water from a value sufficient to erode the sediment to a value less than that necessary to keep the sediment in motion. The load reduction bank contrasts with the more common deposits such as bars and clay banks in being a more localized and prominent feature that is related more clearly to the passage configuration.

The erosive force of a stream can be expressed in two different ways, depending on the nature of the sediment being eroded. Where fine-grained sediment forms a continuous blanket over part or all of the cave floor, the erosive ability of the stream is usually expressed in terms of shear stress—the drag that is exerted on the sediment by the water flowing past it. The water molecules in contact with the sediment adhere to the solid surface and do not slip, while the overlying water flowing past exerts a drag because of the viscosity of the water. On the other hand, where individual grains of sediment project upward into the flow, the erosive ability of the stream depends on the impact of the water hitting and swirling around each grain. When the sediment is swept up by the flow and held in suspension by turbulent eddies, this drag force keeps the sediment in motion.

Actually, both processes take place simultaneously to varying degrees and are interrelated. In either case, the erosive force is proportional to the square of the flow velocity and the size of any given particle. The following is a simplified analysis of this rather complex subject based on Newtonian mechanics:

$$\text{Erosive force} = Kv^2r^2$$

where v = flow velocity, r = radius of sediment grain, and K is a factor that depends on the density and turbulence of the water. From the standpoint of shear stress, the mean flow velocity can be used for v. The drag force, however, depends on the *local* velocity hitting the sediment particle, which may be only indirectly related to the mean velocity in the cave passage.

The resistance of a sediment grain to erosion depends on its weight, its density in relation to the water, the slope on which it is situated, and how snugly it is nestled among its neighbors.

$$\text{Resistive force} = \Delta\rho g r^3 (C + \sin A)$$

where $\Delta\rho$ = density difference between the grain and water, g = gravitational field strength, A = slope angle of the passage floor (upward slope is positive), and C is an experimental factor that depends on the packing of the sediment grains.

Sediment is eroded when the erosive force exceeds the resistive force and is deposited when the erosive force drops below the resistive force. A load reduction bank is formed where this drop occurs abruptly over a short distance.

By equating the erosive and resistive forces, using values of K and C that are appropriate for spherical grains of well-sorted sand or gravel, we can find the flow velocity below which the water must drop in order to allow the sediment to come to rest. The rather approximate experimental constants were determined by A. Palmer in laboratory flumes using quartz sand.

$$v^2 \approx 12rg (\sin A + 0.7)$$

in cgs units, where v = local velocity in the vicinity of the sediment grains. At a load reduction bank, this equation can be used to obtain a rough estimate of the water in which the sediment was deposited.

The most common reasons for sediment to be deposited as a load reduction bank are as follows: (1) either the velocity can drop below the critical value because of an increase in the cross-sectional area, particularly during tube-full conditions, or (2) the passage can make a sharp upward bend, suddenly increasing the velocity needed to keep the sediment in transport. A combination of both factors is often responsible. Load reduction banks can also occur in sheltered spots downstream from sharp horizontal bends in a passage, where turbulent back-eddies sweep sediment from the fast-moving central part of the flow into relatively stagnant water.

These processes can operate in either open-channel flow or closed-conduit "pipe" flow, but are most effective in the latter. Where it is apparent that a load reduction bank has formed under closed-conduit flow, a crude estimate of the discharge through the passage at the time the bank was deposited can be obtained by multiplying the calculated value of v by the cross-sectional area of the passage at the upstream end of the bank.

Some examples illustrate the cave settings in which load reduction banks are found. Swinnerton Avenue in the Flint Ridge Cave System is tubular trunk passage with general dimensions 5 m wide and 2 m high. For 600 m it follows a single bedding parting, then sharply rises stratigraphically 3-4 m at a joint in the former downstream direction, and resumes as a bedding-developed passage. The horizontal sections are floored with silt overlying stratified sand and gravel, with a sand bank at the top of the upward jog in the passage (Figure 7). The meter-high sand bank is the load-reduction bank, and is an indication that flow was rising up the enlarged joint from the lower horizontal portion of the passage. If flow had been in the opposite direction, the sand would not have been deposited at all, or perhaps would have formed a thin, extensive deposit at the base of the slope.

A second example is taken from Cumberland Caverns, Tennessee. An essentially horizontal, tubular crawl less than a meter high and three meters wide opens up into the Sand Room at the lowest point in the room. A sand bank, one of the few in the cave, forms a slope leading from the crawl to the upper portion of the wide room. Paleoflow was into the room from the crawl. In the intricate mazes of Cumberland Caverns, where scallops are uncommon, this load-reduction bank is one of the few paleoflow indicators available. This example had the typical weakness that the sand banks could have been deposited by the most recent flow in a direction opposite to that which predominated over most of the passage's history, if a flow reversal had occured.

A third example is found in Emerson's Cave, Edmonson Co., KY. A narrow crawl leading off the main stream hits a "terminal" equilibrium slope of rounded gravel known as the Penny Pile. By pulling the noisy gravel away at the bottom of this rock mill, one can slide up the slope against the ceiling (formed along a joint) and enter a wide, horizontal upper level with flat mud floor, 3 m above the bottom of the Penny Pile. Emerson's Cave is subject to flooding, with rises in water level of more than 6 m. Passages in the cave have crudely rectilinear profiles, with local steep jogs upward and downward where flood flows fill the passage entirely. The presence of the polished gravel in this load reduction bank indicates that flood flow is usually away from the main stream and upward past the Penny Pile.

A fourth example is found in Mammoth River Cave, Hart Co., KY. The main stream near the Raft Landing leaves a 4 m wide passage, with water depth over two meters, to enter a passage 8 m wide which is joined by a 4 m wide side passage carrying a tributary stream. Gravel brought in by the main stream has been dropped where the passage widens, creating a gravel dam (load reduction bank) that ponds the water upstream. This has created the deep water section where rafts or inner tubes are used for travel.

In tubular passages load reduction banks commonly act as spillover dams at the downstream ends of sumps. As with most stream deposits, larger sediments are transported during the most rapid flow (i.e., during major floods) and dropped as the floods diminish or as a downstream constriction reduces the velocity by ponding. The coarser sediments deposited in or upon load reduction banks are carried there by relatively high-velocity flow.

Some sediments of that size will not be dropped if their deposition would constrict the passage enough to momentarily increase velocity again to a magnitude that would pick that last deposit up again. In other words, a type of homeostasis is at work, and the details depend on flow volume and the range of sediment sizes being transported from upstream. As flow subsides after a flood, the velocity is reduced, and the top of the spillover bank deposited by the floodwaters then serves to dam up waters behind it. At these spillover banks with upstream sumps, digging to remove cobbles, gravel or sand at the spillover lip will serve to lower water levels upstream.

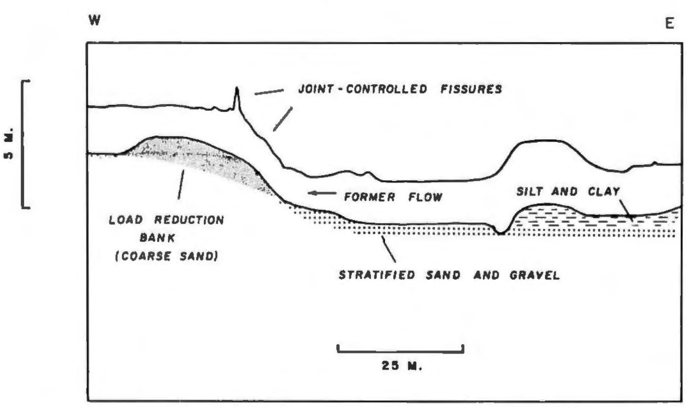

Figure 7. Load reduction bank in Swinnerton Avenue, Flint Ridge Cave System, Kentucky.

Mineralogy of Blanchard Springs Caverns

Carol A. Hill

A visit was made to the commercial sections of Blanchard Springs Caverns, Ozark National Forest, Arkansas, and a brief mineralogy survey of the cave was conducted.

Blanchard Springs Caverns has a variety of dripstone and flowstone carbonate speleothems which issue forth along both bedding planes and joints: stalactites, stalagmites, columns, draperies, popcorn, flowstone, rimstone dams and rimstone shelves. The tallest column, "the Giant," is about 20 m high and extends from the ceiling to the floor. A small number of helictites intermixed with aragonite frostwork occur along the right wall of the Cathedral Room next to the Giant column, but these two speleothem types are not spectacular.

The most impressive speleothem type in the cave is the flowstone waterfall cascades of travertine, both along the left wall of the main upper passage and especially the massive stone waterfall at the end of the Discovery Tour (Figure 8). This last frozen waterfall is 50 m long and 10 m high, has a series of rimstone pools along its upper lip, and is a lovely salmon-pink color. A nice free-standing shield occurs in this same area along the wall opposite the waterfall.

There are three main areas of well-developed rimstone dams. In the Discovery Room the rimstone dams are 20-45 cm high and are semi-convoluted similar to the Chinese Walls of New Cave, Carlsbad Caverns National Park (Hill, 1976). In the Entrance Room a beautiful cascade of orange rimstone dams occurs: their coloration may possibly derive from bat guano that is supplied from bat roosts upstream from the dams. Rimstone dams up to 75 cm high exist before the Christmas Tree Room (these dammed pools are lined with subaqueous popcorn). At this same dam occurrence are massive columns which have been broken cross-sectionally by natural forces, perhaps by slumping of the clay banks underneath the columns, or by an earthquake. The lower portion of the broken columns have been displaced about ½-1 cm from the top portion. Above the columns, solutions issue forth along thin-bedded limestone bedding planes in the ceiling dome and thus have formed concentric rings of stalactites around the centrally located columns. A good display of canopies, or "stalactiflats," occurs past the Entrance Room where the clay banks have been removed from beneath small stalactites attached to flowstone (Figure 9).

Many of the calcite speleothems in Blanchard Springs Cavern possess macrocrystalline texture; this texture causes them to sparkle like sugar candy. Old macrocrystalline layers have dried up so that the large crystal facets no longer reflect light and appear to have lost their sparkle. However, in observing massive flowstone cut by a tunnel going into the Christmas Tree Room, one can see the macrocrystalline texture preserved in 1-cm long crystal faces.

There is one area in the Main Passage where some black debris coats a flowstone cascade. These spots seem related to black nodules in the ceiling limestone above the flowstone (part of the Boone Formation). It is not known if these are manganese nodules, iron nodules, or coal-like nodules in the limestone (the black easily rubs off on the fingers). Blackened stones were notices in the river next to the Entrance Room which possibly may have derived from the Boone Formation in the upper cave levels, or they may be blackened by manganese.

In both the Upper Passage by the Giant column and also in a short tunnel before the Ghost Room are what appear to be "water lines" of popcorn which, on a small scale, appear similar to the "popcorn water lines" of Carlsbad Caverns. In Blanchard Springs Caverns these are most likely caused by air flow currents, since these two areas are isolated from one another and do not appear to be related in elevation.

The Forest Service is to be congratulated for doing such a marvelous job in protecting their speleothems via a multi-gate entry system and also for the very attractive display of the speleothems in Blanchard Springs Caverns!

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Figure 8. Frozen "waterfall" in Blanchard Springs Caverns, Arkansas. (Photo by U.S.D.A. Forest Service.)

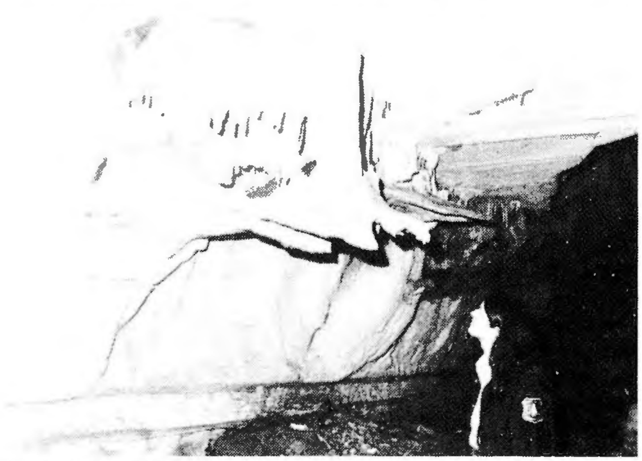

Figure 9. "Stalactiflat" canopies formed when silt banks were eroded from under a composite column-flowstone speleothem. (Photo by U.S.D.A. Forest Service.)

Landform Development on Moraines of the Klutlan Glacier, Yukon Territory, Canada

Richard A. Watson

Abstract

The landform evolution of the Klutlan moraines is described and explained primarily with processes that cause voids in which debris is deposited. Morainal deposits of different ages provide examples of landforms at different stages of development, so that continuous ideal evolutionary sequences can be inferred. Specific features are classified as those on material of the same depositional age that develop mostly in a

vertical direction with numerous topographic reversals and those cross-cutting materials of different depositional age that develop primarily in a horizontal direction. The evolution of slopes is often terminated by their destruction as the underlying ice melts, but former slopes on morainal debris are traceable to ice-ridge slopes on the original glacier surface. The general process of evolution is one of downwasting by surficial icemelt, in which a grand topographic reversal takes place as the original ice mass with a gently convex surface melts to leave a basin floored by a concave mantle of morainal debris. The primary glacial process of melting differs from the primary karst process of solution, but many minor glacial processes and major glacial forms are similar to minor karst processes and major karst forms.

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Analysis of Fractures and Speleogenesis at Lilburn Cave, California

Gail McCoy

The major effort during 1981 was writing a Master's thesis presenting the past four years' research. Completion of the thesis is anticipated in December, 1981, and conferral of the Master of Science degree in Geology is scheduled for June, 1982. Expeditions during 1981 were devoted to field checking data, consultations with other geologists and refining selected parts of cave maps. The following paragraphs summarize my research.

Lilburn Cave is a 12 km (7.5 mi) part of a complex karstic network formed in marble by subterranean streams. Located in the southern Sierra Nevada, Tulare County, California, the cave's entrances are at about 1585 m (5200 ft). This study examines relations among the fractures in massive marble and speleogenesis. Fractures and multiple foliations exist throughout this marble lens. Study of the fracture-patterns reveals the great importance of jointing to the speleogenesis of the entire cave as well as to the development and the visual features of individual passages. Faulting is scarce and pervasive foliations in the marble apparently do not influence the subsequent speleogenesis. Bedding planes and insoluble beds, structures which commonly influence speleogenesis in other terrains, do not exist in Lilburn Cave.

The frequency, orientation, and speleogenetic effect of jointing were examined in seven sets of passages selected throughout the horizontal and vertical range of Lilburn Cave. The jointing varies in orientation and frequency from area to area, but summations of data in rose diagrams reveal the following trends:

A strong unimodel trend centered at 340 deg characterizes observed subsurface joints. Joints measured in surface outcrops, including all lithologies, are bimodally distributed around 345 deg and 70 deg. Similarity of the northwest-trend for subterranean and surficial joint-sets suggests a single northwest-trending joint-set exists. The northeast-trending joint-set appears mainly in surficial exposures, but a lack of jointing with this trend has not been established within the cave.

The map of Lilburn Cave shows the majority of passages trend northwest-southwest, parallel to the dominant subsurface joint-set. A smaller proportion of the cave trends northeast-southwest, sub-parallel to the trend of the 70 deg joint-set.

The direction of regional water flow and the trends of joints are sub-parallel; these major components in cavern development have reinforced each other in this cave. The marble lens and the canyon both strike generally north. Sub-parallelism of the dominant subsurface joint-set (340°) with the average trend of Lilburn Cave (345°), as well as the trends of many passages sub-parallel to associated joints, indicate the strong influence of joints on the development of this cave.

The strong linearity of the cave apparently results from joints that control the access and flow of subterranean water. The northwest-trending joint-set exerts greater control on speleogenesis than the northeast-trending set presumably because the former is aligned sub-parallel to the regional water gradient.

Fluvial Hydrology of Lilburn Cave, Tulare County, California

Luther B. Perry

Lilburn Cave (11.5 km) is located in Redwood Canyon, an undeveloped area of Kings Canyon National Park, California; the area is accessible only by trail. The middle reach of the Redwood Canyon is underlain chiefly by marble and is mantled by an alluvial fill. During most of the year, Redwood Creek sinks near the middle of the marble. Within Lilburn Cave there is a stream having a discharge comparable to the volume of Redwood Creek that siphons at the lower end of the cave. About one kilometer beyond the cave's terminus, there is a resurgence in Redwood Canyon. The resurgence, Big Spring, is an ebb-and-flow spring: inside Lilburn Cave, water levels synchronously fluctuate with variable discharge measured at Big Spring.

One objective of this study is to investigate suspected interconnections among surface and subsurface streams, identify the points where streams interconnect, and measure the water transit times. A second objective is to measure the flow volumes to determine if all or only part of the discharge of Redwood Creek and its tributaries is involved in the cave system.

During a low-discharge period, Redwood Creek flow has been traced to the Lilburn Cave stream at the Upstream Rise, the Lake Room, and the Z-Room. These locations are separated by full siphons, each several hundred meters long. Transit time is between 60 hours and three weeks. In addition, Mays Creek, a Redwood Canyon tributary, has been traced to the Lilburn Cave stream at the Lake Room; the transit time is between 8½ and 30 hours. Tracing was accomplished using fluorescein dye and activated charcoal detectors. Concentrations of the dye were such that detection was visually obvious.

Sedimentology at Lilburn Cave, Kings Canyon National Park, California

John C. Tinsley

Past investigations of sediments preserved in Lilburn Cave reveal the stratigraphic relations among cave fills deposited during three principal depositional phases. This research is summarized in short papers by Tinsley (1981) and Tinsley and others (1981).

Thinly laminated silts, clayey silts and silty clays comprise the oldest sediments in the cave. These deposits are termed "rhythmites" because of the cyclical attributes of their bedding.

They contain a normally magnetized secular paleomagnetic record at least 10,000 years long. We will continue efforts to correlate the Lilburn paleomagnetic record with paleomagnetic records of cores recovered from Pleistocene lake deposits in the Great Basin and in the western Sierra Nevada, California, as the latter studies become available. Future field studies of sediments in Lilburn Cave will emphasize the older of two coarse clastic fills, designated informally as the Old Coarse Clastics (OCC).

The OCC deposits are composed of sand, gravel, cobbles, and occasionally boulders. These coarse deposits contrast markedly with the underlying rhythmites and indicate the hydrology and sediment supply have fundamentally changed since the rhythmites were deposited. I hypothesized the OCC deposits to be chiefly bed load deposits of Redwood Creek; these clastics were carried into the cave when Redwood Creek downcut into the network of cave passages in the central part of Lilburn Cave. This hypothesis is known to constitute an oversimplified interpretation.

I plan to map the nature and distribution of the OCC deposits, including the configuration of the deposits in relation to conduits serving as probably avenues of ingress, and the relative degrees of weathering of clasts and matrix in the OCC deposits. If suitable samples can be located, limiting radiometric ages can be obtained for the OCC deposits by employing U-Th analytical techniques.

The degree of sorting in the sediment indicates the OCC deposits were transported by surface streams to swallets above the cave. The sediments entered the cave as a result of (1) gravity-driven slumping and collapse of sink holes or (2) direct sediment transport by running water. OCC deposits having the former origin and which have not been reworked by running water are poorly sorted, and contain a matrix of sand and silt. Water-laid conglomeratic deposits and slump deposits reworked by running water within the cave environment lack appreciable fine sediment in the matrix.

Observable variations in the degree of weathering of granitic and metamorphic clasts may permit the OCC deposits to be subdivided stratigraphically. For example, in certain areas in the cave, OCC deposits contain granitic clasts that can be crumbled easily by hand to grus; these clasts were not transported into the cave in that weathered condition. Such clasts must have undergone some weathering in the spelean environment. Nearly constant temperature (8° + 1°C) and high moisture (approximately 100% Relative Humidity in an oxidizing environment) conditions prevail in the cave. This situation effectively eliminates the temperature and moisture parameters as variables in considering weathering rates of clasts. If radiometric dating can constrain the age of the OCC deposits, excellent rates of weathering can be derived for wide range of lithologies under the stated conditions of temperature and moisture. In any event, relative weathering criteria such as the degrees of grusification, amount of grain relief on the surface of clasts, amount of pitting, prominence of fractures, thickness of weathering rinds on clasts, can provide a basis for stratigraphically subdividing the OCC deposits in Lilburn Cave.

Giant "Cones" Found on the Balcony of the Lake of the Clouds, Carlsbad Caverns

Carol A. Hill

"Cones" are a speleothem type composed of piles of sunken calcite rafts (Hill, 1976). Water dripping from the cave ceiling sinks floating rafts to the bottom of a pool. These rafts build up into talus piles of raft debris. Most cones are only tens of centimeters high: the cones in Carlsbad Caverns are up to 10 m high. The cones in Carlsbad occur on the Balcony approximately one-half way down the slope which leads to the Lake of the Clouds. Aragonite trees have grown subaerially on the tops of the cone piles from the same drips that caused the calcite rafts to sink when the Lake of the Clouds pool was at the Balcony level. Because of their enormous size, the true nature of the cone-shaped piles was not previously suspected.

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Hydromagnesite Balloons Deflating in Carlsbad Caverns

Carol A. Hill

In 1973 hydromagnesite balloons (Figure 6) were discovered in the Left Hand Tunnel of Carlsbad Caverns (Hill, 1973). At that time it was suspected that these balloons might possibly have grown very rapidly (in a few months time) since other investigators working in the balloon area had not previously spotted the balloons. In 1981 I again inspected the balloons and found that the largest had deflated from approximately 2.5 cm to 1.5 cm in diameter. A small hole was observed in this same balloon. The balloons had also changed from a pearly transparent color to a more silvery opaque color. These observations suggest that the balloons are relatively short-lived speleothems.

Balloons have been reported from only 3 caves: Carlsbad Caverns, New Mexico; Jewel Cave, South Dakota; and Silent River Cave, Grand Canyon, Arizona. The balloons in Silent River Cave were first reported by Mowat (1960) who called them "nacrolites." Donald Davis (personal communication, 1979) later confirmed them to be balloons.

Method of balloon growth has never been substantiated (Hill, 1976). I propose the following mechanism for their growth: solutions diffusing into the cave have a partial pressure of CO_2 at least 25 times higher than the cave air. Hydromagnesite is a carbonate mineral which is extremely fine-grained and can be very plastic when it contains just the right amount of water. Thus, if incoming solutions high in CO_2 reach hydromagnesite blobs on the cave wall containing the right amount of water (and thus are correspondingly highly plastic), then the knobs blow up as balloons. In a relatively low humidity cave like Carlsbad Caverns, the fragile balloons can quickly dry, crack, deflate, and change in luster.

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Mineralogy of Fort Stanton Cave

Carol A. Hill

Fort Stanton Cave is located about 17 km east of the city of Capitan, Lincoln County, New Mexico on United States Bureau of Land Management land. The cave is heavily gated, both on the outside and inside, and access is controlled by a permit system.

Fort Stanton Cave is developed in the San Andres Limestone of Upper Permian age which is sparsely fossiliferous, cherty, dolomitic and sandy, with some interbedded gypsum. The San Andres Limestone in the vicinity of Capitan, New Mexico contains Tertiary intrusives (basalt dikes) and is intensely faulted. Drainage for the region is generally subsurface; the outlet for the Fort Stanton Cave area is believed to be Government Springs, located 2.64 km NNE of the entrance of Fort Stanton Cave. The spring issues from a wide limestone crack on the south bank of the Rio Bonito.

Fort Stanton Cave is dissolved along a major fault in the San Andres Limestone trending NNE (Carpenter and Schluter, 1961). The Main Corridor alone is over 1.5 km in length and 13 m wide by 20 m high. The average cave temperature is 11.1°C and the humidity is 97%. Cave sediment banks up to 12 m thick occur as flood deposits (Kessler and Baer, 1977).

Fort Stanton Cave was first visited by white men in the late 1800's when soldiers of the United States Cavalry from nearby Fort Stanton partially explored the cave. Among the first reports on the mineralogy of the cave were the descriptions by Green (1891) and Hills (1895) of the selenite needles in the Crystal Crawl area. At the time of discovery the selenite needles completely covered the floor of Crystal Crawl (about 250 m long and 7 m wide) and were reported up to 15 cm in length. Since that time, almost all of the needles in Crystal Crawl have been removed by rock hounds and collectors. One chunk of needles is now on display at the University of New Mexico Geology Museum. The specimen, donated by Walt Mourant and Jim Albright, is shown in Figure 10.

Besides selenite needles, Fort Stanton Cave contains other unusual speleothems such as starburst gypsum, tabular gypsum, epsomite cotton and hair, aragonite trees, velvet, calcite rafts ("snowflakes"), manganese coatings and opal needles. It also contains the more usual speleothems such as stalactites, stalagmites, draperies, flowstone, helictites, coralloids, flowers and crust. An example of velvet flowstone is shown in Figure 11.

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Figure 10. Selenite needles approximately 5 cm long from Crystal Crawl in Fort Stanton Cave, New Mexico. (Photo by Ronald Gretgey.)

Figure 11. Velvet flowstone in Fort Stanton Cave, New Mexico. Note 10 cm calipers near center of picture. (Photo by Pete Lindsley.)

Celestite Growing in Floyd Collins Crystal Cave

Carol A. Hill

In 1971 celestite ($SrSO_4$) was found by Dave Jagnow and Carol Hill in Floyd Collins Crystal Cave, Flint-Mammoth Cave System, Kentucky along the right wall just before Scotchman's Trap (White, 1971).

The celestite occurs as a light, sky-blue crust a few millimeters thick underneath a much thicker gypsum crust up to a few cm thick. The celestite growth as examined in 1971 covered a wall area approximately 30 cm in diameter. In July, 1981, I reexamined the celestite and found that it now covered a wall area approximately 12 m long and 1 m wide. The celestite growth is concentrated along a horizontal level 1-3 m high above the floor which possibly correlates with a horizontal bedding plane in the wall rock. Celestite-bearing solutions issuing forth along the bedding plane have pushed out previously-formed gypsum crust.

REFERENCE

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Geochronology of Speleothems from the Mammoth Cave System, Kentucky

John W. Hess and Russell S. Harmon

Seventeen $^{230}Th/^{234}U$ ages for flowstones and dripstones from various levels of the cave system have been determined. Pertinent analytical data, ages and elevations for the locations samples are presented in Table 1. As seen from this data, it is clear that the older ages are associated with the higher cave levels and vice versa. Three specific points can be made as regards the age of particular levels of the cave system (Table 2):

(1) The highest levels of the cave at 207 m (680 ft.) are in excess of 350,000 years old by U-series dating and in excess of 700,000 years old by the fact that flowstone sample 80501 from Collins Avenue has reversed magnetic polarity (Schmidt, personal communication);

(2) Cave levels above 152 m (500 ft.) are greater than 350,000 years old;

(3) Cave levels near 143 m (470 ft.) are only slightly greater than 140,000 years old, as the sample 77538 is a thin flowstone carapice on a sediment bank in Mud Avenue only 3 m above present base level.

These results confirm the antiquity of the Mammoth System. The highest cave levels between 213 m (700 ft.) and 183 m (600 ft.) are of likely Early Pleistocene age; intermediate levels between 168 m (550 ft.) and 152 m (500 ft.) are of Middle Pleistocene age, and levels below 146 m (480 ft.) are of Late Pleistocene age. The excavated sediment in Mud Avenue must have been emplaced prior to 140,000 years B.P., the penultimate glacial period, so that the cave passage itself probably was formed during the penultimate interglacial period at about 220,000 to 180,000 years B.P. If this is the case and approximately the lowest 10 m of the cave (the flooded portion) is presently infilled with sediments of last glacial age, then the entrenchment of the Green River over the past two glacial cycles occurred at a rate of 0.12 $m/10^3y$.

It is striking to us that there are approximately half as many cave levels as Pleistocene glacial/interglacial cycles. This suggests to us a sequence of development whereby large phreatic cave passages are initially formed during the latter stages of interglacial period when river level was stabilized at a certain level. These were then to some extent infilled with sediment and the passages concurrently dissolved upwards at or near base level during the subsequent glacial period, and finally the major passages re-excavated and narrow vadose canyons cut as a result of raid river entrenchment during the next interglacial periods when hydraulic gradients were high.

Table 1. U Concentrations, Isotope Activity Ratios, and Calculated Ages for Speleothems from the Mammoth Cave System, Kentucky.

Sample Number	*Description*	*U conc. (ppm)*	$\left[\frac{^{234}U}{^{238}U}\right]$	$\left[\frac{^{230}Th}{^{234}U}\right]$	$\left[\frac{^{230}Th}{^{232}Th}\right]$	*Age (ky)*	*Elev. (ft)*	*(m)*
77540	stalagmite—Violet City entrance	0.32	1.07 ± .03	.07 ± .01	>200	7 ± 0.8	675	205
77544	stalagmite—Radio Room	0.27	1.09 ± .02	.69 ± .05	49	123 ± 15	485	198
77545	stalagmite—Gothic Avenue breakdown	0.24	1.41 ± .02	.01 ± .001	7	2	600	183
77546	stalagmite—Mammoth Dome	0.16	1.62 ± .05	.31 ± .02	20	40 ± 3	490	150
77547	stalagmite—end Audubon Avenue	0.22	1.50 ± .03	.13 ± .01	6	15 ± 1	600	183
80501	flowstone—Collins Avenue	7.0	1.15 ± .03	1.02 ± .04	>200	7350	680	207
71100	stalagmite—New Discovery	1.5	1.15 ± .03	0.06 ± .01	47	6 ± 1	?	?
77538	flowstone—Mud Avenue	5.3	1.11 ± .02	.74 ± .03	150	141 ± 11	430	131
72035:1	flowstone (base)—Edwards Avenue	1.1	1.14 ± .03	1.02 ± .04	50	350	580	177
:2	flowstone (top) — Edwards Avenue	1.2	1.21 ± .02	.90 ± .04	24	350	580	177
						213^{+33}_{-25}		
72036:5	flowstone (base)—Davis Hall	0.28	.99 ± .01	1.05 ± .01	21	350	500	152
:4	flowstone (top) — Davis Hall	0.25	.97 ± .10	1.14 ± .08	75	350	500	152
72037:1	stalagmite—Colossal Dome	0.25	.99 ± .05	1.05 ± .08	20	350	500	152
72041:5	stalagmite (base) —Davis Hall	0.6	1.17 ± .02	.87 ± .03	61	202 ± 21	500	152
:9	stalagmite (middle) — Davis Hall	1.3	1.12 ± .02	.79 ± .01	>200	159 ± .10	500	152
:13	stalagmite (top) — Davis Hall	1.5	1.16 ± .02	.70 ± .02	37	121 ± 5	500	152
74009:1	flowstone—Great Onyx	53.1	1.05 ± .03	.90 ± .02	>200	$247 \pm ^{28}_{22}$	500	152

Table 2. Age-Elevation Relationships for the Mammoth Cave System, Kentucky

Elevation (meters)	*(feet)*	*Typical Passage*	*Oldest Speleothem Age*
207	680	Collins Avenue (top)	>700,000 y B.P.
189	620	Dyer Avenue; Thomas Avenue	—
183-180	600-590	Edwards Avenue; Gothic Avenue	>350,000 y B.P.
168	550	"L" Survey, Grand Avenue	>350,000 y B.P.
159	520	Flat Room	—
152	500	Lost Passage, Davis Hall	>350,000 y B.P.
146	440	Pohl Avenue, Radio Room	>123,000 y B.P.
143	470	Mud Avenue (top)	—
131	430	Mud Avenue (canyon)	>141,000 y B.P.
128-125	420-410	Active and submerged levels	—

This rapid downcutting is terminated by alluviation and sedimentation during the next glacial period which partially infills the recently formed canyons. This sediment is quickly removed during the early stages of the third interglacial event in the sequence, finally permitting a long episode of base-level erosion and conduit development late in this interglacial period. Thus there are approximately half as many cave levels as Pleistocene glacial/interglacial cycles.

Connate Contamination and Karstic "Pollution Conduits" in the Big Sinking Creek Oil Field

Gerry Estes

Abstract

Scanning electron microscope and x-ray photoelectron spectroscopy (ESCA) analysis of the evaporated particulate residue from surface and subsurface water samples taken in the karstic region of the Big Sinking Creek oil field in Estill and Lee Counties, Kentucky, discloses a high sodium chloride content. This sodium chloride, believed to be the connate overflow from abandoned and uncapped oil and gas wells, plays an important part in the area ecosystem and consequently contributes to a general lack of aquatic wildlife. Major undelineated cave systems within the oil field have become "pollution conduits" for uncontained crude oil spills and connate seepage, spreading localized contamination to an area exceeding 50 square miles.

Introduction

Oil has been produced in commercial quantities from shallow wells in the Big Sinking Creek oil field of Estill, Lee and Powell Counties, Kentucky. The oil field was discovered in 1918, reached maximum production of 6 million barrels per year by 1919, and declined to less than 1 million barrels per year by 1929 (McFarlan, 1943). The petroliferous rock unit is a sequence of Silurian and Devonian age dolomite, limestone, and shale whose top is about 700 feet (214 m) below the base of the Newman Limestone (Robinson, 1927). Many wells have been abandoned; however in 1974, commercial quantities were still being produced in the Furnace, Kentucky area. This oil and gas field, interlaced with extensive pipelines (usually running along creek bottoms), pumping stations, and storage tanks, is subject to numerous oil spills and burnoffs resulting in severe ecological problems. Groundwater resources in the southern part of the region reside in: 1)wells in the alluvium of the Kentucky River (500 gal per day), 2) seasonal springs at the base of the Corbin Sandstone, and 3) springs and cave resurgences in the lower part of the Newman Limestone and near the base of the Renfro Dolomite. Figure 12 shows a composite stratigraphic column for the ares (Estes, 1981).

In general, the chemical composition of water tends to reflect the chemical composition of the host rock independent of climatic and hydrological conditions. In sedimentary rocks the freshest waters are located in siliceous sands and sandstones, essentially formed by quartz. Their ionic composition is: Ca > Na > Mg > (CO_3 + HCO_3) > Cl > SO_4, but may exceed Ca. The most mineralized waters are those in contact with deposits of evaporites with very high contents of SO_4, Cl, Ca-Mg or Na. Clays with their high porosity and great contact surface can, in the presence of salts retained by adsorption on colloidal

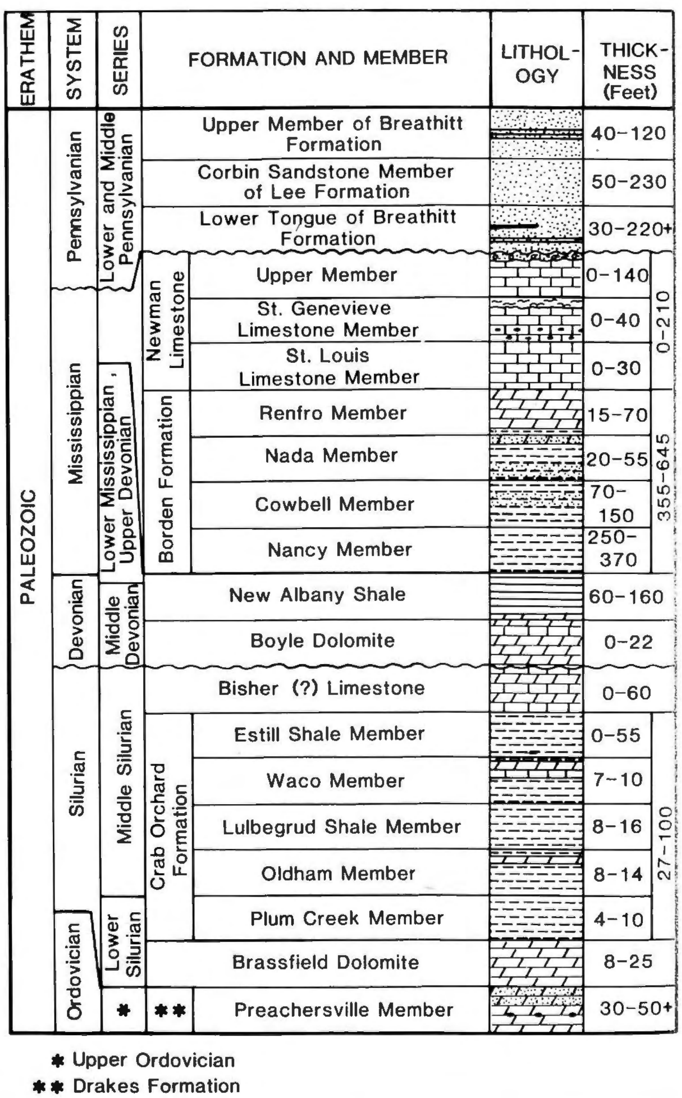

Figure 12. Composite stratigraphic column for the Big Sinking Creek Oil Field. Seasonal springs are often found at the base of the Corbin sandstone while perrenial springs and cave resurgences occur in the St. Louis limestone and Renfro dolomite (from Estes, 1981).

Table 3. Typical natural water composition in ppm. (Pfafflin and Ziegler, 1976).

	Na	*K*	*Ca*	*Mg*	*Cl*	*SO*	*CO*	*TOTAL*
SOFT	16	—	100	—	19	7	12	65
HARD	21	16	65	14	41	25	119	300
SEA	10700	390	420	1310	19300	2690	73	34900

particles at the time of sedimentation, have a rather high salt content (several thousand ppm). Limestones contain carbonate waters low in Cl, SO_4, and total saline matter with saline content increasing with extensive fracture due to the development of contact surfaces (Swaine and Schneider, 1971). Table 3 shows typical surface water composition (Pfafflin and Ziegler, 1976).

From 1979 to 1981, over 100 cave entrances have been logged inside the oil field and a pattern of extensive surbsurface drainage is in the process of being studied. This subsurface drainage can redistribute localized pollution to a much greater area than may be apparent from the study of regional geological maps (Haney, 1976). For example: 1) some cave systems in the area have their resurgence updip from the known recharge, 2) there is a strong indication that underground floodwater routes can cross through ridges and into adjacent drainage basins, and 3) there is evidence of paleo-karst features which may be in the process of being exhumed complicating otherwise simple drainage patterns.

Experimental

Four representative water samples were collected from the Big Sinking Creek oil field. These limited samples are typical midstream examples of average conditions and may only show general trends. A much more extensive sampling program would be needed to obtain specific data. Sample 1 (Quicksand Cave) represents the projected resurgence or output from Flood Cave (sample 2). Any difference between samples 1 and 2 can be attributed to input into the system from side passages and undisclosed sources. Sample 3 represents Big Sinking Creek which appears and disappears numerous times through a sinking stream system. Sample 4 represents Cave Hollow Cave which is a blind valley perched more than 120 feet above surface stream elevations and is far removed from any oil field activity. Samples 1, 2, and 3 represent open drainage areas in which there are numerous oil wells, pumping stations, pipelines, and storage tanks directly over cave passage. Sample 4 has all of its known recharge from the Corbin Sandstone and no oil wells are

Table 4. Total dissolved solids found in six water samples.

Sample	*Location*	*Particulate*
(1)	Quicksand Cave-insurgence	12100 ppm
(2)	Flood Cave-resurgence of Quicksand Cave	16900 ppm
(3)	Big Sinking Creek-main stream	1050 ppm
(4)	Cave Hollow Cave-resurgence	4280 ppm
(5)	Lexington Kentucky city water	4280 ppm
(6)	Distilled water	0000 ppm

present within the projected drainage basin. Approximately .04 g of sample water was slowly evaporated onto carbon SEM mounting studs. Each stud was weighed on a Metler A-30 electronic balance to the nearest 0.1 mg before and after evaporation. The weight of the particulate residue was determined to be the total dissolved solids within the water sample. Each specimen was placed in an ETEC scanning electron microscope (SEM) and analyzed for elemental composition utilizing a PGT energy dispersive spectrometer (EDS). As an additional check for accuracy, sample 2 was also analyzed utilizing x-ray photoelectron spectroscopy (ESCA).

Results

Energy dispersive analyses of samples 1, 2, and 3 disclose a composition mainly of Na, Cl, and Ca while analysis of sample 4 shows a composition of Na, Mg, Si, P, S, Cl, K, and Ca. The photomicrograph in Figure 13 reveals many cubic structures ranging in size from about .005 μm to 1 μm. By defining the energy range around the centroid of an element peak, an energy window can be created which when superimposed upon the micrograph can show the spatial distribution of an element in the form of a small white dot. Figure 14 shows the spatial distribution of sodium in Flood Cave water (sample 2) and Figure 15 shows the distribution of sodium plus chlorine. From the elemental distribution, it can be seen that the cubic structures are mostly NaCl while the amorphous structures are most likely CaCl. A sample of Lexington city water was run as a reference. The elemental compositon is similar to sample 4 (Cave Hollow Cave) with greater quantities of Mg and S and lower quantities of K. The photomicrograph indicated a general lack of particulate matter except for a few isolated Si particles.

X-ray photoelectron spectroscopy of sample 2 (Flood Cave water) confirm the EDS analysis with the addition of carbon and oxygen. Elements with atomic numbers lower than sodium cannot be seen by EDS methods.

Weight measurements of the dissolved solids as shown in

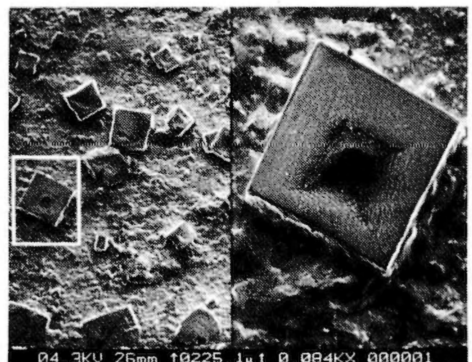

Figure 13. Photomicrographs of particulate matter from the Big Sinking Creek. The cubic structures are mostly sodium chloride and the more amorphous background matrix is predominantly calcium chloride with traces of magnesium, silica, phosphorus, sulfur and potassium.

Figure 14. Each white dot represents the spatial distribution of sodium in Flood Cave water (sample 2).

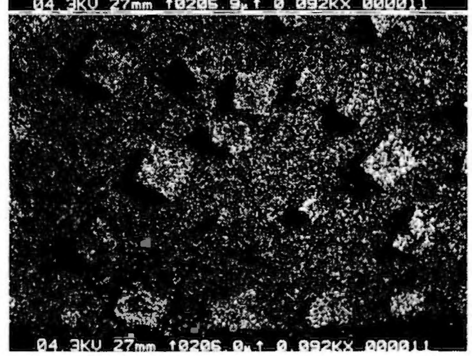

Figure 15. Each white dot represents the spatial distribution of sodium plus chlorine in Flood Cave water. It can be seen that the density of sodium chloride is greatest around the large cubic structures while the background matrix is composed mainly of calcium chloride.

Table 4 reveal that Big Sinking Creek (sample 3) has the greatest amount of dissolved solids (19,700 ppm) followed by Flood Cave (sample 2), Quicksand Cave (sample 1), and Cave Hollow Cave (sample 4) which has a total dissolved solids content lower than that of Lexington city water.

Field investigations have disclosed a surface film of oil in most of the streams in the Big Sinking Creek area. Particularly susceptible areas such as creeks in which pipelines run along their bottom, have numerous tar balls and a thick coating of oil tar on trees, bushes, and rock outcrops. Cave systems underlying pipelines, storage tanks, and pumping stations have their limestone walls thickly covered with about 1/4 inch oil tar deposits. Rock outcrops along pipelines in which burnoff has occurred have been spalled from the intense heat (Figure 16). There are reports of locally-owned oil companies washing out oil storage tanks and dumping the sludge into nearby sinkholes.

Conclusions

Because of a lack of fresh water wells, many local residents are using Big Sinking Creek, local springs, and many cave resurgences as their primary source of potable water. There is an absence of fish and other aquatic wildlife in local surface streams even though local residents say that Big Sinking Creek used to abound with trout. Dead crayfish have been seen in Big Sinking Creek after the 1980 oil spill and resulting burnoff. The mineral content of surface stream water plus the quantity of total dissolved solids suggest that there is connate brine leaking into the streams from uncapped and abandoned oil and gas wells. Pending more conclusive standardized water quality testing procedures, it can be seen in Table 5 that these waters do not meet the minimum criteria for Kentucky surface waters, warmwater aquatic habitat, nor domestic water supply sources according to 401 KAR 5:031. Although the sampling has been limited to several typical examples of oil field waters in "open" and "closed" drainage basins, the following observations can be made: 1) oil spills and connate waters are in the process of being unintentionally redistributed to local potable water supplies via undelineated cave systems, 2) in an area, such as Cave Hollow, where geologically it is unlikely to occur, the presence of connate minerals suggests that there is a direct connection between adjacent drainage basins resulting in a certain unpredictability in determining the extent of which localized contamination can be spread, and 3) connate minerals and oil residue within the Big Sinking Creek oil field are in direct violation of Kentucky Water Standards 401 KAR 5:031. Consequently, surface water within the oil field is unfit for domestic use.

Figure 16. Sections of Cumberland National Forest have been burned from oil spill fires. The pipeline in the foreground is a main oil pipeline which runs along the Big Sinking Creek for many miles. This section of the creek comes out of a cave 100 ft. (30 m) upstream and goes into another cave just to the left of the picture. (Photo by Gerry Estes.)

Additional study is needed within the Big Sinking Creek oil field to: 1) more precisely determine the extent of water pollution, and 2) define subsurface drainage systems through which contaminants are being transported.

Table 5. Minimum Criteria Applicable To All Surface Waters in Kentucky (taken from Kentucky Water Standards 401 KAR 5:031).

A-1 *Minimum Criteria Applicable To All Surface Waters*

The following minimum water quality criteria are applicable to all surface waters. Surface waters shall not be aesthetically or otherwise degraded by substances that:

1) Settle to form objectionable deposits;
2) Float as debris, scum, oil, or other matter to form a nuisance;
3) Produce objectionable color, odor, taste, or turbidity;
4) Injure, be toxic to or produce adverse physiological or behavioral responses in humans, fish, shellfish, and aquatic life.

A-II Aquatic Life

Maximum allowable concentrations

1) Chlorine, total, residual- 10µg/ l (.01 ppm)

A-III Domestic Water Supply Use

Maximum allowable concentrations to be applicable at the point of withdrawal for use for domestic water withdrawal from surface sources are specified as follows:

1) Chloride, total-250 mg/l (250 ppm)
2) Manganese-.05 mg/l (.05 ppm)
3) Sulfate, total-250 mg/l (250 ppm)
4) Total dissolved solids-750 mg/l (750 ppm)

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Ecology Program

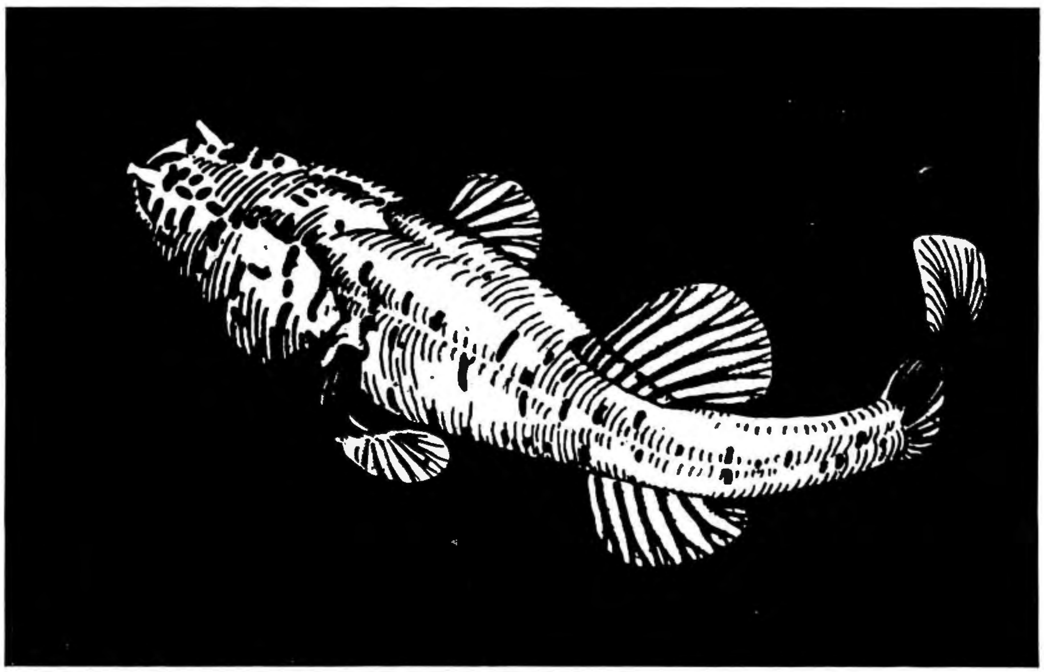

Figure 17. Drawing of *Amblyopsis spelaea* (½ size) by Thomas L. Poulson.

Ecological Genetics of Carabid Cave Beetles

Thomas C. Kane

Using the systematic work of Barr (1979), grounded on morphological and biogeographic considerations, as a basis, the preliminary study of Giuseffi et al. (1978) on electrophoretic variability in *Neaphaenops tellkampfi* was extended over the past two years (see Turanchik and Kane, 1979; Brunner and Kane, 1981; Kane, in press). A total of 18 populations of this cave beetle have been sampled. These studies show that levels of genetic variability in this species approach those of surface invertebrates, and that smaller surface rivers, such as the Green and Nolin Rivers, do not act as dispersal barriers to underground movement by *N. tellkampfi* (**Figure 18, Table 6**).

Barr (1979) divided *N. tellkampfi* into four subspecies (Figure 18) employing morphological and biogeographical criteria. Electrophoretic data (Brunner and Kane, 1981; Kane, in press) confirm three of the four subspecies designations in *Drosophila* (Ayala, et al., 1974). The similarity value between *N. t. henroti* and *N. t. tellkampfi*, the two most similar species morphologically, is greater than 0.90, although single individuals of either subspecies may be readily differentiated from the other subspecies by diagnostic characters cited by Barr (1979) (i.e., the subspecies are taxonomically sound, but have unusually high genetic identity).

Table 6. Genetic variability in four subspecies of *Neaphaenops tellkampfi*. A locus was considered polymorphic if the most common variant had a frequency less than 0.95. P = proportion of loci polymorphic. H = average heterozygosity. (Data on *N. tellkampfi* taken from Turanchik and Kane, 1979).

Subspecies	*P*	*H*
henroti	0.571	0.091
viator	0.428	0.082
meridionalis	0.500	0.137
tellkampfi	0.470	0.154
tell. x merid. (hybrid)	0.429	0.050

Table 7. Genetic similarity values (I) above the diagonal and genetic distance values (D) below the diagonal for four subspecies of *N. tellkampfi*. Values on the principal diagonal represent within subspecies similarities. (Data for *N. tellkampfi* were calculated from Turanchik and Kane, 1979).

	henroti	*viator*	*meridionalis*	*tellkampfi*	*tell. x merid.*
henroti	0.982	0.733	0.777	0.966	0.970
viator	0.311	0.940	0.758	0.767	0.674
meridionalis	0.252	0.277	0.958	0.785	0.758
tellkampfi	0.035	0.265	0.242	0.973	0.923
tell. x merid.	0.030	0.394	0.277	0.080	NA

Table 8. Genetic Variability of *Pseudanophthalmus menetriesi* in Little Beauty Cave.

Locus	*N*	*Allele*	*Frequency*	*H*
PGM	24	0.91	0.04	
		1.00	0.56	
		1.11	0.40	0.625
PGI	10	1.00	0.90	
		1.26	0.10	0.200
			Overall H =	0.422

$H_{PGM + PGI}$ for *N. t.* local populations = 0.000

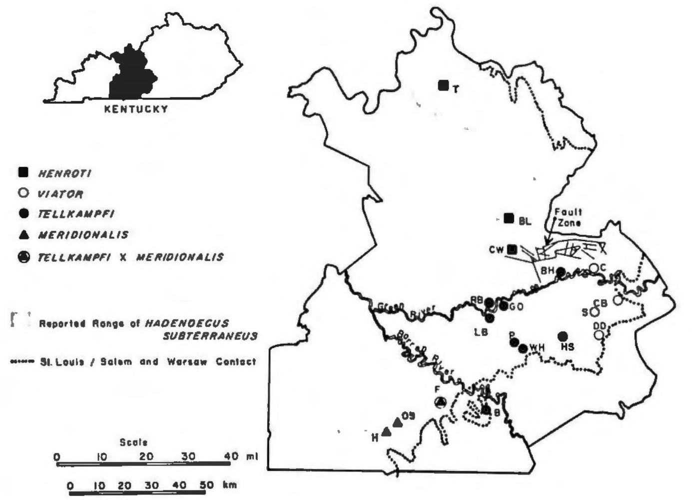

Figure 18. Map showing where subspecies (as defined by Barr, 1979) of the cave beetle *Neaphaenops tellkampfii* have been found.

The phosphoglucose isomerase locus (PGI) has been particularly useful in assessing relationships among subspecies. Three electromorphs have been uncovered at this locus, with *t. henroti* and *t. tellkampfi* fixed for a fast migrating form, *t. viator* fixed for a form of intermediate mobility, and *t. meridionalis* fixed for a slow migrating form. A single polymorphic population is one which Barr (1979) interpreted as *t. tellkampfi x t. meriodionalis* (Figure 18, Table 7). The population is morphologically intermediate in eight of ten diagnostic characters differentiating the two subspecies.

There is a strong preliminary indication that levels of variability in cave trechines such *N. tellkampfi* may be maintained through natural selection. *Pseudanophthalmus menetriesi* is a closely related trechine which is sympatric with *N. tellkampfi* in part of its range. Its geographic range is smaller, and the mean local population size is smaller than that of *N. tellkampfi*, however. Barr (1979) indicated that *P. menetriesi* and *N. tellkampfi* diverged from common ancestral stock at approximately the same time. A hypothesis based on (a) time since the bottleneck and/or (b) effective population size would therefore predict that *P. menetriesi* would show reduced variability compared to *N. tellkampfi*, assuming selective neutrality of amino acid substitutions. Data for the PGI and PGM loci in the LB population of *P. menetriesi* (Table 8) indicate that in fact this species may be more variable than *N. tellkampfi*. This result is consistent with the observation that *P. menetriesi* does not show the specialized cricket egg predation behavior of *N. tellkampfi*, but rather is a much more generalized predator.

Acknowledgements

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Observations on Aquatic Communities in the Historic Section of Mammoth Cave

Julian Lewis

Research on the aquatic communities of the Mammoth Cave System has this year resulted in the expansion of some of the ideas presented in the previous annual report (Lewis and Lewis, 1980) and the modification of others. Perhaps the most significant and interesting information that this stud;y has brought to light is the diversity which has been found in the structure of aquatic communities in the different sections of the cave system. This diversity was alluded to previously in the use of different habitats by the two species of troglobitic isopods found in Mammoth Cave. The following is an expansion of the scenario presented by Lewis and Lewis (1980).

The Aquatic Communities

For the sake of simplicity, Mammoth Cave is considered here to be formed on five levels. From a biological standpoint, these can be divided into upper, middle and base level habitats. The majority of observations reported here were conducted in habitats within the Historic Section of Mammoth Cave, or other caves in Mammoth Cave Ridge. In the uppermost levels four types of aquatic habitats can be delineated: (1) shaft drains, (2) terminal breakdown streams, (3) rimstone pools, and (4) isolated drip pools. The shaft drains are the most common of the four types, and will be considered first. In Shalers Brook, where no obvious organic enrichment is present, the community is comprised most entirely of isopods, *Caecidotea stygia*, with much fewer numbers of amphipods, *Stygobromus vitreus*, and flatworms, *Spalloplana percoeca* (Figure 19). In contrast, in Cathedral Domes, where large amounts of wood are present in the stream, the community is considerably different. Here, *Caecidotea stygia* is again present, but the amphipod *Crangonyx packardi* is relatively more abundant (Figure 20). The larger, vestigially eyed *Crangonyx packardi* seems to require a greater food supply than is available in Shalers Brook, where only *Stygobromus* occurs. Further collaboration of this observation is provided from old records of *Crangonyx packardi* in Shalers Brook, which at one time was enriched by sewage effluent from the Mammoth Cave Hotel. The sewage problem in Shalers Brook has now abated, and *Crangonyx packardi* is no longer present. In addition to *Caecidotea stygia* and *Crangonyx packardi*, other species present in Cathedral Domes are flatworms, *Spalloplana* sp., salamander larvae, *Eurycea lucifuga* (?), and the amphipod *Stygobromus vitreus*. Thus only three species are found in Shalers Brook, while five are found at Cathedral Domes.

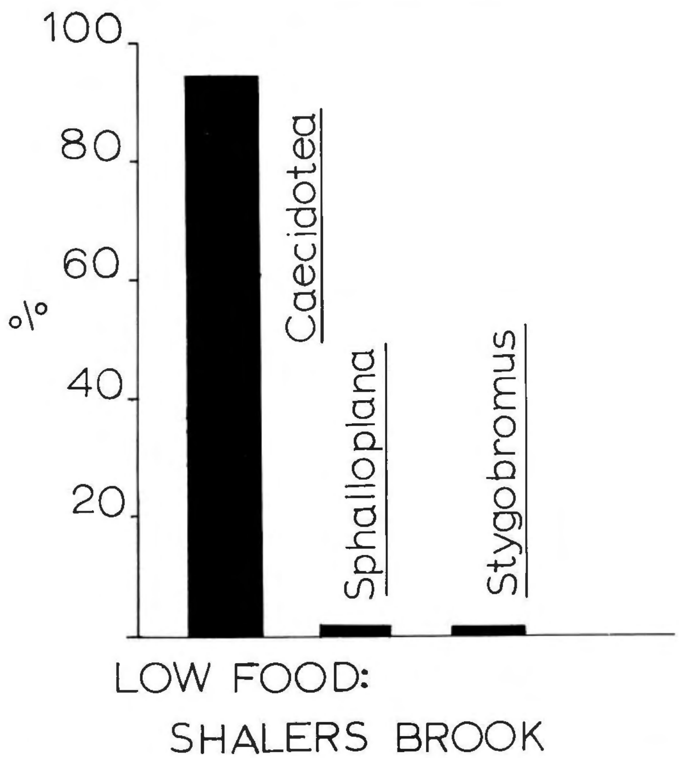

Figure 19. The aquatic fauna of Shalers Brook, a typical shaft drain stream located in Gratz Avenue, Mammoth Cave. Typical relative abundance of each species present is illustrated, taken from monthly census data at six fixed, randomly located 15 cm^2 plots.

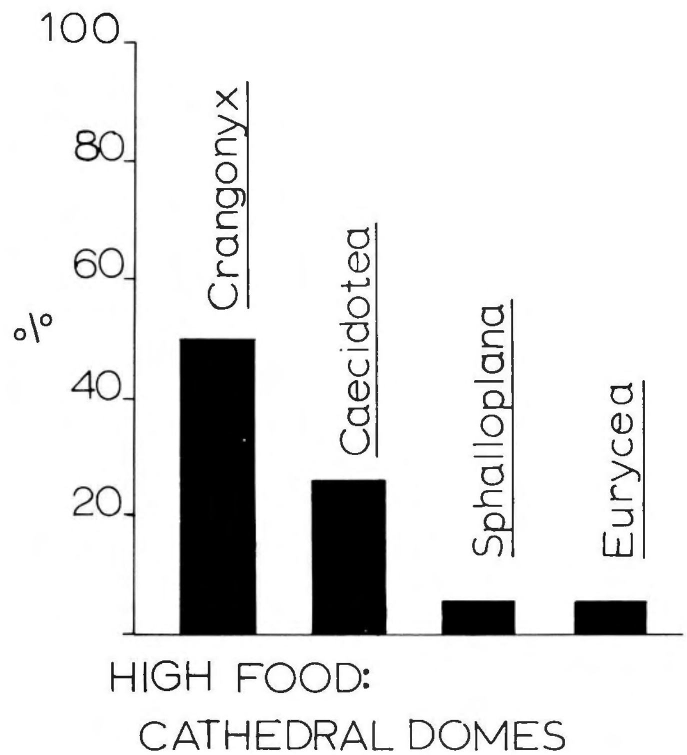

Figure 20. The aquatic fauna of the stream in Cathedral Domes, a shaft drain containing large amounts of decaying timbers, the remains of a defunct staircase. Typical relative abundance of each species present is illustrated, taken from a census of random 15 cm^2 plots.

Two terminal breakdown streams have been sampled, at Rafinesque Hall and Blackall Avenue. The communities there are similar to that of Shalers Brook, dominated by *Caecidotea stygia*, with much fewer numbers of *Sphalloplana* and *Stygobromus*. Unidentified aquatic oligochaetes also occur in small numbers occasionally. Several other terminal breakdowns have been visited repeatedly, such as the breakdown previously thought to terminate Gothic Avenue. Both sides of this breakdown (which can be bypassed through a crawlway) have small streams during parts of the year, but are apparently too ephemeral to support macroscopic animals. Rimstone pool habitats occur abundantly in White Cave, near the entrance of Great Onyx Cave (Flint Ridge), and to a lesser extent near the Devils Cooling Tub, in Gratz Avenue. Similar to the terminal breakdown streams, these pools are subject to drying up, and as such constitute a marginal habitat. In both White and Great Onyx caves, *Spalloplana* occur regularly in the rimstone pools, but crustaceans are absent or irregular. In White Cave, a dead *Eurycea lucifuga* in a pool harbored a large number of *Spalloplana* and a few amphipods. The rimstone pools in Gratz Avenue fill only during wet weather and have not been observed to be populated by either *Spalloplana* or any of the crustaceans. The final category consists of pools of various sizes which mostly do not appear to be fed by actively flowing streams. Shallow pools several meters long extend along the trail in Martel Avenue at times, but no fauna has been seen there despite repeated searching. Likewise, Lake Purity in Gratz Avenue usually appears devoid of life. However, on occasion these habitats must be invaded by invertebrates. Small, mud-bottomed pools created by boot tracks in the back section of White Cave contained *Caecidotea stygia*, *Stygobromus* and *Spalloplana* during a July visit, while another inspection a few weeks prior had revealed only the isopods. The fauna of these pools is obviously a function of what enters them via drippage from above, since flooding from base-level streams is eliminated by the high elevation on the ridge. The final upper level habitat that merits mention is Crystal Lake, located near the Frozen Niagara Entrance. This body of water does not qualify under any of the four other upper level categories as it was artificially created by damming what presumably used to be a short shaft drain. Barr and Kuchno (1971) reported grab samples of *Caecidotea stygia* and the presence of *Orconectes pellucidus*. However, several trips to Crystal Lake to check for these invertebrates have proved unfruitful. Prying boards from the bottom on the lake uncovers a black layer of anerobically produced *sapropel* with its characteristic accompanying odor, a habitat which does not seem conducive to cavernicoles. As to the presence of *Orconectes*, it is not out of the question that the crayfish were introduced there during the time a commercial boatride was conducted on Crystal Lake. Whatever the case, none have been seen there recently.

Mid-level Communities

The mid-level communities again reflect the types of habitats present. Deeper under the ridge terminal breakdown streams like that at Rafinesque Hall are no longer found. However, shaft complexes are common in some areas, ranging in size from small seeps like Richardson's Spring (Black Snake Avenue) to larger streams like that in Flint Dome (Jessup Avenue). At Gorins Dome, several small seeps or streams flow into the dome at various points through the mid and lower levels and fall directly to the base-level stream at the bottom of the pit. It is in the mid levels of the cave that the fauna typical of the base level rivers intergrades with that of the upper levels. Thus, in rimstone and drip pools in the Labyrinth, only *Caecidotea stygia* has been found. Similarly, in Richardson's Spring, the fauna is more diverse, but still identical with that found in the upper levels: *Caecidotea stygia, Stygobromus vitreus* and *Spalloplana* sp. In other mid-level habitats the streams become larger, and of a more permanent nature as shaft drains coalesce to form the master shaft drains feeding the cave rivers, with a concomitant change in fauna.

The change between upper and lower-level faunas is best observed in the distribution of the two species of troglobitic isopods, as previously discussed (Lewis and Lewis, 1980). In short, *Caecidotea stygia* occurs only in the upper levels of the cave, while *Caecidotea* sp. (being described by Lewis and Bowman, in press) inhabits mostly base-level or near base-level streams. Inevitably, the two species meet and intergrade somewhere in the mid-levels of the system. This happens at Flint Dome, where both species occur, along with *Stygobromus*, *Sphalloplana* and *Orconectes*. Lower in the system, in cave passages directly above base level, two locations where only *Caecoditea* sp. occurs (without *Caecoditea stygia*) have been found. These are the small cave directly above Styx River Spring (where *Orconectes pellucidus* and *Sphalloplana* also occur) and pools in Carlos Way. The diversity of mid-level communities is not especially great, with the Flint Dome assemblage being the best yet located, consisting of five species. Undoubtedly, faunal diversity increases as one follows streams closer to the cave rivers, picking up base-level inhabitants. *Orconectes pellucidus* and *Caecidotea* sp. are the first such species found in the mid levels which are more typical of the cave rivers. Unfortunately, many of the areas that might be studied at or near base level, such as the master shaft drains that flow into the cave rivers, are submerged or nearly submerged by backflooding from the Green River (caused by Dam No. 6). Only two large rivers occur under Mammoth Cave Ridge, Styx River and Echo/Roaring River. Styx River is exposed for only a short distance, siphoning both upstream and downstream. In the upstream, freeflowing part of the Styx, the only area where animals can be found predictably is at the breakdown-strewn area shortly downstream from the Natural Bridge. Here *Caecidotea stygia* and *Caecidotea* sp. occur (see Lewis and Lewis, 1980, for an explanation of the occurrence of both species at base level) with *Orconectes pellucidus*. The fauna of Echo and Roaring Rivers is more interesting. The fauna of the Shrimp Pools has been discussed by Barr and Keuhne (1971) and will not be repeated here. Upstream of the Shrimp Pools, another pool area can be reached by taking a short boat trip up Roaring River. Here, *Caecidotea stygia* and *Caecidotea* sp. again both occur, along with *Orconectes pellucidus* and *Typhlichthys subterraneus*. Unfortunately, a slight rise in river level puts this area beyond, due to a dip in the ceiling shortly upstream from the Shrimp Pools.

During the past year, Echo River has received a great deal of attention due to the physical connection by divers of Echo Spring to passages in Mammoth Cave, with the discovery of the blind shrimp, *Palaemonias ganteri*, in both the flooded spring tube and the part of Echo River currently being used for the commercial boat tour. The divers also reported numerous *Amblyopsis spelaea, Cottus carolinae* (Sculpin) and other unidentified epigean fish presumably originating in the Green River. In this same general area, such as at Purgatory Slough, the snail Antroseltes spiralis can also be seen occasionally on the undersides of rocks, in the company of *Caecidotea stygia* and *Orconectes pellucidus*.

Community Studies

Research still proceeds at Shalers Brook and the stream at Rafinesque Hall. Starting in 1980, all animals present at randomly placed, permanent census stations were counted with 15 cm^2 quadrants at these two locations. This year the task of measuring each isopod present (by far the most abundant species in each community) was initiated and much new information has been accumulated as a result. Among other things, size data gathered to date indicates that last years' speculation about a late spring reproductive period among *Caecidotea* (based on a large increase in the population at that time) is probably in error. Part of the surge in population recorded during June 1980 also occurred during the same time period this year, but due to an apparent migration of *Caecidotea* into the area of the third census station at Shalers Brook, which happens to be at the confluence of two small streams. Further discussion on the communities at Shalers Brook and Rafinesque Hall must be deferred until more data has been gathered.

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Archeology, Anthropology, and Paleontology Program

Figure 21. Tammy Bennington assists as Louise Robbins prepares a cast of the human footprints in Aborigine Avenue, Jaguar Cave, Tennessee. (Photo by W. McCuddy.)

CRF Archeological Project and Shellmound Archeological Project, 1981

Patty Jo Watson

We are investigating a number of aspects of prehistoric life in the middle Green River drainage of western Kentucky, particularly aboriginal cave exploring and cave mining and the subsistence patterns of the ancient cavers. The significance of archeological materials from Mammoth Cave National Park has been demonstrated in earlier publications (Watson ed., 1974; Watson, et al., 1969). Botanical remains we have recently recovered from shellmound sites in the Big Bend of Green River (near Logansport) downstream from the Park in Butler County are also crucial to understanding horticultural origins in the middle Green River region. At about 700 B.C., the pre-Columbian Indians who mined and explored Salts and Mammoth Caves in Mammoth Cave National Park were growing squashes and gourds (tropical plants first domesticated in Mexico about 9000 years ago) and also some native western and midwestern species (sunflower and a related plant called sumpweed, as well as goosefoot weed). At about 2500 B.C., the shellmound dwellers in the Big Bend of Green River, who were predecessors of the caving Indians, grew squash, but apparently none of the other species just listed. During the past few years we have expanded our cave archeology projects to include recording of caves in northern Tennessee (Figures 22 and 23; also see Annual Reports for 1977-1980). We have also been very interested in the results of a study undertaken at Wyandotte Cave, Indiana, by archeologists Patrick and Cheryl Munson of Indiana University (Munson and Munson, 1981). The Wyandotte data to the north and the Tennessee data to the south of the Mammoth Cave system reinforce earlier impressions that many aboriginal populations throughout this mid-continental karst region made good use of the cave resources. The highlight of 1981 was the Eighth International Congress of Speleology in Bowling Green, Kentucky, with several day-long, pre- and post-Congress camps at the CRF field station on Flint Ridge. The CRF Archeological Project was well represented in all three contexts, as indicated in the summary below. Another high point, a prelude to the Congress, was the 6-day, Western Kentucky University course in Cave Archeology taught in Mammoth Cave National Park in mid-June by Pat Watson, ably assisted by Tammy Bennington, Amy Finkel, Jack Freeman, Red Watson, Ron Wilson, and Gail Wagner.

Summary Account of CRF Supported Archeological Research in 1980-81

I. Archeological Work in Mammoth Cave National Park, 1981

The 11 students in "Cave Archeology" spent 6 days (June 15-20) taking field trips and learning something about the research we have been doing in the Mammoth Cave System and in other caves and rock shelters in the Park. The class visited various parts of the extensive series of passages and rooms that were explored and mined by the Indians in Mammoth Cave and Salts Cave. We also went to Owl Cave in Cedar Sink, and then to Jaguar Cave in northern Tennessee. Emphasis was placed not only on the specific archeological situations at these sites, but also on generalizable methods and techniques of documenting them. Other archeological activities during 1981 included the completion of George Crothers' Senior Thesis project at Sand Cave with visits to the cave itself on July 12 and 13. George presented a copy of his thesis and the cleaned and cataloged historic artifacts from Sand Cave to Superintendent Deskins and Assistant Superintendent James Wiggins on July 17.

During the Congress camps at Flint Ridge, archeological trips were made to Upper and Lower Salts and upper and lower Mammoth Caves. Indian Avenue in Lower Salts was resurveyed, and an aborigian scaling pole was found on a ledge just below the passage ceiling near I49. The pole had been found in Indian Avenue during the first modern exploration of that part of the cave in the 1950s and placed on the ledge for safe-keeping, but the findspot was lost and its existence had become somewhat legendary. It was rediscovered in July only after three people had spent several hours on two separate trips systematically chimneying up to and examining every possible high ledge along the passage. On July 24, Pat Watson led a trip into Upper Salts Cave to show the archeological materials to Wyandotte Cave archeologists Patrick and Cheryl Munson, and to several of the cavers who have assisted our work in Tennessee (Bill Deane, Jay Arnold, and Ernie Garza).

II. Archeological Work in the Big Bend, 1981

Work in the Logansport area was minimal because we are trying to complete our report of fieldwork and analyses to date before carrying out more research there. However, we were fortunate in securing the services of Tom Gatus, a graduate student in archeology at the University of Kentucky and a specialist in chert sources within the state. Tom agreed to spend a week searching out all the sources of workable chert near our shellmound sites. After an introductory tour conducted by Bill Marquardt and Pat Watson on July 11, Tom spent the first week of August doing this chert source reconnaissance. We anticipate obtaining some interesting information on communication networks when we compare his results with the kinds of chert present at the Carlton Annis shellmound and at other sites in the Big Bend area.

On July 8, Pat Watson visited Bt 5 (the Carlton Annis shellmound) briefly with Cheryl Claassen—a graduate student in archeology at Harvard University—who is doing her dissertation research on East Coast shellmounds. Working with marine shells, she has been able to get a considerable amount of detailed information on seasonality and relative chronology

Figure 22. Aboriginal torch smudge, Jaguar Cave, Tennessee. (Photo by D. Daunt-Mergens and W. McCuddy.)

from thin-sections she prepares of the best-preserved shells. She took several examples of shell from Bt 5 to see whether her techniques would enable us to say anything more about seasonality for that site than what we have inferred from other biological remains.

III. Archeologial Work in Tennessee Caves, 1980-1981.

As the result of strenuous efforts on the part of several Washington University student archeologists and CRF JVs, we finished mapping and making casts of the human footprints in Aborigine Avenue of Jaguar Cave on November 27, 1980. There are 269 prints in our catalog and on our maps; these represent 9 different people. Louise Robbins now has casts of one foot of each of the 9. These data were obtained just in time to be incorporated in the MS report Louise, Ron Wilson, and Pat Watson prepared for the International Congress (Robbins, Wilson, and Watson, 1981). Bill McCuddy directed another photo crew to record the footprint casting procedure (Figures 3a, b, c) and to get some more photos of the large rooms and passages. In mid-April, 1981, an archeological trip was made to another cave in northern Tennessee, Saltpetre Cave, where Bill Deane had told us of human footprints and some charcoal scatters. There is also evidence of chert mining. The footprints are not nearly so well preserved or numerous as in Jaguar Cave, but otherwise are quite comparable. Louise Robbins was able to get several casts; Bill McCuddy took photos of that activity, and of other archeological remains in the cave (mostly charcoal scatters and smudge marks). The remains in Saltpetre Cave were of sufficient interest to necessitate another trip in June with two archeologists from the University of Tennessee (Professor Charles Faulkner and graduate student Gerald Kline) when preliminary plans were made for detailed recording of the chert mining area by another University of Tennessee student, Lee Ferguson. Accordingly, Lee spent the second week of September at Saltpetre Cave with a crew of CRF JVs and University of Tennessee student archeologists, materially aided on the two weekends by CRF and NSS cavers. Lee will analyze and describe the results of this work in his Master's thesis.

Acknowledgements

The work of the CRF Archeological Project is partially supported by Washington University Faculty Research Grants; Shellmound Archeological Project activities were partly funded by a National Science Foundation grant. We are grateful to Mammoth Cave National Park Superintendent Robert Deskins and Assistant Superintendent James Wiggins for their interest in our research and for their continuing aid and assistance in all aspects of our work in the Park. In the Logansport area we remain deeply indebted to the hospitable inhabitants of the Big Bend, especially Waldemar and Ethie Annis who own the Bt 5 site, and John L. and Kathleen Thomas, facilitators and expeditors of all phases of the shellmound research. We are also grateful to the owners of property above and adjacent to Jaguar Cave for their aid, and their concern with our results: Mr. and Mrs. J. C. Copley, the Misses Lera and Loma Pile, and Mr. James Williams. Tennessee caver Bill Deane first told us of Saltpetre Cave and has provided a variety of logistical support in

Figure 23. Louise Robbins and Tammy Bennington inspecting the human footprints in Aborigine Avenue, Jaguar Cave, Tennessee. (Photo by W. McCuddy.)

our cooperative work there with archeologists from the University of Tennessee. Needless to say, none of our work underground could be done without the willing and cheerful assistance of numerous CRF JVs and Members, who volunteer their caving and their other skills, their cars, and themselves to aid us in all the research areas referred to in this report.

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Paleontological Remains from Pit of the Skulls, Barren County, Kentucky

Ronald C. Wilson and Patty Jo Watson

Pit of the Skulls was recently discovered by CRF JV Michael Hennion, and is of considerable interest because it contains both human and non-human skeletal remains. On September 7, 1981, Hennion led a group consisting of John Branstetter, Don Coons, Sheri Engler, and Ron Wilson to the pit so Wilson could identify the bones still in situ there. Three fragmentary human skulls had been removed on Hennion's previous visit, and—with the remains collected on the September trip—are now in Wilson's laboratory in Louisville. Like those from Crystal Onyx Cave near Cave City, the human remains from this pit presumably represent people whose bodies were thrown into the shaft by surviving relatives or friends, although some could perhaps have fallen in accidentally. The latter circumstance is doubtless the explanation for most if not all of the other animals whose bones we found at the bottom of the pit. These included a few birds and reptiles as well as a variety of mammals. The only somewhat remarkable species is the elk, which has not been present in Barren County since pioneer days. Preliminary examination of the human skulls indicates they are surely aboriginal (i.e., from a native American population and probably a few hundred years old or older), but they await detailed study by a specialist. The species list of animals whose bones came to rest in the pit include the following (identifications by Ronald C. Wilson):

Reptiles:
- box turtle—*Terrapene carolina*
- copperhead—*Agkistrodon contortrix*

Birds:
- red-tailed hawk—*Buteo jamaicensis*
- crow—*Corvus brachyrhychos*

Mammals:
- human—*Homo sapiens*
- opposum—*Didelphis virginianus*
- short-tailed shrew—*Blarina brevicauda*
- gray squirrel—*Sciurus carolinensis*
- fox squirrel—*Sciurus niger*
- woodrat—*Neotoma floridanus*
- white-footed mouse—*Peromyscus leocopus*
- rabbit—*Sylvilagus floridanus*
- white-tailed deer—*Odocoileus virginianus*
- elk—*Cervus elaphus*
- cow—*Bos taurus*
- raccoon—*Procyon lotor*
- gray fox—*Urocyon cinereoargenteus*
- striped skunk—*Mephitis mephitis*

Interpretation and Education Programs

Figure 24. International group of speleologists in attendance at the post-Congress camp at Carlsbad Caverns, New Mexico. Photo by Robert Nymeyer.

History Program

Figure 25. Artifact recovered from the Echo River in Mammoth Cave. This old Budweiser bottle, 235 mm tall, was manufactured sometime between 1883 and 1902. (Photo by Dr. John Otto.)

Exploration and Survey of Echo River

Roger Miller

Echo River in Mammoth Cave, KY, was discovered in 1838 by Stephen Bishop. Although the water was known to emerge on the surface at Echo River Spring, a few hundred yards from the Green River, guides had not been able to locate the beginning nor any other part of the submerged section of the conduit inside the cave. Divers Roger Miller and Frank Fogarty in 1973 commenced a series of scuba-equipped penetrations of the Echo River Spring that led to a successful traverse of the underwater conduit. The explorers completed their 1048.5 m (3440 ft.) survey that ended when they surfaced in Echo River in the cave on 25 January 1981 (Figure 26).

The underwater conduit is an elliptical tube varying in cross-section from 4 to 8 m wide x 1.5 to 4 m high, at a depth of about 2 m below the pool stage of the Green River, and with an almost flat profile. A few coffin-size breakdown blocks are present, and only one pocket of air was found in a ceiling recess. The silt floor is heaped against the side walls, and in places appears to have been carved by the current into a deep V-shaped canyon. The bedrock walls are scalloped.

Animal life consists of aquatic forms, including cave crayfish, several terrestrial bluegills, and cave blindfish. One specimen of the Kentucky cave shrimp was observed during the initial dives. The report of sighting the Kentucky cave shrimp was greeted with excitement by cave biologists, for the species had not been seen since 1967. It was feared to be extinct.

Near the Mammoth Cave end of the submerged conduit the divers found several antique glass bottles, parts of boat planking studded with cut-nails, and finally a complete boat wedged across the passage. Farther along the flooded passage are ten more boats of apparently different ages of construction. These artifacts were subsequently described and some of the bottles photographed.

Several maps showing Echo River were drawn prior to 1906. Those show that several hundred meters of the now-submerged upstream conduit were accessible during the 1800s. The map drawn by Max Kaemper in 1908 does not show this passageway, because it became flooded in 1906 behind the newly-constructed Lock and Dam No. 6 on the Green River near Brownsville. The emergence of Roger Miller and Frank Fogarty into an air-filled passage on January 15, 1981, marked the first time Echo River Spring had been used as an entrance to Mammoth Cave, becoming the 22nd known entrance.

On January 17, 1981, Frank Fogarty retrieved five objects (Figure 27) from the bottom of Echo River. Dr. John Otto, a historical archeologist at the Archeological Survey, University of Louisville, examined them. Descriptions of the materials are summarized:

1. Bottle. Aqua glass; 235 mm high, 65 mm diameter; manufactured with a semi-automatic bottle-making machine between 1883 and 1902; originally had a wire closure. Molded lettering on bottle reads "C. Conrad & Co's original *Budweiser* U.S. Patent No. 6376."
2. Bottle. Opaque olive green glass; 201 mm high, 77 mm diameter; blown in dip mold, probably during mid-19th century; shows asymmetrical neck. This type of bottle was typically used for brewed beverages or cheap wines. Found between submerged passage and Purgatory Slough.
3. Bottle. Green glass. 255 mm high, 78 mm diameter; blown in dip mold; string rim; mid to late-19th century. This type of bottle was used for good quality wines. Found between the submerged passage and Purgatory Slough.
4. Bottle. Green glass. 303 mm high, 98 mm diameter; blown in dip mold; string rim; mid to late-19th century. This type of bottle was used for champagne. Found in a sunken boat between the submerged passage and Purgatory Slough.
5. Glass tumbler. Clear glass, cracked, 98 mm high, 82 mm rim diameter, late-19th century. Found in a sunken boat between the submerged passage and Purgatory Slough.

In addition to the above, the divers reported hundreds of bottles (mostly broken) and glass fragments, many boat parts,

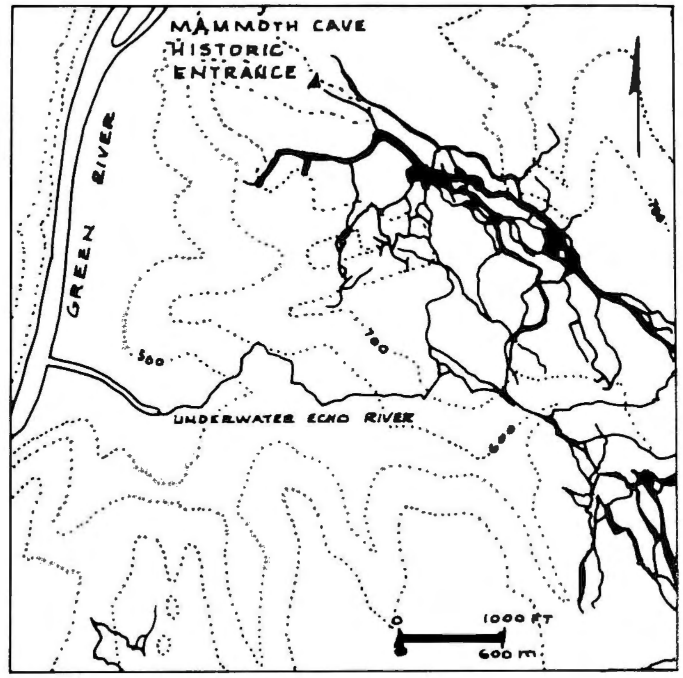

Figure 26. Line plot of the underwater portion of Echo River in Mammoth Cave, surveyed by Frank Fogarty and Roger Miller. Plot was drafted using the facilities at CRF's Louisville map factory.

Figure 27. Glassware recovered from the bottom of Echo River in Mammoth Cave. The tallest bottle is 303 mm high and the tumbler is 98 mm high. (Photo by Dr. John Otto.)

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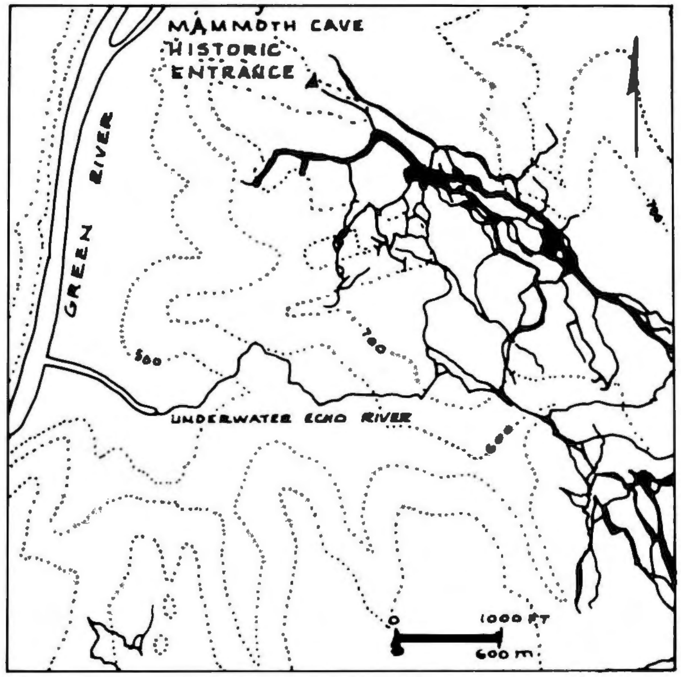

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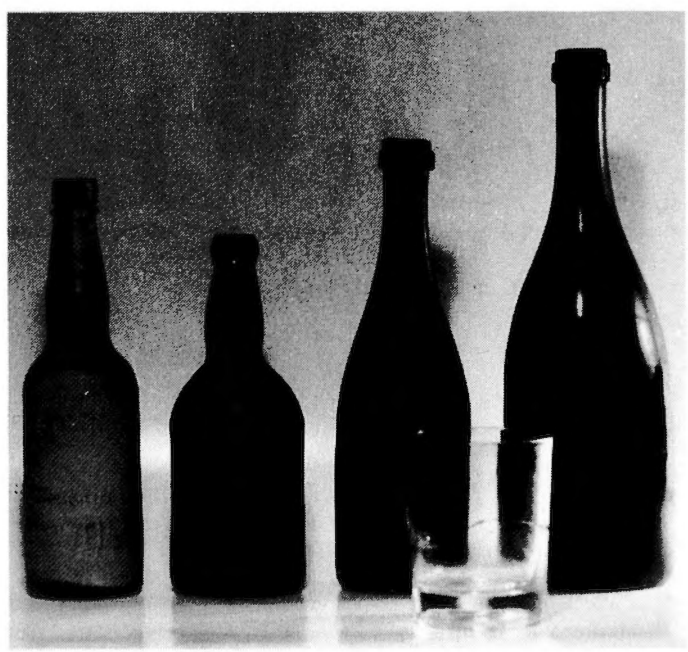

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saddles, lanterns, an iron pot, and other artifacts of historical interest.

It was suggested by John Otto and Patty Jo Watson that the site be assessed by an underwater archeologist before additional objects are collected. Otto recommended that the photographed bottles be retained for exhibit use, but that the bulk of the materials probably should remain on the river bottom so that future archeologists may study them *in situ*. All items are of museum quality and were placed in the care of Park officials for possible use in future exhibits or interpretive programs.

Great Saltpetre Cave: Prototype to the Wilkins-Gratz Mammoth Cave Saltpetre Operation

Duane DePaepe

Beginning in the last quarter of the 18th century, the saltpetre recovery operation at Mammoth Cave began with several leaching vats installed inside the Historic Entrance, as depicted by the circa 1810 "Eye Draught" map (Faust, 1967). Years later, to meet the demand created by the War of 1812, the works were greatly enlarged and enhanced using the then state of the art engineering technology. The original works near the Historic Entrance were abandoned and the new leaching hoppers, serviced by a log pipeline and pump towers, were constructed in the Rotunda and Booth's Amphitheatre. The owners during this redevelopment were the partnership of Hyman Gratz and Charles Wilkins. Gratz, a Philadelphian, furnished the necessary investment capital and Wilkins, a prominent Lexington, Kentucky, saltpetre merchant, is credited with engineering expertise and marketing skills. Lexington was the regional center of the saltpetre recovery industry and by 1810 supported six gunpowder mills (Perrin, 1882).

A letter dated December 30, 1812 from Archibald McCall, saltpetre dealer, to E. I. duPont, Philadelphia gunpowder manufacturer, states: "I received an answer to my letter to Mr. Charles Wilkins of Lexington, in which he mentions, that having been obliged to repair their works they had made but very little Salt Petre this season..." This document, now in the collections of the Eleutherian Mills Historical Library, Greenville, Delaware, apparently references the time of construction of the War of 1812 nitrate processing works now seen in Mammoth Cave.

Great Saltpetre Cave, also known as Kincaid's Cave, located some 40 miles south of Lexington, was that region's most noted saltpetre producing cave, not only from the quantity of its deposits, but also for its advance applied technology. The cave was discovered in 1799 by John Baker. Great Saltpetre Cave employed 60 to 70 workers during the War of 1812 (Maxon, 1932), the same number for the period as in Mammoth Cave. Charles Wilkins undoubtedly was familiar with this operation and ideas for the pumping system, ox-cart routing and other techniques were transferred by him to Mammoth Cave.

In 1806, Dr. Samuel Brown, Professor of Chemistry and Medicine, Transylvania College Medical School at Lexington, read before the prestigious American Philosophical Society his classic work on cave saltpetre mining. Brown visited Great Saltpetre Cave as early as 1802 and eventually became a part owner (Padgett, 1937). He recorded this saltpetre mining venture as his type study. Faust (1967) thought that Brown and Wilkins may have become business partners in the Lexington saltpetre trade. Brown's thesis included methods for prospecting nitrates and one might suspect that these techniques were later used by the Mammoth Cave miners:

> "The workmen have different modes of forming an opinion with regard to the quantity of nitre with which the earth may be impregnated. They generally trust to their taste; but it is always considered as made on the dust by the hand or foot, is in a very short time effaced. Where the nitre is very abundant the impression made to-day, will be scarcely visible to-morrow. Where there is a great deal of sand mixed with the dust, it is commonly believed that a small quantity of potash will suffice for the saturation of the acid." (Brown, 1806).

It could be further speculated that these prospecting methods were the ones used for the nitre quantification shown on the promotional circa 1810 "Eye Draught" map of Mammoth Cave.

Originally, the leaching process at Great Saltpetre Cave occurred on the surface near Crooked Creek (Brown, 1806). However, once a pumping system was installed a more efficient, therefore larger scale, operation resulted when the leaching could be accomplished inside the cavern near the place of the mining. The vastly improved system was enthusiastically expected to produce 1000 pounds of saltpetre daily (Padgett, 1937). A detailed description of the Great Saltpetre Cave mining effort can be found in the early journals of Dr. George Hunter:

> "The very water appending in drops form the arch above tastes manifestly nitrous, bitter of nitrat of Lime—The best earth seems to be that containing the greatest proportion of clay & least sand-
>
> ...-We found bout 20 hoppers in the cave in two or three places, ...the earth, as we learnt that they found water in some parts of the cave in the winter—when they worked them upon the spot without the trouble of moving the earth—
>
> Their Hoppers are formed of splits of wood like staves fixed in a square frame terminating in a point, under which is a wooden trough to receive the ley or Nitrat of Lime—The Ntrous earth is said to yield from lbs 1 to lbs 3 pr bushel of earth, altho generally averaging lbs 1½ or lbs 2.
>
> -Here & there are fallen down from the arched ceiling immense Stones which have been in part moved to make the road.
>
> -The earth is dragged out of the cave from where it appears strongest impregnated with nitrate of lime in small carts with 2 low wheels, drawn by two oxen which carry out about 150 bushels pr Day, down the hill to the creek side where it is put into a sort of hopper which contain about 70 bushels each. Cold water is put on this & repeated until the ley is extracted; This ley contg nitrat of Lime if poured upon wood ashes boiling hot, & the liquor when it appears to precipitate the lime & clear itself, is put into 4, or 5 Iron Kettles, and boiled until it appears fit to christallize when it is poured into hollow wooden troughs for that purpose.-
>
> In this form it is sold, at 12½ to 15 cents pr lb—It requires to be cristallized once more in order to make it fit for gun powder. on one side of the hill they use 18 hoppers for the Nitrous earth & 8 for Ashes. on the other side, the works are rather upon a larger scale—They have each about 16 Kettles rudely fired in stone—from 4 to 6 in a row & over one fire. each pot about 15 Galls."—(McDermott, 1963).

Today, Great Saltpetre Cave is developed as a visitor attraction and the saltpetre workings are an important interpretive feature. Although the historic artifacts and general cave environment have been altered to accommodate visitor improvements, the saltpetre workings are still suggestive of the Mammoth Cave operation.

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Conservation and Safety Programs

Figure 28. Gypsum flower, approximately 5 cm across, found in Cottonwood Cave, New Mexico. (Photo by Pete Lindsley.)

Conservation Notes from the Southwest

Jim Goodbar

Two conservation expeditions were held this year, both in conjunction with the NSS. The projects were held jointly to increase available manpower and to improve relations between the two organizations.

The Labor Day expedition was held in the Lincoln National Forest with 31 participants, 9 of which were CRF. The primary objectives were to establish or maintain trails in Cottonwood or Virgin Caves and replace the gate at Hell Below. A bit of formation restoration was done on the rimstone dams in the entrance of Cottonwood and attempts were made to remove an "unnatural log" from the vertical entrance of Hidden Cave.

The Thanksgiving expedition is to be held at Carlsbad Caverns under the direction of Ron Kerbo. Major projects planned are: cleaning of trash and litter from commercial trails; the removal of old rusting bridges from the Left Hand Tunnel and replacing them with non-rusting ones and cleaning the rust from the pools which they cross; replacing ladders in the Bottomless Pit; removal of old rotted handlines in various parts of the caves; and the cleaning and restoration of formations and establishment of trails in selected parts of the cave.

Another project which will have significant conservation impacts in the near future is the inventory and mapping of caves in the gypsum karst to the southwest of Carlsbad. This area is coming under intensified oil and gas production with a dramatic increase in the number of oil and gas wells being drilled and pipelines being constructed there. So far there have been no mishaps such as oil spills or ruptured pipelines which might drain into the underground systems or pipeline trenches cutting into cave passages. The inventory of this area should be intensified in order to document existing critical habitats and species in case such mishaps do occur.

The Washington Committee For Mammoth Cave

Sarah G. Bishop

Organized in the mid 1960s for the purpose of helping develop a good master plan for MCNP, the Washington Committee for Mammoth Cave was reactivated in 1979 to address some serious problems in the park. The Cave Research Foundation, which is a member of the Committee along with representatives from the National Parks and Conservation Association, the Wilderness Society, the National Speleological Society, the Sierra Club and others, was particularly concerned about pollution in the caves caused by leaky sewage lagoons at the Great Onyx Job Corps Center. Other Committee interests include the adverse effects of Lock and Dam No. 6 on the natural base level circulation of water in the caves, the endangered species status of the Kentucky blind cave shrimp, the implementation of a regional sewage system, and the implementation of the approved master plan for the park.

Proposed Removal of the Job Corp Camp: When members of the Washington Committee sued to have the Job Corp Camp closed down, the Departments of Labor and the Interior agreed to move the camp by September 1981. Land was purchased near the northwest corner of the park and preliminary work begun to prepare the site for construction. However, when the summer of 1981 came and went, and construction bids had not even been requested, it seemed quite probable that the extremely costly new Job Corp Center was feeling the budget cutting axe of the Reagan administration. Members of the Committee are still pressing suit to have the present Job Corp site removed, and further legal action is being considered.

Impact Study of Lock and Dam No. 6: The Washington Committee has urged the National Park Service to take a strong stand in favor of removing the non-functional navigational lock and dam No. 6 on the Green River. The pool of water formed by the obsolete structure artificially raises the base water level of the caves in MCNP and adversely affects aquatic habitats and species. NPS has said it will not take a public stand until an Army Corps of Engineers study on the impact of the structure is complete. In the meantime, however, park officials are independently looking at the impact the lock and dam have on the Kentucky blind cave shrimp.

Endangered Species Status of the Kentucky Blind Cave Shrimp: After a public hearing concerning possible endangered status for the Kentucky blind cave shrimp, the Office of Endangered Species requested that the shrimp receive further study before a ruling was made. Through the urgings of the Washington Committee and others, the National Park Service released funds to support this important study.

Regional Sewage System Plan: The Washington Committee is pressing NPS to be a full participant in the recommended EPA sewage treatment plan for the Mammoth Cave Region. Whether or not MCNP is a participant in the system, the NPS has a legitimate interest in the proper disposal of wastes from communities that surround MCNP. Long-term geohydrologic studies conducted by CRF and Park Service personnel have revealed direct connections between the outflow of adjacent communities and water flow through the caves in the park.

Proposed Changes in the MCNP Master Plan: During the summer local newspapers reported that a growing topic of interest in the Mammoth Cave area was some proposed changes to the approved Master Plan. The Washington Committee met with Superintendent Deskins and representatives of the regional and National Park Service offices to discuss their intentions with regard to the Master Plan. NPS's major concern is that Congressman Natcher, the chair of the Appropriations Subcommittee for Parks, has not allowed the Master Plan to be implemented. Hoping to find a way to gain the Congressman's acceptance of a Master Plan for MCNP, NPS is considering amending the current Master Plan. The amendment process, while requiring public participation, does not require an entire rewrite of the plan. Items being considered for amendment are the location of the staging area and new facilities for the north part of the park. The Washington Committee has endorsed the amendment process, and has encouraged the NPS to prepare its amendments for public comment as soon as possible.

National Park Action Project: The National Parks and Conservation Association has formed the National Park Action Project in which the Cave Research Foundation is a participant. The initial group of participants in the project consists of 50 individuals and representatives of organizations that are concerned about threats to the national parks, will be involved in park planning, and will be active in protecting park resources. Approximately 35 of these participants met to discuss a strategy for launching the project and for getting the attention of decision makers. The group endorsed a plan of action that NPCA will direct with the active assistance of project participants.

World Heritage List Status of Mammoth Cave National Park and the Guadalupe Escarpment: On October 27, 1981 the World Heritage Committee unanimously designated Mammoth Cave

National Park a World Heritage List property. Based on the CRF document, "The Mammoth Cave Region: A Nomination for the World Heritage List," the United States nominated MCNP for the list in December, 1980. In July 1981, the International Speleological Congress passed a resolution supporting the U.S. nomination of MCNP to the list, and directed its president to urge member nations to write their appropriate government officials in support of that nomination. As a World Heritage property, MCNP will receive both recognition as a natural feature of universal value and protection for the enjoyment of future generations. The nomination statement cites MCNP as being part of the premier model karst system and containing the longest cave in the world, with the diverse cave ecosystem, many rare minerals, and unique archeological sites.

In September 1981 the National Park Service asked for comments on a list of potential U.S. nominations to the World Heritage List. Included in the list were both Carlsbad Caverns and Guadalupe Mountains National Parks. CRF responded that the two parks should indeed be considered for WHL status, but that it is the geological unit that links the two parks that is of significance. This unit is the Guadalupe Escarpment that stretches from Guadalupe Mountains National Park through Forest Service and BLM land to Carlsbad Caverns National Park. It is the most spectacular and scientifically important exposure of a fossil reef in the world. It clearly meets WHL criteria as "an outstanding example illustrating a major stage of the earth's evolutionary history."

Third Cave Project Workshop

Roger W. Brucker

On Saturday and Sunday, September 12-13, 1981, 27 individuals from around the country attended the Third Cave Project Workshop, sponsored jointly by the Cave Research Foundation, Central Kentucky Karst Coalition, and the National Speleological Society. The weekend meetings were held at the Geology Department of the University of Kentucky. Jim Currens and Roger Brucker organized and moderated the program. The first Workshop was held in 1979 at the NSS Convention in Minnesota. The second, the following year in Springfield, VA. Both of those were sponsored by the NSS. This year the emphasis was on personnel problems and opportunities associated with cave projects. The narrowly focused discussions were informal, yet pertinent to the needs of long-term projects that concentrate on a single cave or group of caves, such as Mammoth Cave or a state cave survey.

Agenda

1.0 Recruitment and training of personnel

2.0 Management of personnel problems underground
- 2.1 Morale
- 2.2 Motivation
- 2.3 Acute fatigue
- 2.4 Cold
- 2.5 Emergencies

3.0 Above ground problems
- 3.1 Unwillingness to follow survey or safety procedures
- 3.2 Unwillingness to follow policies (i.e., cave access)
- 3.3 Cream skimmers (glory hounds who avoid the difficult)
- 3.4 Drugs and drink

4.0 Social problems
- 4.1 The abandonment syndrome (spouse, sweetheart, ec.)
- 4.2 Entertainment and diversion for noncaving families

5.0 Public relations
- 5.1 Landowners
- 5.2 Local cavers and residents
- 5.3 Other groups, grottos, projects
- 5.4 Agencies, i.e., NPS, BLM

6.0 Financial problems
- 6.1 Sources of funds
- 6.2 Management of finances
- 6.3 Distribution of funds

The 1982 Cave Project Workshop is expected to be held in conjunction with the NSS Convention in Oregon.

Status Report on the Kentucky Cave Shrimp

Edward A. Lisowski

The discovery of a dead Kentucky cave shrimp, *Plaemonias ganteri*, in the Shrimp Pools of Roaring River on 1 September 1979 renewed hopes that the species is not extinct. While scuba diving in a submerged side passage in Echo River, S. Maegerlein and J. Dickerson observed six live shrimp on 30 November 1980. CRF biologists found three more shrimp on 10 January 1981 in the Golden Triangle (Crystal Cave), where they had not been seen since 1967. During scuba dives in the 1050m long submerged passage between Echo River Spring and the historic section of Echo River, F. Fogarty and R. Miller saw two shrimp on 15 January 1981, five on 24 January 1981, and one on 25 January 1981. Fogarty also saw nine shrimp between Purgatory Slough and Minnehaha Island during an intensive search of the historic section of Echo River on 17 January 1981. Since 1967 we have observed a total of 27 shrimp. Fogarty's observation of nine shrimp was the greatest number seen on a single day. He searched a distance of nearly 400m and a surface area of approximately 2400 sq. m. Prior to 1967 Barr and Kuehne and other workers observed dozens of shrimp per visit to the Shrimp Pools. Barr and Kuehne note that they searched 1 to 2 square meters to find one shrimp. The current census data support our belief that the population size of *P. ganteri* has been drastically reduced, and that the shrimp is endangered with extinction.

On 28 March 1980, the U.S. Fish and Wildlife Service (USFWS) announced the acceptance of a petition submitted by Dr. Raymond Bouchard to list the Kentucky cave shrimp as an Endangered or Threatened species. On 17 October 1980 they reproposed that the species be listed as an Endangered Species and designated Roaring River in Mammoth Cave as critical habitat. Several CRF Members and JVs supported the USFWS proposal during a "public meeting" on 10 December 1980. A public hearing was then scheduled for 25 February 1981 in Horse Cave, Kentucky, but was later cancelled.

The USFWS has accepted a proposal by Mr. Arthur T. Leitheuser to determine the status of the Kentucky cave shrimp. He began a one year project in October 1981 and will do extensive diving in the base-level streams of the Mammoth Cave area. The purpose of the study is to determine the distribution and population densities of the shrimp, define its microhabitat, and evaluate the possible threats to its continued existence. The identification and analysis of these crucial aspects of its biology will be used to develop a conservation program.

CRF Safety Program at Mammoth Cave National Park

Ken Sumner

During the year many areas of safety have been examined and several have been found to be in need of revision. While we were in need of improvement in some areas, we were operating well within safe limits.

One of the primary objectives of this renewed effort was the revision of the "accident procedure," written in 1973. This document is our primary operating procedure, in the event of an in-cave emergency and was in need of examination by both CRF and the NPS to correct the personnel and policies that have changed over the years.

In early April, a safety meeting was held with officials of the NPS and CRF at Mammoth Cave. During this meeting the CRF "accident procedure" was reviewed to determine what changes need be made to bring it up to date. Sections were modified to reflect the current policies of CRF and NPS regarding emergencies in the system, manpower changes since 1973, and incorporation of the NPS "action plan for cave rescue." Rescue efforts and techniques were discussed and coordinated and the rescue supplies, maintained by Mammoth Cave National Park, were inspected. Due to this meeting we have been able to revise our accident procedure and will have copies available by early 1982.

On August 21, 1981 a practice telephone rescue alert was conducted. This practice was intended to help evaluate our call-out procedure and show areas that are in need of improvement in the safety program. The alert required about 2 hours to complete and log, with 17 telephone calls being placed. The alert was planned so as to be at about the hour a party would become dangerously overdue.

Of the 17 calls placed, there were a total of 10 individuals contacted who could be available for rescue operation at the Park. Of the 10 persons available:

8 individuals could arrive at MCNP within 8 hours (5 of these could be on site in 4-5 hours.
2 individuals would require approximately 12 hours
50% of the personnel could leave for MCNP within 30 minutes of being notified and the remainder within an hour
80% would travel to the cave by car, most by carpooling.

This practice alert had opened some new ideas that we plan to work on in the coming year to improve our response time and to increase the number available for an actual emergency.

Vertical training has been stressed at the expeditions in MCNP this year, with at least 6 of these having some training conducted. During the pre-congress week-long camp, several sessions of technique and practice wereee held in cave with international participation and exchanges of ideas. This increased effort in vertical work will increase the number as well as quality of JVs that can operate in the more difficult areas of the cave system.

In 1981, we completed 20 first-aid kits for the MCNP. Of these, 5 were transferred to the CRF Sylamore project. These 5 kits are being replaced to maintain our stock at MCNP and allow us to have enough for 10 cave parties on any given day. The remaining 10 kits are held in reserve for later use and/or exchange as needed. Thus far, the use of the kits has been as visualizedd, i.e., treatment of minor headaches, abrasions or indigestion.

Additionally, we have a poster on display at the Austin house listing each item so new personnel can become familiar with them before a need arises.

In the next year, there are many areas that will receive concentrated effort.

These are remnants of the 1973 procedures and will be somewhat changed. These include revision of our call-out procedure, increased rescue preparedness, rebuilding of our in-cave emergency supply caches, increased vertical training and an increase in the number of JVs involved in the areas of safety and emergency supplies. This inclusion of new personnel will initiate new ideas and techniques and provide us with a continuing program for the future.

The work that remains to be done is extensive and shall require a great deal of effort on all of our parts. It is hoped that all of this effort is purely theoretical and that it will never be required. As long as we continue to work toward a safe cave trip and maintain ourselves, both physically and in equipment, we can look on these efforts in safety as an insurance policy, hopefully never to be needed.

Special Programs

Figure 29. Exploration camp held at Mammoth Cave National Park before the Eighth International Congress of Speleology meeting. (Photo by Lynn Weller.)

Report on the Eighth International Congress of Speleology

Richard A. Watson

The Cave Research Foundation acted as a Cooperating Organization of the Eighth International Congress of Speleology, held in Bowling Green, Kentucky, 18-24 July 1981. More than 75 CRF Members and Joint Venturers participated as Congress officers, committee members and pre/post-Congress field camps staff.

Perhaps the most central CRF participant was Roger E. McClure whose handling of Sales (Congress T-shirts, pins, etc.) helped the National Speleological Society come out of the Congress several thousand dollars in the black.

The grandest excursion during the Congress was a trek by nearly 1000 registrants throughout Mammoth Cave. Over 50 CRF Members and JVs helped guide and lecture during the excursion.

The Flint Ridge Field Station was readied for the Congress during the summers of 1980 and 1981 by more than 100 CRF Members and JVs under the direction of Richard A. Watson and Roger W. Brucker. Through the cooperation of Robert Deskins, Superintendent of Mammoth Cave National Park, and James Wiggins, MCNP Management Assistant, the Austin House was remodeled, the entrance road regraded, and the grounds cleared of brush.

A pre-Congress camp in cave exploration and cartography at the Flint Ridge Field Station (July 6-12, 1981) was directed by R. Pete Lindsley. There were 14 registrants from several countries. More than 20 CRF Members and JVs provided support. Instruction was given in horizontal caving techniques (many of the foreigners were primarily vertical cavers), comparisons were made among various vertical techniques, and exploration methods were discussed and tried. CRF cartographic techniques—survey, data processing, map making—were demonstrated, and comparisons were made with European techniques, particularly with the French "lost string" technique demonstrated by Claude Chabert. Cave photography techniques were also fully debated and demonstrated, particularly by the French cave photographers, Francois-Marie Callot and Yann Callot. Many of the pictures they took during the camp appear in their recent book, *Photographier Sous Terre* (Paris: Editions V. M. , 1984).

A post-Congress science camp at the Flint Ridge Field Station (July 25-30, 1981) was directed by Arthur N. Palmer, Thomas L. Poulson, and Patty Jo Watson. There were 41 registrants from several countries, plus 15 day-guests sponsored by CRF. Again more than 20 CRF Members and JVs provided support. Palmer led a number of field trips to exhibit the geology and hydrology of the Mammoth Cave Area.

Techniques of water sammpling, analysis, and interpretation were discussed. Poulson exhibited the cave life of the area, and conducted several underground seminars of the use of the cave systems as natural underground laboratories. Watson took registrants on numerous archaeological field trips, illustrating relations between surface and underground sites, and demonstrating the immense interpretive value of organic materials preserved in the caves.

Contributing enormously to the success of both MCNP field camps were the meals prepared by Judy Parker, Karen Lindsley and Karen Kastning for the pre-Congress camp and Kathleen Lavoie and James Lavoie for the post-Congress camp.

A number of cavers converged at the Carlsbad Caverns Camp in the Guadalupe Mountains in New Mexico, following the main Kentucky activities. The weather was not as expected—there were a couple of really wild thunderstorms which dumped rain, and it was much cooler than expected—a blessing for our foreign visitors. Prior to the start of camp a mountain of supplies was moved from Albuquerque down to the cave. The hard core organizers included Karen Welbourn, Cal Welbourn, Ron Bridgemon, Sue Bridgemon, Doug Rhodes, Bob Buecher, Debbie Buecher and Diana Kerbo. Camp Manager Karen Welbourn was also assisted by Steve Wells, Dave Jagnow, John Branstetter, Mike Queen, Buzz Hummel and Kay Rhode, among others.

Everyone from the youngest participant to the oldest (a favorite 72 year old lady) seemed to enjoy everything from "The Magnificent Cave " to the "Magnificent Steak." They all loved the BBQ steaks and Mexican food. There was one vegetarian all week until steak was served, at which time the cooks had to throw another steak on the grill!

At the last minute it was discovered that the NSS had promised the Hungarians (some 14 individuals) that they could attend the Carlsbad Camp as well as visit Mammoth Cave. Since the group would have been denied attendance (by their home country) at the International Congress if they could not visit both major cave Parks, it was decided to forget the previous rules and add the 14 to an already full expedition. Thanks to the assistance of the National Park Service and the 22 JV's at the Carlsbad Camp, a final total of 53 visitors was hosted instead of the maximum advertised 30 people. Countries represented included Turkey, the United Kingdom, Hungary, Australia, Roumania, France, Germany, Italy, South Africa, Canada and the USA.

All three field camps were outstanding successes. It was wonderful to be able to show the caves, especially to our foreign visitors, and CRF received much praise from the registrants, several of whom said that the experience was the most memorable of their speleological lives. The contacts and interactions among speleologists from around the world that were made possible at these camps are very important benefits to the Cave Research Foundation.

For the Congress, CRF published The Cave Research Foundation: Origins and the First Twelve Years 1957-1968 edited by Richard A. Watson with a Preface by Philip M. Smith and a Foreward by William B. White. The volume contains 496 pages of material from the history of CRF, including reprints of some early articles, many previously unpublished papers, and annual reports through 1968. This and other cave books were available at the CRF book booth managed by Roger E. McClure and Claire B. Weedman.

Seventy five papers were presented at the Congress by 55 CRF Members and JVs. Almost everyone in CRF participated in some way or another to help insure the success of this Eighth International Congress of Speleology. Such service to speleology is one of the primary purposes of the Cave Research Foundation.

Cave Books: An Update

Richard A. Watson

CRF has been publishing material since its founding in 1957, and for a number of years has been operating a small wholesale and retail outlet for cave books under the operation of Roger E. McClure and Claire B. Weedman. In 1980, under the mandate of the CRF articles of incorporation "to assist in the interpretation of caves through education," the CRF publication and distribution programs were combined formally as Cave Books, a publishing, distribution, and sales imprint with the International Standard Book Number (ISBN9 prefix-0-939-748-). Five books have been published so far:

Palmer, Margaret V. (ed.), *Cave Research Foundation 1980 Annual Report.* 1980, paperback, $5.00, iv and 47 pp.

Daunt-Mergens, Diana O. (ed.), *Cave Research Foundation Personnel Manual.* (third edition), 1981, paperback, $10.00, xxi and 155 pp.

Watson, Richard A. (ed.), *Cave Research Foundation: Origins and the First Twelve Years: 1957-1968.* 1981, paperback, $15.00, 494 pp.

Conn, Herb and Jan, *The Jewel Cave Adventure.* (Revised edition), 1981, paperback, $6.95, 240 pp.

Moore, George W. and G. Nicholas Sullivan, *Speleology: The Study of Caves.* (Revised edition), 1981, paperback, $5.95, xiii and 150 pp.

Three books are scheduled for publication:

Brucker, Roger W., W. Calvin Welbourn, (eds.), *Cave Research Foundation 1981 Annual Report.*

Palmer, Arthur N. and Margaret V. Palmer (eds.), *Cave Research Foundation 1982 Annual Report.*

Steele, William. *Yochib: The River Cave.*

Books published by Cave Books are now listed in *Books in Print*, and Cave Books is listed in the standard directories as a publishing house with interests in nonfiction and fiction having to do with caves, karst, and speleology. The capital base for the publishing venture has been provided by contributions from CRF Joint Venturers. The volunteer staff consists of:

Roger E. McClure, Publisher for the Cave Research Foundation
Richard A. Watson, Editor
Thomas A. Brucker, Stock
Claire B. Weedman, Sales

The general address is:
Cave Books
756 Harvard Avenue
St. Louis, MO 63130 USA

This move into formal publishing is an important and significant step for the Cave Research Foundation. Today, most regular trade publishers will not publish books that are not assured a guarantee of at least 10,000 copies. Most books on caves, karst and speleology are of such special interest that even university presses will not consider them. Cave Books was founded to publish one to three volumes a year with runs of 1000 to 1500 copies each, with the intent of earning enough returns to keep the capital base intact for continued publishing, and as a service to speleology.

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Figure 30. Cal Welbourn inspecting an articulated skeleton at the bottom of The Rift, Dry Cave, New Mexico. (Photo by Pete Lindsley.)

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———, 1980, Extinct and endangered species from Kentucky caves: Lecture presented to the Kentucky Natural History Society, Louisville, KY, May.
———, 1981, Kentucky cave conservation: Lecture presented at the Kentucky Conservation Committee Annual Meeting, Shakerstown at Pleasant Hill, KY, May.
———, 1981, Kentucky caves: Lecture presented at the Museum of History and Science, Louisville, KY, November.
———, 1981, The recognition, evaluation and management of cave bone deposits: Lecture presented at the National Cave Management Symposium, Mammoth Cave National Park, KY, October.
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Watson, Patty Jo, 1981: Cave archeology: Course presented as part of the University in the Park series, sponsored by Western Kentucky University and Mammoth Cave National Park, June.

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SERVICE

Austin, Bill, 1981: Organizing Committee: Horse Cave Theatre, Program Department, Eighth Intl. Cong. of Speleol., Bowling Green, KY, July.

Bennington, Tammy, George Crothers and Patty Jo Watson, 1981: Organized the Paleontology and Archeology of Jaguar Cave, Tennessee exhibit, Eighth Intl. Cong. of Speleol., Bowling Green, KY, July.

Brucker, Roger W., 1981: Organizing Committee: Circulars, Publications Department, Eighth Intl. Cong. of Speleol., Bowling Green, KY, July.

———, 1981: Organizing Committee: Format and design, Publicity Department, Eighth Intl. Cong. of Speleol., Bowling Green, KY, July.

———, 1981: Steering Committee, Eighth Intl. Cong. of Speleol., Bowling Green, KY, July.

Crawford, Nicholas, 1981: Organizing Committee: Facilities, Secretariat, Eighth Intl. Cong. of Speleol., Bowling Green, KY, July.

————, 1981: Organizing Committee: Sessions, Program Department, Eighth Intl. Cong. of Speleol., Bowling Green, KY, July.

Curl, Rane L., 1981: Chairman, Eighth Intl. Cong. of Speleol., Bowling Green, KY, July.

Daunt-Mergens, Diana, 1981: Organizing Committee: Slides and films, Program Department, Eighth Intl. Cong. of Speleol., Bowling Green, KY, July.

Davis, Roy, 1981: Organizing Committee: Gala Excursion, Program Department, Eighth Intl. Cong. of Speleol., Bowling Green, KY, July.

Emerson, Diana L., 1981: Organizing Committee: Signs, Secretariat, Eighth Intl. Cong. of Speleol., Bowling Green, KY, July.

Estes, Beth, 1980: Chairman, Conservation Committee of the National Speleological Society (also chairman during 1979).

————, 1981: Chairman, Mammoth Cave Conservation Task Force of the National Speleological Society.

————, 1981: Coordinator, Permit Caving Advisory Committee of the National Speleological Society to the Mammoth Cave National Park administrators.

Ford, Derek C., 1981: Steering Committee, Eighth Intl. Cong. of Speleol., Bowling Green, KY, July.

Gurnee, Jeanne, 1981: Organizing Committee: Chairman, Publicity Department, Eighth Intl. Cong. of Speleol., Bowling Green, KY, July.

————, 1981: Organizing Committee: Poster, Publications Department, Eighth Intl. Cong. of Speleol., Bowling Green, KY, July.

Gurnee, Russell H., 1981: President, Eighth Intl. Cong. of Speleol., Bowling Green, KY, July.

Halliday, William R., 1981: Steering Committee, Eighth Intl. Cong. of Speleol., Bowling Green, KY, July.

Hargrove, Eugene, 1981: Steering Committee, Eighth Intl. Cong. of Speleol., Bowling Green, KY, July.

Harmon, Russell, 1981: Organizing Committee: Assistance Department, Eighth Intl. Cong. of Speleol., Bowling Green, KY, July.

————, 1981: Scientific Program Committee, Eighth Intl. Cong. of Speleol., Bowling Green, KY, July.

Hedges, James, 1981: Organizing Committee: Cave stamp, Publicity Department, Eighth Intl. Cong. of Speleol., Bowling Green, KY, July.

Helfman, Sheldon S., 1981: Organizing Committee: Exhibits, Program Committee, Eighth Intl. Cong. of Speleol., Bowling Green, KY, July.

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————, 1981, Organizing Committee: Chairman, Program Department, Eighth Intl. Cong. of Speleol., Bowling Green, KY, July.

————, 1981: Organizing Committee: Programs, Publications Department, Eighth Intl. Cong. of Speleol., Bowling Green, KY, July.

Kastning, Karen, 1981: Organizing Committee: Photographic Salon, Program Department, Eighth Intl. Cong. of Speleol., Bowling Green, KY, July.

Moore, George W., 1981: Scientific Program Committee, Eighth Intl. Cong. of Speleol., Bowling Green, KY, July.

Mylroie, John E., 1981, Organizing Committee: Assistance Department, Eighth Intl. Cong. of Speleol., Bowling Green, KY, July.

————, 1981, Secretary, Eighth Intl. Cong. of Speleol., July.

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————, 1981, Scientific Program Committee, Eighth Intl. Cong. of Speleol., Bowling Green, KY, July.

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Quinlan, James, 1981: Organizing Committee: Hydrology excursions, Program Department, Eighth Intl. Cong. of Speleol., Bowling Green, KY, July.

————, 1981: Scientific Program Committee, Eighth Intl. Cong. of Speleol., Bowling Green, KY, July.

McClure, Roger, 1981: Chairman, Sales Department, Eighth Intl. Cong. of Speleol., Bowling Green, KY, July.

Mylroie, John E., 1981: Organizing Committee: Assistance Department, Eighth Intl. Cong. of Speleol., Bowling Green, KY, July.

————, 1981: Steering Committee, Eighth Intl. Cong. of Speleol., Bowling Green, KY, July.

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Watson, Richard A., 1981: Chair, Cultural Committee, Eighth Intl. Cong. of Speleol., Bowling Green, KY, July.

————, 1981: Editor, Speleologia Series, Zephyrus Press.

————, 1981, Editorial Board: *Environmental Ethics*.

————, 1981, Trustee of the National Parks and Conservation Association.

————, Patty Jo Watson and Tammy Bennington, 1981: Consultants to the Horse Cave Theatre (Horse Cave, KY) on the writing and production of the play *Time and the Rock*, written by Warren Hammack et al.

Weedman, Claire, 1981: Organizing Committee: Packing/Mailings, Sales Department, Eighth Intl. Cong. of Speleol.,

Bowling Green, KY, July.
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The Cave Research Foundation

Figure 31. Glistening water drops on translucent helictites. (Photo by Pete Lindsley.)

Management Structure

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Chief Scientist	Thomas L. Poulson
Newsletter	Diana Daunt-Mergens
Personnel Records	Kathleen Dickerson
Computer Records	William F. Mann
Cave Books	Claire B. Weedman

Central Kentucky Area Management Personnel:

Manager	Charles F. Hildebolt
Personnel	Walter A. Lipton
Cartography	Richard B. Zopf
Medical	Stanley D. Sides
Safety	Ken Sumner
Supplies	Mike Mergens
Vertical Supplies	Lynn M. Weller
Log Keeper	Kathleen Dickerson
Field Station Maintenance	Robert O. Eggers
Field Station Summer Manager	Richard A. Watson

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Personnel	Ron Lipinski
Cartography	Robert H. Buecher
Safety	Don P. Morris
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Field Station	Ron Kerbo
Log Keeper and Survey Book Coordinator	Diana Northup

California Area Management Personnel

Manager	David DesMarais
Personnel	Luther Perry
Cartography	David DesMarais Lee Blackburn
Safety	Howard Hurtt
Science	John C. Tinsley
Field Station	Tom Mathey

Arkansas Area Management Personnel

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

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Ron Wilson, Chairman
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W. Calvin Welbourn
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Rondal R. Bridgemon
Douglass W. Rhodes

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

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Williamm P. Bishop
David DesMarais
Charles E. Hildebolt
L. Kay Sides
Linda Starr
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*Interpretation and Information Committee:*Deals with the dispersal of information in a form suitable for the public. This includes the areas of training sessions for guides and naturalists, the preparation of interpretive materials and slide programs, and local library interface. Present membership is:

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

William P. Bishop, Chairman
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Initiatives Committee: A special committee charged with stimulating long-range thought about "provocative and risky" future directions. Present membership is:

Sarah G. Bishop, Chairman
Kip Duchon
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Richard A. Watson
Joseph K. Davisdson
Roger E. McClure
Diana Daunt-Mergens
Richard B. Zopf
Walter A. Lipton

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

Thomas L. Poulson, Chairman, Kentucky Area
Steve G. Wells, Guadalupe Area
David DesMarais, California Area
W. Calvin Welbourn, Special Projects
William B. Bishop
Arthur N. Palmer
Patty Jo Watson
Carol A. Hill

Computer Committee: Coordinates computer-related goals for the Foundation. Present membership is:

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Roger Brucker
Richard Hardison
Roger McClure
Lynn Weller
Pat Wilcox
John Bridge
Bob Buecher
Bill Mann
Bob Snider
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