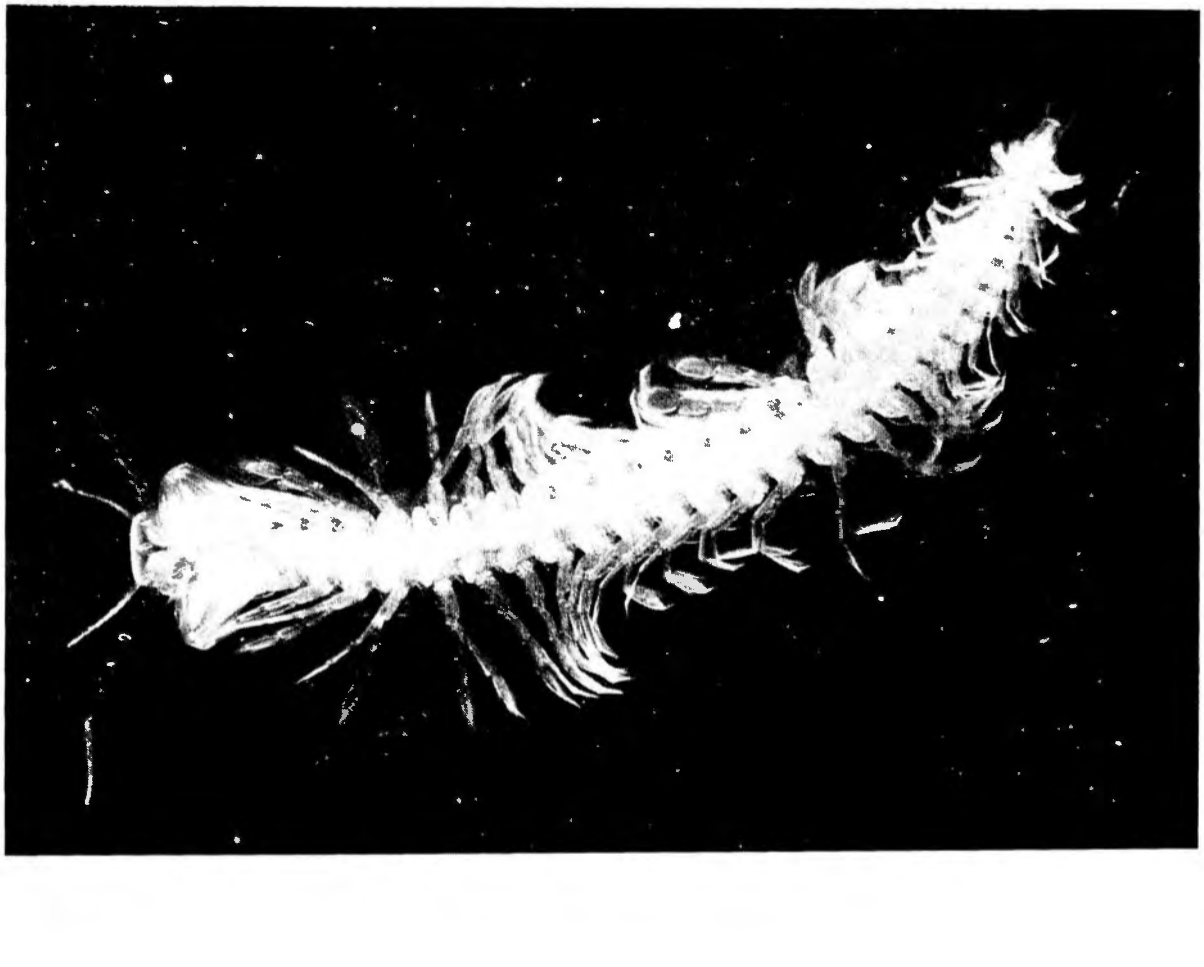
1985 ANNUAL REPORT



CAVE RESEARCH FOUNDATION

Cave Research Foundation
1985
Annual Report

Cave Research Foundation
1019 Maplewood Dr., No. 211
Cedar Falls, IA 50613
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 karst wilderness features, and to assist in the interpretation of caves through education.

Cover Photo: A typical remipedian crustacean as found in anchialine caves in the Bahamas. This photo of a live, swimming remipede shows the characteristic raptorial feeding appendages and a trunk with many similar segments, each bearing a pair of biramous swimming appendages. See report on page 21. (Photo by Dennis W. Williams).

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CAVE CONSERVATION

The caves in which we carry out our scientific work and exploration are natural, living laboratories. Without these laboratories, little of what is described in this Annual Report could be studied. The Cave Research Foundation is committed to the preservation of all underground resources.

Caves are fragile in many ways. We take considerable care that we do not destroy that which we study because many of the cave features take hundreds of thousands of years to form. Also, many of the processes that formed the caves passages we travel are no longer active in these areas. People who unthinkingly take or break stalactites and other cave formations cause great and irreparable damage. Cave life, such as blind fish, live in precarious ecological balance in their isolated underground environment. Disturbances, such as causing bats to fly during winter hibernation, can be as fatal to them as shooting them.

Caves are wonderful places for research, recreation and adventure. But before you enter a cave, we urge you to first learn how to be a careful and conservation-minded caver by contacting the National Speleological Society, Cave Avenue, Huntsville, AL 35810, USA, for excellent advice and guidance for novice and experienced alike.

Cave Research Foundation Directors

1985

Highlights of 1985

In 1985, Cave Research Foundation scientists and directors attained a highly significant goal: completion of negotiations begun in 1983 by Sarah Bishop for a new long-term agreement with the National Park Service. When Sarah resigned as president of CRF in May, 1985, she left a Foundation firmly established in the communication channels of policy-making government agencies. The new Memorandum of Understanding with the National Park Service will include a Declaration of Mutual Interest between the two organizations. By means of this new NPS agreement, the agreement signed in 1984 with the Bureau of Land Management, and continuing dialogue with other Federal land managers, CRF is now actively influencing and participating in the education of Federal land managers regarding cave resources. This is important because of the large quantity and high quality of cave resources entrusted to federal management and protection.

In November, 1985, for example, CRF personnel were major contributors to the National Park Service's first Cave Resource Management Seminar held at Carlsbad Caverns National Park. Most instructors in Western Kentucky University's Summer University in the Park at Mammoth Cave continue to be CRF affiliated. These training efforts have far-ranging impacts as participants continue or enter jobs that include cave management responsibilities. The completion of the Kentucky Library Project and the ongoing success of Cave Books are other examples of CRF's program of providing accurate information about caves to those who most need it.

The contents of this annual report reflect the diversity and strength of CRF programs. Cartography, history, geology, hydrology, biology, archaeology, paleontology and management projects are all well represented. There is good balance between basic and applied research. Continuing successful investment of our endowment fund permits us to provide financial support to deserving projects of graduate student speleologists. Reports of several projects funded by that program are reported in this volume.

New initiatives of the Foundation promise even greater accessibility to the data and experience accumulated by CRF personnel during several decades of concentrated observation and research. A plan for producing comprehensive and specialized maps of Mammoth Cave is being formalized using cartography talent that includes CRF individuals with nationally recognized cave mapping skills. Systematic cave resource inventories are underway and long-term baseline studies continue. The future of the Cave Research Foundation includes exciting new challenges, production of more mangement-oriented reports, a commitment to basic science and cartography and alertness to the constantly fluctuating challenges of understanding and protecting the great caves of the world.

Ronald C. Wilson
President, Cave Research Foundation

TABLE OF CONTENTS

Acknowledgements

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

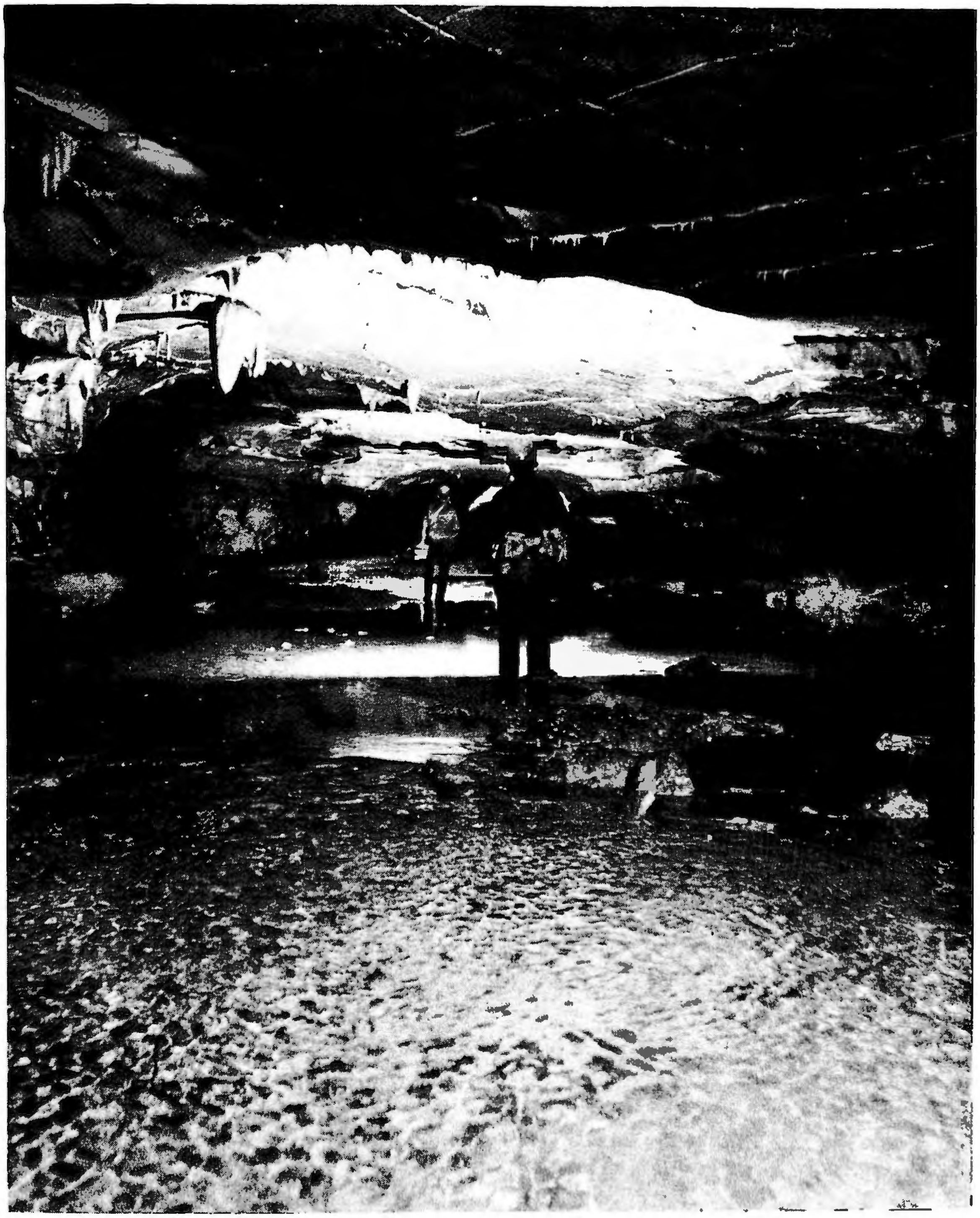

Figure 1: Beautiful cross-section of passageway in Hawkins River, photographed during a special trip which utilized the core-hole entrance to this section of Mammoth Cave. (Photograph by Roger Miller).

Cartography Programs

Lilburn Cartography

Peter Bosted

The year 1985 was a good one for cartography at Lilburn Cave, California. A little over six hundred stations were surveyed, for a total length of 8700 feet (2652 m). Most of the effort involved re-surveying known passages, but about twenty percent of the stations were in previously unsurveyed sections. The total cave length is now 36,300 feet (11,064 m). At least 5000 feet (1524 m) of known passage are left to be done, there are many unpushed leads.

An area of the cave that was intensively studied was the Attic section, with six survey trips. Several new passages were found, all involving tight squeezes. Another important advance was the surveying of the main stream from the Lake Room all the way to the sump near the River Pit. The surveyors wore wetsuits and reported the banding in the marble in this passage to be exceptionally nice. Upper levels near the Lilburn entrance saw seven trips. Work concentrated on the Canopy/Jefferson Memorial areas and the 2x2 Complex. Much mop-up work will still be needed to finish these areas. Finally, the Muddy/Bloody Ways to the South Seas were resurveyed. Five side leads, each going at least 100 feet (30.48 m), were found on this trip, and none of them had been surveyed! This area has great promise. Exploration is much facilitated by the use of Styx or Petzl suits to fight ubiquitous and gooey mud.

Although the total distance surveyed was as large as last year's survey, there has been a steady decline in the number of regular participants. Only eleven people participated in trips with significant accomplishments. Five of these people make the Hundred Station club this year: Peter Bosted (352), Carol Vesely (221), Dan Clardy (166), Bill Farr (145) and Ann Bosted (145). Hopefully when we pass the previous survey's total of 40,000 feet (12,192 m) sometime next year there will be renewed interest in discovering and surveying previously unknown passages by a wider group of people.

Most of the data collected to date has been drawn up and transferred to the master mylar at a scale of twenty feet per inch. Cross sections of passages and heights of drops have not yet been shown on the inked version, owing to the great complexity of most of the cave. Alternatives are being considered and a solution to this problem will have to be found soon as many areas are nearing completion. Plans for the future include making a 100 foot per inch scale map in color to aid in visualizing the different levels, and making a three dimensional model of the cave out of clay.

Guadalupe Escarpment Area

Rich Wolfert

CRF Guadalupe Escarpment Area field activities for 1985 centered primarily in Carlsbad Caverns National Park. Some work was also done in a Bureau of Land Management cave. Nine expeditions were fielded during the year, with JV participation reaching a five year high.

As in previous years, there was a significant emphasis on cartography. The surveyors kept busy producing profiles of the large rooms and passages in some of the major park caves. Additional profiles were produced of Carlsbad Cavern, including the Bottomless Pit and the East Passage. Profile work was also done in Ogle Cave. Most of the profile effort was conducted in New Cave, where numerous trips were required to map all of the tall cross joint passages. Work also continued on the set of 50 feet to the inch Carlsbad Cavern quadrangles, and Helen's Cave, a small cave near Ogle, was resurveyed.

Field support was provided for geology and mineralogy work, and biologists conducted a cave cricket study in Carlsbad Cavern. This included a cricket population census in various parts of the cave, a study of cricket diets, and observations of their behavior and mating habits.

Some minor new passages were explored and surveyed in Carlsbad Cavern, including Painted Canyon, a fissure and boneyard complex between Main Corridor and the Lunch Room. This connects to the Lunch Room via holes in the ceiling of that room. A large passage was found in an intermediate level below the Hall of the White Giant, and a beautiful helictite passage was discovered in the New Section. This helictite passage was named Southern Splendor and features rare beaded helictites up to nine inches (23 cm) in length.

An expedition was fielded at Crystal Caverns, a recently discovered B.L.M. cave system north of Roswell, New Mexico. This cave, developed in gypsum bedrock, has areas of highly crystallized walls which sometimes are tinted red or light green. Over 4200 feet (1280 m) of passage was surveyed and approximately 2000 feet (610 m) of additional passage was discovered, but not yet mapped. Many unchecked leads remain, and much additional work needs to be done in this interesting new system.

Exploration and Cartography in the Mammoth Cave Region

Richard A. Zopf

1985 was a year of very little discovery of new cave areas, but a year of many discoveries of the complexity of the caves of the Mammoth Region. A combination of a desire to have more uniform and detailed maps coupled with an influx of new cartographers has yielded both new strategies for producing maps and new maps of several areas. The scope and methods of data collection are being increased and both a greater variety of maps and other formats are being investigated to delineate the caves of the Mammoth Region.

Underground work yielded no major passage discoveries. The network of base level passages surrounding the River Section of the cave continues to grow. Survey of passages comprising parts of upstream Mystic River in Mammoth have presented an area of complex flow patterns. The Felicia's Dome area of Mammoth appears to extend vertically through almost the full extent of passages and interconnects several levels. There is also considerable vertical extent and interconnections in the Ganter/Albert's Domes section of Mammoth.

Resurvey work took place throughout the Mammoth System and in some of the smaller caves in the area. These efforts are being directed towards the production of several sets of maps. Detailed maps of the Historic tour and the Frozen Niagara tour have been completed; work for similar maps of the other tours is in progress. New manuscript maps of the major passages accessible from the Austin Entrance are progressing. The bulk of the resurvey to define trunk passage detail has been completed and survey notes of smaller passages are being reviewed to ascertain whether they can be used directly or whether resurvey is necessary. Manuscript maps of the areas around the Historic and Frozen Niagara tours are also being assembled. Smith Valley Cave is being resurveyed in order to produce a detailed map. Major surveys of the last ten years have been incorporated in a new map card which depicts the 300 miles of the Mammoth System. Several special purpose maps were produced to support biological research and to provide resource reference data for Mammoth Cave National Park.

Several variations on traditional survey were also employed this year. A project to inventory the smaller caves and significant surface karst features of the area was begun. In coordination with this project has been a specific effort to locate new entrances. Trial efforts to systematically record cave passages with camera and video camera were tried with promising results. Further efforts along these lines will continue in order to more completely interpret the karst resources of the area.

Fitton Cave Survey Project

Pete Lindsley

The Fitton Cave Survey Project, initiated in 1984, has a primary Project goal to survey the "trunk passage" of the cave by September, 1986. By the end of 1985 the Foundation had fielded approximately 11 field trips and the field work portion of the above goal was 60% complete. Areas of the cave still needing field work include the Crystal Passage section, the Jergen's Leap and Millipede passages, the Tennouri / Helictite section, and the East Passage between the Out Room and the Needle's Eye. This initial portion of the field work is scheduled for completion by summer of 1986.The cartography of Fitton Cave is being performed by a team of cartographers, each emphasizing their respective area maps. David Hoffman, acting as Chief Surveyor, is continuing several previous years of field work on the precision transit survey including numerous brass cap installations. Dave has also compiled previous survey data that may be used as the Project team links the loops together and determines closures. Gary Schaecher is working Crystal Passage, drafting three sheets for this extensive passage. Jack Regal has already started field checking his section of the cave - the East Passage from the Entrance to the Needle's Eye. John Brooks is working the Out Room / Round House Room circle in addition to the Tennouri Passage area map. Robert Taylor is concentrating on the East Passage between the Out Room and the Needle's Eye. The long range cartographic goal of the Project is to achieve a 0.1% closure error along a precision base line through many of the trunk passages.

The map format will be a multiple quadrangle design that will allow flexibility. The primary cartographic task for 1986 is to finalize exact map quadrangle size and orientation. The Fitton Cave map will be at a scale of 1"=50' and the Project team will be inking mylar "quads" as closures are verified. The Park Service has been provided blueline working copies for use by Park management and other researchers. A 3-page newsletter was published for distribution to the Project participants in July, 1985.

As with other CRF field operations, the Expedition Leader is in charge of each expedition and assumes responsibility for party assignment as well as data items required by the Park. Party leaders are assigned for each group working in the cave and are responsible for maintaining survey accuracy and sketch quality. Interested qualified cave surveyors or cartographers are invited to participate in the Project and should contact the Area Manager, Paul Blore, at Rt. 1, Box 297A, Farmington, AR 72730, for additional information. Expeditions are limited to a maximum of 21 party members underground in interest of protection of the cave resource.

Investigation of the Hydrology of Redwood Canyon Karst

John W. Hess and Mike Spiess

The objectives of the research are to gain a improved understanding of the physical and chemical hydrology of the Redwood Canyon Karst, Kings Canyon National Park and to develop better conceptual models of the ebb and flow discharge behavior of Big Spring. Methods used include discharge measurements, dye tracing, time series analysis of stable isotope ratios, water temperature, electrical conductivity and gross chemistry.

The above data have been collected over the past three and one half years. The surface water sampling points are shown on Figure 2 and the in-cave water sample points on Figure 5.

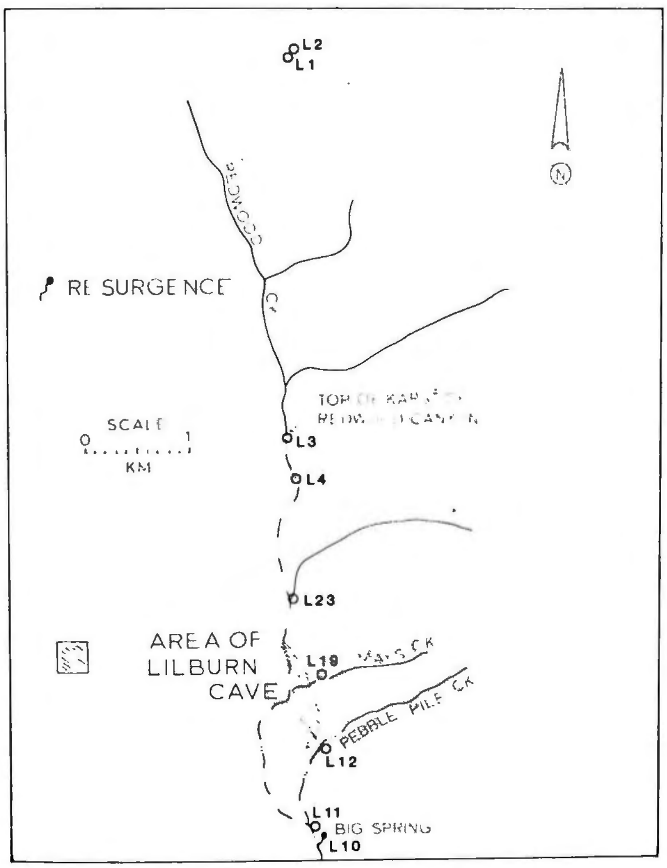

Figure 2: Hydrology of the Redwood Canyon area

Figures 3 and 4 are plots of representative temperature and electrical conductivity data respectively. They are plotted for different times of the year along the main flow path. Distance zero corresponds to point L3 on Figure 2 where Redwood Creek first losses water to the subsurface drainage system. The points connected by the lines are along the main Redwood Creek and Lilburn Cave Stream. Big Spring at distance 4 km is located at L10 on Figure 2. It is the main discharge from the cave system. The two points not connected to the line are the East Stream and West Stream respectively. They represent cave tributary streams. Data points between 0 and 4 km are the in-cave sample points at White Rapids, Lake Room and Z Room on Figure 5. Table 1 indicates representative hydrogen isotope data from surface and cave waters.

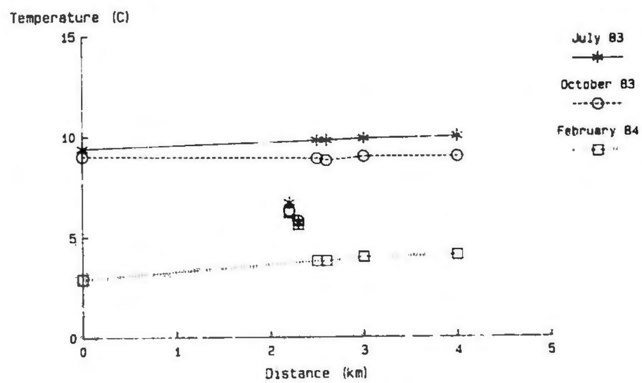

Figure 3: Temperatures

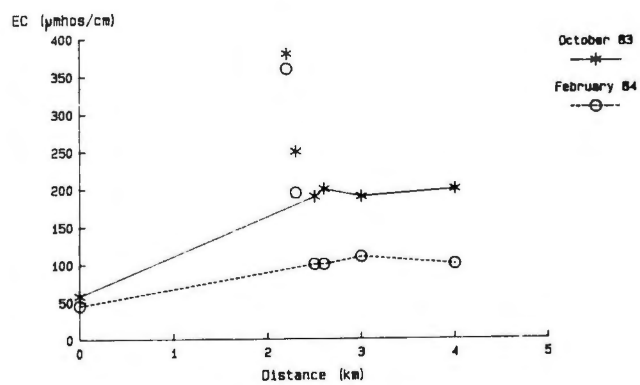

Figure 4: Electrical conductivity

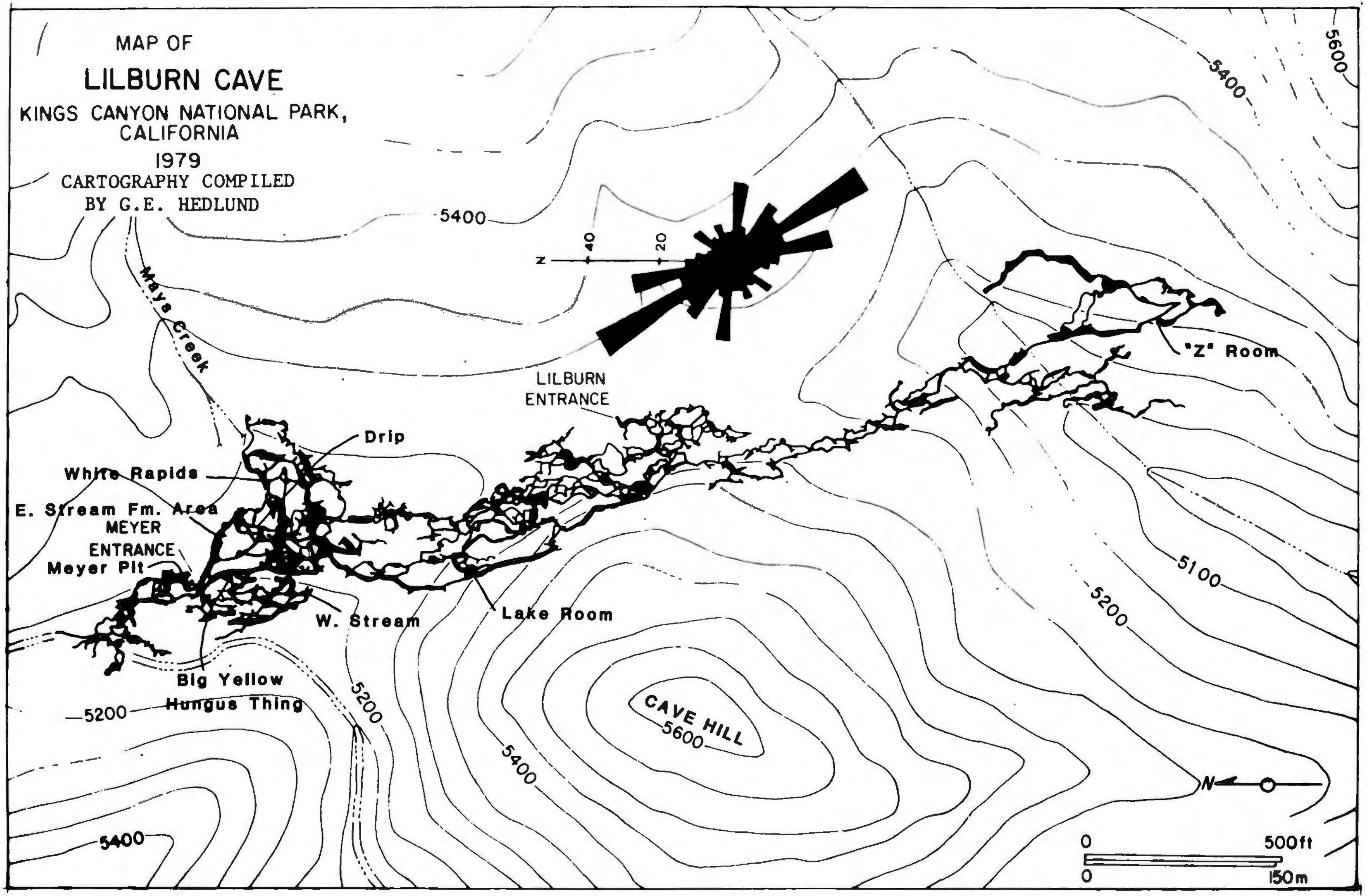

Figure 5: Map of Lilburn Cave showing the in-cave water sampling points

Table 1: Representative Hydrogen Isotope Data for Surface and Cave Waters

δD %. (V - SMOW)

	82		83
	MAY	OCT	MAY
Redwood Creek	-82	-80	---
East Stream	-78	-72	-80
West Stream	-84	---	-81
White Rapids	-80	-79	-82
Lake Room	---	---	---
Z Room	-80	---	-80
Big Spring	-80	-76	-81
Redwood Creek	-81	-76	-80
Volvo Hill	-82	-87	-83
Mays	---	---	-82
Pebble Pile	-80	-76	-77
Meyers Drip	-75	---	-79
Hex Drip	-77	---	-83
BYHT	-78	-77	---
East Stream Drip 1	-36	---	---
East Stream Drip 2	-77	---	-79
Snow	-74	---	-73
Snow Melt	-75	-82	-76

Preliminary conclusions point to two different karst flow systems within the Redwood Canyon Karst. Redwood Creek and the main Lilburn Cave Stream exhibit seasonal variations in temperature, electrical conductivity and discharge and has uniform stable isotope ratios indicating short residence times with little mixing of different waters. The tributaries have uniform temperature, electrical conductivity, discharge and stable isotope ratios indicating longer residence times and mixing of different waters. The same source of water is indicated to both systems based on the isotope data.

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

Luther Perry

This is a supplemental progress note to accompany the more detailed summary submitted for 1983 and the brief supplement in 1984. The 1984 supplement reported that we had achieved a major objective, a dye trace between Pebble Pile Creek (a surface tributary stream) and the Lilburn Cave Stream. Detection was made at the cave stream resurgence, but not inside the cave. The transit time was such that we had to mount special expeditions to retrieve the detectors, and unexpectedly high dye adsorption or dilution made detection difficult.

A new trace was designed in 1985 with more dye, better detectors, and special expeditions. This trace was very successful, resulting in dye detection at two underground locations on the main cave stream, as well as at the resurgence, with a transit time of between 1.94 and 12 days. We had previously suspected that Pebble Pile Creek would flow into the main cave stream between the River Pit and the Z-Room, but dye was detected at both locations, a significant finding.

The apparent dye concentration, based on density observed during detector processing, varied noticeably, with the Z-Room concentration estimated at 0.5 and the farther upstream River Pit concentration estimated at 0.2 of the resurgence concentration. Conclusions based on observed differences in dye density are speculative, but these results may indicate a diffuse rather than single point confluence for Pebble Pile Creek and the underground cave stream. A possible diffuse confluence, very slow transit over the short distance, and very high dye loss or dilution are a pattern of some significance in understanding the cave structure.

Tephrochronology of Sinkhole Deposits in the Redwood Canyon Karst, Kings Canyon National Park, California

John C. Tinsley

Introduction

The objective is to improve understanding of rates and processes of hillslope erosion within the Redwood Canyon karst, Kings Canyon National Park. Volumes of eroded sediment are estimated on the basis of studies of the sedimentology and stratigraphy of sinkhole sediments. The karst contains dozens of sinkholes, many of which have trapped sediment eroded from hillslopes under a coniferous forest vegetation. The sinkhole sediments are composed chiefly of gravel, sand, silt and clay derived from the granitic and metamorphic wall rock comprising the canyon and from alluvial deposits of Redwood Creek and its tributaries. Of special significance to this study is the presence of a volcanic ash layer that forms a marker bed for these stratigraphic studies.

About 720 radiocarbon years ago, one of California's several volcanic centers erupted explosively in the Mammoth Lakes area in the southern part of the Inyo Craters volcanic chain, south of Mono Lake in east The resulting plume of fine-grained volcanic ejecta, termed tephra or volcanic ash, drifted to the south and west across the Sierran crest, where it blanketed much of the southern Sierra Nevada, including the karst area in Redwood Canyon. The powdery tephra, identified by its distinctive trace-element chemistry as a product of the Deadman Dome vent, then was eroded from hillslopes, rivulets and gullies and was delivered to the sinkholes. What happened then depended on the nature of the sinkhole in question.

Sinkholes containing open conduits in their bottoms apparently transmitted most if not all of the deposits of sediment and ash directly to the cave below, for these sinkholes preserve little if any record of the ash. Alternatively, a sinkhole floored with a permeable sediment plug composed of silt and sand effectively trap air- and water-borne sediment, including tephra; these sediments then become part of that sinkhole's sedimentary record and the water slowly seeps away. Deposits on non-tephra-bearing sediment continue to wash into sinkholes and bury the tephra deposits.

Geologists prize deposits of tephra, especially those formed by airfall processes, because they are isochronous, or the same age everywhere that they occur. Such deposits have been erupted, transported and deposited within a very short span of geologic time, and enable geologists to establish age equivalence among deposits that occur in widely separated localities. In the context of Redwood Canyon and its karst, this tephra deposit is a 700 year old marker bed or datum that enables geologists to estimate the rate of erosion of adjacent upland areas under conditions of a coniferous forest cover, a modern climate and varying slope angles. The Redwood Canyon karst is a convenient laboratory in which to study rates and processes of slope erosion, because of the tephra-clock preserved in many sinkholes.

Methods

The tephra deposit is used as a marker bed and time delimiter. In each sinkhole, an array of 15 to 30 holes are excavated using a hand-powered soil auger and the respective thicknesses of tephra and post-tephra sediment are measured in each hole. From the suite of measured thicknesses of sediment, the respective volumes of tephra and post-tephra sediment are estimated using isopach mapping techniques. The quotient of the tephra volume (or post-tephra sediment volume) divided by the area of the drainage basin draining into the sinkhole yields an estimate of the vertical thickness of tephra or post-tephra sediment eroded into the sinkhole from the drainage basin, provided the sinkhole has been behaving itself properly and functioned as a sediment trap and has not leaked appreciable sediment to the cave system. Comparing as many sinkhole and drainage basins as possible, the estimated erosion rates among a population of small basins can be studied as functions of basin size, slope aspect, vegetation or other parameter of interest. The estimated erosion rates would be applicable to the coniferous forest ecosystem under conditions of present climate which prevailed during the past 700 years.

There are 65 sinkholes known in the Redwood Canyon karst; about 1/3 of these will be suitable for this study. Some of the sinkholes contain abundant deposits of granite boulders and cobbles, unyielding opponents to the soil auger as well as unsuitable media for efficiently trapping silt-size particles of tephra. Other sinkholes serve as principal inputs of water and sediment to the Lilburn Cave system. The open conduits commonly observed in these sinkholes are not capable of trapping tephra or most post-tephra sediments and estimated erosion rates in these drainage basins thus would be biased too low relative to reality. Only by comparing results from a number of sinkholes can we obtain estimates that are amenable to statistical analysis.

Results

Fifteen sinkholes have been examined and eight sinkholes have been augered as of 12/31/85. Hillslopes of less than 10% tend to retain at least part of the mantle of volcanic ash, which then becomes mixed with the soil owing to biological and physical processes. Slopes steeper than about 10% generally shed their ash mantle readily into the sinkholes and are more efficient contributors of sediment, especially coarse sediment, than their more gently-sloping neighbors. The tephra blanket apparently ranged in thickness from 1 to 5 cm thick in the Redwood Canyon area. Erosion rates of the soil mantle measured in this way range from 0.5 - 1.5 cm/yr. The coming year will see us measuring a large number of rather broad, shallow sinkholes which have small drainage basins. The volume of tephra contained in the sinkholes under these conditions of low slope and relatively small basin area should enable us to improve the estimates of soil erosion rates and tephra thickness at the small end of the range of drainage basins examined in this study.

Extent of Karstification East of Livingston Ridge, Eddy County Southeastern New Mexico

Richard H. Phillips

The Delaware Basin of southeastern New Mexico and western Texas is recognized as one of the largest karst lands of the United States. Within this karst land lied the Mescalero Plain, between the Pecos River on the west and the Llano Estacado on the east. A renewed scientific interest in the area has arisen with the decision by the United States Department of Energy (DOE) to bury plutonium waste from the nuclear weapons program in Permian salt beds which underlie the Mescalero Plain.

The Waste Isolation Pilot Plant (WIPP) site is centered about 26 miles (42 km) east of Carlsbad, New Mexico. Just west of the WIPP site is Livingston Ridge, an escarpment capped by Dewey Lake Redbeds and Mescalero caliche. Livingston Ridge marks the eastern edge of Nash Draw, a broad, closed, karstic depression resulting from dissolution of underlying evaporite rocks. While sinkholes are a common occurrence in Nash Draw, a scientific dispute rages over the reported presence of sinkholes due to localized solution in the area east of Livingston Ridge.

The Mescalero caliche is composed of white, well cemented limestone, and fine-grained quartz sand, both of which were deposited by wind. The Mescalero caliche forms a fairly continuous mantle east of Livingston Ridge, where its resistance to weathering in the semi-arid climate has allowed it to form extensive surfaces.

The Mescalero caliche has been claimed to be an impermeable barrier to the infiltration of precipitation, preventing rainwater from percolating downward through the porous Dewey Lake Redbeds and into the soluble evaporite and carbonate rocks of the Rustler Formation. The interpretation that karst is not present east of Livingston Ridge rests primarily on this assumption of continuous caliche cover. But while caliche caprocks (calcretes) are resistant to erosion when exposed at the land surface, calcium carbonate is a readily soluble material. In places where the caliche is overlain by non-calcareous soils or unconsolidated deposits, irregular solution cavities penetrating downward into the caliche are common features.

If the karst conduits in the Rustler Formation are active hydrologic features, then rainwater must be able to penetrate the Mescalero caliche through fractures, joints or solution pipes, through dissolved caliche, or through places where the caliche is absent altogether. Conversely, if the Rustler karst conduits are relict features, then the Mescalero caliche should be everywhere present and impermeable.

If the area east of Livingston Ridge is karstic, then it is a covered karst. The evaporite and carbonate rocks of the Rustler Formation are covered by red sandstones and siltstones, a caliche soil profile, and Quaternary sands. Karst features are obscured by parabolic dunes, shrub-coppice dunes, and deflation basins, or blowouts.

Because the Mescalero caliche surface is covered with dune sands, simple field observations are not sufficient to define its role in karst hydrology. Accordingly, the caliche profile was probed with a sand auger in grid patterns along surveyed compass courses. More than 1000 test holes, no more than 100 to 110 feet apart, were augered in five study areas within the WIPP site. Color, texture and cohesiveness were carefully noted, as were calcareous materials and consolidated sandstones.

The surface elevations of all auger holes were professionally surveyed, making possible the construction of generalized topographic maps of the sand surface; isopach maps of the thickness of surface sands and of calcareous dissolution residue above the calcrete surface; structural contour maps of the calcrete surface, or of underlying sandstone beds in places where a sand auger was able to pass through the entire caliche profile; and geomorphic cross-sections showing the relationships between closed depressions in the surface sands, closed depressions or holes in the calcrete surface and calcareous dissolution residue.

Borehole WIPP-33 was drilled into a closed topographic depression in the northwestern part of the WIPP site, more than one mile east of Livingston Ridge. The depression is floored by loose sand and low brush, and clumps of matted leaves and debris washed in during occasional flooding. One of the few small arroyos in the WIPP site area disappears into this depression from the southwest, yet there is no evaporite crust as would be expected in an undrained playa.

WIPP-33 penetrated four water-filled cavities totaling 24 feet (7.3 m) within a vertical distance of 52 feet (15.8 m) in the Magenta dolomite and Forty-Niner gypsum member of the Rustler Formation. WIPP-33 also coincides with one of the most pronounced negative gravity anomalies in the WIPP site gravity survey. This indicates an anomalous low in the earth's gravitational field, much too pronounced to be attributable to topography, but originating instead from missing rock in the subsurface, no deeper than the Rustler Formation. All halite has been completely removed from the Rustler at this location, and all anhydrite has been hydrated to gypsum.

Four hundred feet (121.9 m) southwest of WIPP-33 is a caliche escarpment, 30 feet (9.1 m) higher than the bottom of the depression. Emanating from the base of the escarpment and extending within 80 feet (24.4 m) of the WIPP-33 drillhole is a cluster of 37 contiguous auger holes which reached the

Pleistocene Gatuna sandstone after passing through the remains of a caliche profile, generally caliche pebbles and/or calcareous dissolution residue. The downhill trend of the bottoms of the auger holes is uninterrupted, dropping 70 feet (21.3 m) from the escarpment to the drillhole, regardless of whether the auger stopped at calcrete or sandstone. The Berino soil, which represents the B-horizon in complete Mescalero caliche profiles, is typically, absent, with caliche overlain only by alluvial deposits and windblown sand. It is concluded that this collapse feature is due to dissolution of the underlying Rustler Formation, that the collapse occurred subsequent to caliche development, and that active karst conditions have since been continuous enough to prevent soil development or calichification.

Borehole WIPP-14, located in the northeastern part of the WIPP site about four miles east of Livingston Ridge, was drilled into a closed topographic depression 9 to 10 feet (2.7 to 3 m) deep and 600 to 700 feet (182.8 to 213.4 m) in diameter. Although no cavities were encountered in the WIPP-14 borehole, five ephemeral water courses drain into this depression from the east. The most extensive gravity anomaly in the WIPP site gravity survey, as great in amplitude as WIPP-33, trends east-west for 1200 feet (365.8 m) and leads into the eastern side of the WIPP-14 depression; reduced in amplitude, it then passes directly underneath the depression in a northwesternly direction.

There is no topographic evidence of dissolution or subsidence along the trend of this negative gravity anomaly. However, this is not a reliable indication of a lack of karst development. Augering has revealed seven closed structural depressions in the calcrete surface, 1 to 2 feet (.3 to .6 m) deep, each partially filled with 6.5 to 24 inches (16.5 cm to 61 cm) of calcareous dissolution residue, each obscured by 9.5 to 13.5 feet (2.9 to 4.1 m) of sand and clay, each coinciding with the negative gravity anomaly.

The WIPP-14 topographic depression is directly underlain by a closed structural depression in the calcrete surface, 5 to 6 feet (1.5 to 1.8 m) deep and 500 to 700 feet (152.4 to 213.4 m) in diameter. This feature is not attributable to the wind, but may be a solution doline resulting from the complete removal of halite above the Culebra dolomite member of the Rustler Formation.

Centered in the southwestern part of the WIPP site, more than two miles east of Livingston Ridge, is a closed topographic depression, 8 to 10 feet (2.4 to 3 m) deep, 1 mile (1.6 km) long, and 200 to 900 feet (61 to 274.3 m) across, trending east-west. There are no boreholes and no gravity surveys for this area, but it is the most obvious closed depression on the USGS 15-minute topographic map, and is starkly apparent in the WIPP site air photos. As with the WIPP-14 depression, the vegetation is denser and more lush within the depression than in the surrounding landscape, with an abundance of mesquite, especially where the depression narrows to 200 feet (61 m) wide in a distinct linear trend. Other small topographic depressions which may be part of this same trend are depicted on the USGS Nash Draw quadrangle, leading westward directly toward the deepest incisions in Livingston Ridge. Near-surface drainage courses expressed at the land surface as vegetation in dendritic patterns are clearly seen in the air photos, leading directly from the depressions to the incisions in Livingston Ridge.

Just 110 feet (33.5 m) east of a caliche pit in the broad eastern part of the large depression, the caliche profile is absent altogether. Permian sandstone (Dewey Lake Redbeds) is only 75 inches (1.9 m) deep. Just 30 feet (9.1 m) to the southeast, 10 inches (25.4 cm) of calcareous dissolution residue was encountered, and the Dewey Lake Redbeds were reached at 72 inches (1.8 m). The thickest dissolution residue encountered was 19.5 inches (49.5 cm) at a point 935 feet (285 m) to the east. Enough holes were augered to reveal a continuous, sinuous trend of dissolution residue all the way from this point to where the residue abruptly terminates at the location where caliche is absent.

Altogether, ten such sink holes in the caliche were found in this depression, always underneath a topographic low, and never underneath the dune crests. The Dewey Lake Redbeds, easily identifiable by white "reduction spots", were reached at all ten locations, four of them within the narrow linear western part of the depression.

A closed topographic depression about 160 feet (48.8 m) long, 80 feet (24.4 m) wide and 8 to 10 feet (2.4 to 3 m) deep, located only 1.4 miles (2.3 km) southwest of the center of the WIPP site, 0.5 miles (.8 km) from the proposed waste emplacement area, and 4 miles (6.4 km) east of Livingston Ridge, is shown on the Bechtel topographic maps of the WIPP site. The depression is floored by loose sand, desiccated clay, and alluvial organic debris. It is shown by augering to be directly underlain by a 6 foot (1.8 m) depression in the calcrete surface, partially filled by up to 15 inches (38 cm) of calcareous dissolution residue. The ten holes with the lowest elevations at the topographic and structural surfaces reached Gatuna sandstone, after passing through 0 to 12 inches (0 to 30.5 cm) of calcareous dissolution residue; none of the other thirty auger holes encountered sandstone. The ten holes comprise an area 100 feet (30.5 m) long and 25 feet (7.6 m) wide, with the same strike as the topograhic depression. Clearly this is a solution doline, not attributable to the wind.

Also shown on the Bechtel topographic maps is a closed topographic depression 6 to 8 feet (1.8 to 2.4 m) deep and 60 feet (18.3 m) in diameter, located 5000 feet (1524 km) northeast of the center of the WIPP site. Unlike the solution doline, this depression is floored only by loose sand, is almost devoid of vegetation, and is ringed by high sand dunes; its floor is higher in elevation than much of the surrounding plain. It is shown by augering to be underlain not by a caliche depression, but rather by a solid calcrete surface which actually drops in elevation in all directions from the central auger hole in the bottom of the depression. Sandstone was encountered in none of twenty auger holes. This depression is interpreted as a deflation basin, or blowout. Because the blowout and the solution doline are indistinguishable on the topographic maps and the air photos, it is concluded that solution dolines and blowouts cannot be positively identified without direct field examination and subsurface exploration.

Hydrology and Water Balance of the Nash Draw Watershed, Eddy County, Southeastern New Mexico

Richard H. Phillips

Laguna Grande de la Sal is a natural salt lake that occupies part of a large, shallow play, known as Alkali Flat, in Nash Draw. It was reported by area settlers as early as 1875; mapped by the General Land Office survey in 1882, and on the New Mexico base map in 1920; studied by Willis T. Lee in 1924; and mapped by the Office of the New Mexico State Engineer in 1934, when it covered about 2,120 acres.

Laguna Grande lies in a sag in the Rustler Formation, which rises in all directions from the lake. The USGS topographic maps clearly indicate that Laguna Grande or from Nash Draw. A low, but discernible topographic divide exists between Laguna Grande and Malaga Bend of the Pecos River.

A "brine aquifer" at the base of the Rustler is the source of the brine springs which discharge at Malaga Bend. The potentiometric surface of the brine aquifer slopes toward Laguna Grande. The brine aquifer seeps upward into Laguna Grande; thus, brine from this lake could not be leaking toward the river.

Shallow groundwater drains from all directions toward Laguna Grande. In none of the wells between Laguna Grande and Malaga Bend was brine found with a chloride concentration comparable to either the lake water or the brine springs at Malaga Bend.

Brine evaporation equals about 90 inches (2.3 m) per year in the Malaga Bend area. When multiplied by the natural areal extent of Laguna Grande (2,120 acres), annual brine evaporation from the lake is found to equal 0.693 billion cubic feet. Because the lake has no outlet, the same amount of water annually is needed to recharge the lake.

Rainfall averages 1.18 feet (35.7 cm) annually on the Nash Draw watershed, encompassing 226,000 acres (9.85 billion square feet). Thus, annual rainfall on the Nash Draw watershed equals about 11.6 billion cubic feet, as compared to 0.693 billion cubic feet needed annually to recharge Laguna Grande. Evapotranspiration does not exceed 94.0%.

Thicknesses of the Magenta and Culebra dolomite aquifers of the Rustler Formation are remarkably uniform throughout the Delaware Basin, averaging 24.37 feet (7.4 m) and 25 feet (7.6 m) respectively. Porosity has generally been assumed to be 10%, although at the H-6 hydro holes, corrected porosities were 9.1% for the Culebra and 0.97% for the Magenta; effective porosity was 0.7%.

The average thickness multiplied by the average effective porosity of the Rustler aquifers, when divided by the average annual rainfall on the watershed multiplied by the percent not evapotranspirated, reveals the length of time it takes for rainfall to completely recharge the Rustler aquifers. The result is 70.1, 63.8, depending on which value for porosity is used. These figures should be representative of the mean groundwater travel time from all points in the Nash Draw watershed to Laguna Grande de la Sal. It is apparent that the Rustler Formation is not a barrier to the migration of groundwater.

The difference in Pecos River discharge between the Malaga and Pierce Canyon Crossing gaging stations (an interval which includes all of Malaga Bend), averaged over 31 water years and corrected for evaporation, is estimated at 2.22 cubic feet per second or 70 million cubic feet per year. This compares to 693 million cubic feet of natural groundwater needed annually to recharge Laguna Grande, which therefore receives about 9.9 times as much natural groundwater discharge as the Malaga Bend brine springs. Laguna Grande de la Sal, not Malaga Bend, is the major outlet of the Rustler aquifers in the Nash Draw watershed, including the WIPP site; Laguna de la Sal is the nearest natural discharge point to the WIPP site. The previous hydrologic models which assumed a groundwater flow path from the WIPP site directly to the Pecos River are, in a word, wrong.

Prior to the initiation of potash refining in Nash Draw, the groundwater system was undoubtedly in equilibrium established through thousands of years of geologic evolution. But the potash refining process requires the importation of a large quantity of water which, released in the form of saturated brine, has changed the water balance.

Based on recent estimates, the potash refining companies discharge a combined total of 8,542 gallons per minute (gpm) of effluent into evaporation ponds within the Nash Draw drainage basin. It is estimated that only 5,949 gpm actually evaporates, while 2,593 gpm seeps into the groundwater system. In comparison with the 9,673 gpm (693 million cubic feet per year) of natural groundwater needed annually to recharge Laguna Grande de la Sal, it would appear that about 78.86% of the water in Laguna Grande is derived from the natural hydrologic system, and that about 21.14% is seepage from potash refinery disposal ponds. The IMC potash refinery accounts for about 50.5% of the potash effluent contaminating the groundwater supply of Nash Draw.

The areal extent of Laguna Grande de la Sal at the onset of potash mining and refining (2,120 acres) was 80.3% of its more recent areal extent (2,640 acres) as determined from the USGS topographic maps. Thus, the transgression of Laguna Grande may be entirely attributable to seepage from the evaporation ponds of the potash refineries. Such transgression is a further indication that Nash Draw is a closed drainage basin.

In comparison to naturally occurring groundwater, geochemical analysis indicates elevated levels of sylvite and langbeinite potash in IMC discharge; elevated levels of dolomite at Surprise Spring, in the northwestern part of Laguna Grande de la Sal; and elevated levels of gypsum in Laguna Pequena, which flows into the northeastern part of Laguna Grande de la Sal. The Culebra dolomite, not Tamarisk gypsum, is the major source of dissolved solids at

Surprise Spring, despite the fact that ephemeral water courses can readily be seen leading into Surprise Spring from gypsum caves in the hills to the northwest of Laguna Grande de la Sal. Although water from Laguna Pequena contains more dissolved gypsum that dissolved dolomite, the Culebra dolomite may still be its major source of groundwater, because the solubility of gypsum is 10 to 30 times greater than the solubility of limestone.

Both Laguna Pequena and Surprise Spring contain concentrations of potash constituents higher than in the IMC potash refinery effluent. This would imply that potash effluent, diluted by mixing with natural groundwater, has been flowing through karst conduits all the way to Laguna Pequena for a sufficiently long time to allow the potash minerals to concentrate in the evaporating water of the salt playa and thus to attain concentrations even higher than in the original potash effluent. The presence at Laguna Pequena of an unusually high level of fluoride and an extremely high level of bromide, both trace elements associated with dissolution of evaporites such as gypsum, corroborates the karst interpretation.

Shortly after record flooding in Eddy and Lea Counties, while the arroyos leading from the gypsum caves into Surprise Spring were dry, the flow from Laguna Pequena into Laguna Grande de la Sal was measured at 394 cubic feet per second. This discharge, more than an order of magnitude higher than the estimated average of 22 cubic feet per second, would be expected in a large, irregular karst spring at a time of record flooding in the region. Certainly Laguna Pequena, not Surprise Spring, is the major inlet to Laguna de la Sal.

Effects of Urbanization on the Quantity and Quality of Storm Water Runoff Recharging through Caves into the Edwards Aquifer, Bexar County, Texas

George Veni

Thesis Abstract †

Eighty-nine caves and 60 sinkholes were investigated in the Edwards Aquifer recharge zone in Bexar County, Texas. The study examined their hydrogeologic and topographic origins and distribution, relationships to major fracture traces, quantity of recharge into the aquifer and degree of sensitivity towards degradation of the aquifer's water quality. Groundwater traces were attempted to determine aquifer flow routes, time of groundwater travel, groundwater volume within conduits, and the aquifer's capacity for dilution and dispersion of recharged contaminants. Trends in water quality were examined to quantify the volume and variety of contaminants recharged into the aquifer and to determine the effects of urbanization upon the Edwards Aquifer. The Edwards recharge zone was hydrogeologically assessed to rate the sensitivity of its areas. Socio-political impacts on recharge zone development were also examined.

Based on the results of the above outlined research method, the conclusions of this investigation are that caves and sinkholes contribute substantial recharge into the Edwards Aquifer, rapidly transmit that recharge to the aquifer and are sensitive sites for potential contamination. The entire recharge zone was determined to be very sensitive to contamination. No significant differences were found between areas within the recharge zone to scale their degree of sensitivity. Major conduit flow networks were found to exist within the aquifer and their groundwater flow paths could be traced. Urban development of the Edwards recharge zone was shown to decrease the volume of recharge and degrade the aquifer's water quality. No significant detrimental effects on the aquifer were observed. The volume of diminished recharge and the concentration of recharge contaminants that were necessary to produce significant adverse effects on the aquifer were not determined due to lack of precipitation during the study period and inconclusive groundwater tracings. It was recommended that further development of urbanization be quantified.

† Veni, George, 1985, Effects of urbanization on the quantity and quality of storm water runoff recharging through caves into the Edwards aquifer, Bexar County, Texas: Western Kentucky University, Thesis directed by the Dept. of Geography and Geology, July, 233 pp.

The History of American Theories of Cave Origin

Richard A. Watson and William B. White

Abstract *

In 1930, William Morris Davis published "Origin of Limestone Caverns" in the GSA Bulletin, initiating an episode of mistaken interpretation and resistance to field evidence almost unique in American geology. Davis proposed a two-cycle, deep-circulation theory of cave genesis by phreatic solution. J. Harlan Bretz made heroic efforts to defend the theory, but geologic facts show it to be mostly wrong.

Davis ignored European literature, particularly the work of Alfred Grund and Jovan Cvijic whose empirical studies demonstrate that many caves are formed by solutional and mechanical action near and above the water table. Davis was misled by his lack of geochemistry and by fanciful maps of Mammoth Cave that show a labyrinth rather than the actual modified dendritic pattern of passages.

Among others, Claude A. Malott and James H. Gardner presented theories that displaced Davis' phreatic theory. In particular, Allyn C. Swinnerton developed a theory of temperate zone cave formation by flow along a seasonally fluctuating water table that is best supported by geologic evidence today. Recent work by Franz-Dieter Miotke, Arthur N. Palmer and others relates episodes of cave formation to Pleistocene glacial periods.

Geochemical work initiated by Clifford A. Kaye and others caused a revolution in cave studies, and these data integrated with geologic, geomorphic and hydrologic details by Derek C. Ford, Ralph O. Ewers and others have led to sophisticated models of cave origin adaptable to all situations.

Some caves are formed by deep phreatic solution, although Carol A. Hill argues that in Carlsbad Caverns the active agent was sulfuric, not carbonic acid. Davis' prestige was so great, however, that his incorrect hypothetical model was an obstacle to the understanding of cave origin, and remains so today because of its continued uncritical incorporation in some elementary texts.

Introduction

In 1899, William Morris Davis toured the Dalmation karst with Albrecht Penck. Davis was at that time interested mainly in glacial processes, and in his written account of the tour he comments only briefly on karst features, referring the reader to Cvijic (1893). Thirty-one years later, Davis published "Origin of Limestone Caverns" (1930), an almost entirely theoretical paper in which he proposes a theory of cave origin involving solution during an initial period of deep-seated phreatic circulation, then regional uplift and lowering of the water table, and then deposition during a subsequent period of shallow vadose water flow.

This two-cycle theory was tested, utilized, and expanded in the field by J Harlan Bretz, who defended it until his death. Davis' two-cycle theory was and is contrary to most European work on the origin of caves, including Penck's and Cvijic's. It embodies a process of anastomosing deep circulation that was accepted by few field karst geologists other than Bretz. Davis' theory did, however, make its way prominently into American textbooks, where it continues to be taken more seriously than it ever should have been. It is inevitable, therefore, that this present study - primarily in the history of ideas - must have at its core an examination of the Davis theory. Nevertheless, our thesis is that numerous other American geologists are more important than Davis in developing theories of cave origin that correspond to and derive from field data, and one of our conclusions is that Davis' influence on karst studies has been generally regressive.

There are three periods of American cave research. The earliest ends in 1930. Then there is a "classic" period in the wake of Davis from 1930 to 1942. This is followed by a hiatus initiated by World War II. It is important to note, however, that this is a period during which many cave explorers and researchers were organized. The National Speleological Society was incorporated in 1941, and in 1957 a group of geologically oriented NSS members incorporated as the Cave Research Foundation. In 1957, the third "modern" period began and extends to the present day.

* Watson, Richard A. and W. B. White, 1985, The History ofAmerican Theories of Cave Origin: Geol. Soc. Am. Centennial Special, Vol.I, pp. 109-123.

Geologic Mapping in Crystal Cave, Mammoth Cave System

Arthur N. Palmer and Margaret V. Palmer

By 1969 most of the Flint Ridge Cave System had been mapped, and yet there was little knowledge of its vertical layout or of the geologic factors governing it. Techniques of leveling with water-filled vinyl tubes and hand levels had been introduced by the authors several years before, and large parts of the cave were surveyed in this manner. However, these surveys were not systematic enough to provide a coherent picture of cave levels. In 1969 we began a leveling and geologic survey of Floyd Collins' Crystal Cave with the following goals: (1) determine the stratigraphic section in which the Flint Ridge System and Mammoth Cave are developed; (2) clarify the presence of passage levels and their geomorphic significance; and (3) produce a detailed map of the cave. Crystal Cave was chosen because its complexity, great stratigraphic range, and close proximity to the Green River would reveal most clearly the relative influence of geology vs. base-level changes on the vertical layout of passages.

Using copies of the original notes, a horizontal base map of the cave was prepared. This has been completed only recently, as it involved considerable field checking, remapping and surveys of newly discovered and re-discovered passages. Surveys span more than 25 years, some dating back to the NSS C-3 Expedition of 1954. They vary greatly in quality as techniques became more refined and as mapping goals changed. Early mappers wanted to find where passages went; now they want to portray their details. The magnetic declination over this period has changed 2.5 degrees.

The base map was used to coordinate a leveling survey of the cave. We originally planned to level every passage in the cave, but the effort fell short at about 90% (18 km) of the total length. However, the leveled passages include all types, providing a comprehensive view of passage interrelationships and their geologic controls. The survey included all upper levels, nearly all of the underlying passages accessible through the Crawlway (Kline Trail), Miller Trail ("Left of the Trap"), and a single line to the Austin Entrance through B Trail, Lehrberger Link, Fishhook Crawl, Storm Sewer, Eyeless Fish Trail and Columbian Avenue.

Since 1975, additional geologic surveys have been made throughout much of the Flint Ridge System and Mammoth Cave for comparison.

Approximately 1500 leveling stations were established in Crystal Cave, using the previous mapping stations to avoid redundancy. At each station the elevation of the solutional ceiling and floor, breakdown levels, past and present water levels, sediment, geologic contacts and major bedding planes were measured. Maximum station spacing was 15 m.

The maximum survey error in closed loops was 25 cm. One preliminary loop error of 1.5 m was traced to a blunder where a change of datum was not recorded. The line through the cave from the Crystal to the Austin Entrance was closed with an overland survey, with a total error of only 6 cm. Surely this closure involved some luck and does not represent the overall accuracy of the survey.

A stratigraphic column was established and correlated throughout the rest of the National Park (Palmer, 1975). Approximately 65 recognizable beds were identified within the 15 exposed members of the Girkin, Ste. Genevieve, and upper St. Louis limestones. With this information the elevation of unleveled passages can be estimated to within about 5 m. Passage levels were described and, in cooperation with Dr. Franz-Dieter Miotke, correlated with the geomorphic history of the surrounding landscape (Miotke and Palmer, 1972). Several recent summaries of the geology of the Mammoth Cave System are based primarily on ideas that originated from the Crystal Cave study (e.g., Palmer, 1981).

The leveling and geologic data are being analyzed to show the effect of geologic structure on passage gradients and trends. One technique is to run a regression plane through the coordinates of all points measured on a given geologic contact to find the mean direction and magnitude of its dip. Residual values between the regression plane and actual measurements reveal local structures superimposed on the mean dip. Comparison of local dip with the gradient and direction of passage segments clarifies the conditions under which the passages formed. Upstream vadose sections (mainly canyons and perched tubes) have steep gradients and trends down the local dip. Downstream phreatic tubes have gradients less than that of the local dip. Many are nearly parallel to the local strike. Sinuosity of both passage types is determined mainly by minor structural variations.

Passage levels were originally defined on the basis of peaks in passage width vs. elevation (Miotke and Palmer, 1972). Once profiles were drawn of all passages, the levels could be more precisely defined by the points where vadose characteristics changed to phreatic (Palmer, 1977). Levels that can be traced throughout the Mammoth Cave System lie at about 180 m (Salts Cave, Thomas Ave., Main Cave), 168 m (Waterfall Trail, Turner Ave., Cleaveland Ave.), and 152 m (Lost Passage, Smith Ave., Great Relief Hall). Several minor levels occur at other elevations. Crystal Cave also contains a major level higher than any other in the system, Collins Ave., which originated under phreatic conditions, with a water table lying at more than 210 m (with respect to present sea level).

A composite map of Crystal Cave is being prepared that will incorporate the leveling and geologic information. Profiles and cross sections will be included to show the relationship of the cave to the local strata, and a short text will describe the geology and passage relationships. The project should be complete within two years.

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A Late Quaternary Mammal Fauna and Paleoclimatic Record from Jackson's Bay Caves, Jamaica

Donald A. McFarlane

In 1979, members of the Jamaica Cave Club brought attention to a significant deposit of fossil bones in the extensive sediments of newly discovered caves associated with Jackson's Bay Great Cave, Jamaica (Wadge et al, 1979). This major cave system underlies a low, coastal limestone shelf with a very xeric, thorn scrub flora. The lower levels of the master cave have been invaded by brackish waters, implying that a major episode of cave development took place during lower sea levels. In June, 1985, Richard E. Gledhill and I undertook a preliminary investigation of the paleontology of the various deposits in both Jackson's Bay Great Cave and in the more recently discovered and little visited upper level caves, assisted by a CRF Graduate Fellowship to McFarlane.

The distinctive sediments of the upper level caves are unique among Jamaican cave paleontological sites in that they are consistently stratified, the 1.5 meters of red/brown earth being interspersed with three discrete flowstone layers and covered with a surface deposit of dry gour pools and extensive beds of cave pearls. The unconsolidated earth horizons have yielded a variety of bat and rodent post-cranial material which is currently undergoing identification.

The age of these fossils is presently undetermined, although the discoverers of the deposits have inferred a pre-Wisconsin origin for the sediments based on geomorphological considerations. At the least, the multiple layers of speleothem in a presently very xeric environment indicate that the fossils accumulated prior to a more pluvial episode of climatic history. The excellent state of preservation of the bone samples from Jackson's Bay furnishes the potential for absolute dating. The size of the expendable sample precludes the use of conventional radiocarbon dating techniques, but representative samples from a number of horizons are presently undergoing analysis using the tandem accelerator mass spectrometer (TAMS) C-14 dating facility at the University of Arizona. Additional samples are being analysed for amino acid racemization signatures, which when calibrated against C-14 dates may provide a cost effective absolute dating technique which would have wide utility at these sites.

The sediments in the upper level caves are capped with extensive dry gour pool and cave pearl formations extending over many hundreds of square meters. In addition, there is extensive development of stalactites, columns and white flowstones which are currently inactive and are conjectured to be of very recent origin. Sectioned cave pearls have revealed annuli indicative of several discrete growth episodes. Many of these pearls have gastropods at their center, and it is anticipated that amino acid racemization dates will be obtained from these organisms.

A further source of proxy paleoclimatic evidence was also discovered by JCC members in the lower cave system, in the form of a very extensive deposit of relict guano. It is hypothesized that the guano accumulated at a time when the surface climate was less xeric and able to sustain a large population of insectivorous bats in the cave. The local extinction of this population with the onset of xeric conditions provides an interesting model for the interpretation of island wide extinctions through Quaternary time. Gastropod specimens from the base of the deposit and samples of the guano itself are expected to yield amino acid racemization ratios that, with the calibration curve being derived from elsewhere in the system, can be used to date the causative climatic shift.

It is hoped that if these techiniques prove successful, work at Jackson's Bay will yield the most extensive dated deposit of Quaternary mammalian fossils yet unearthed in Jamaica, and may serve to test hypotheses of Caribbean faunal history and late Quaternary climate.

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The Investigation of Anchialine Caves of the Bahamas

Jill Yager

Introduction

My research involves the study of an extraordinary class of Crustacea, the Remipedia, and their environment. Remipedes are presently known only from low oxygen, aphotic anchialine cave environments that are associated with islands of very old geologic origins. One main objective of my research is to investigate the Bahamaian anchialine cave environment in order to identify the ecological factors that may influence the distribution of Remipedia.

Evolutionary Significance of Remipedia

The class Remipedia (Yager, 1981) is characterized by a head with raptorial feeding appendages and a trunk with many similar segments, each bearing a pair of biramous swimming appendages (see cover photo). These primitive characters are of great evolutionary significance for two reasons: they are remarkably similar morphologically to those of the 250 million year old Pennsylvanian fossil *Tesnusocaris goldichi*, and they closely resemble the proposed hypothetical ancestral crustacean of Cannon and Manton (1927).

Geographic Distribution of Remipedia

To date, remipedes have been collected only from anchialine caves on both sides of the North Atlantic Ocean: the Bahamaian archipelago on the western side, and Lanzarote (Canary Islands) on the eastern side. A total of eight species representing possibly five genera and two families have been collected. The distribution of remipede species on islands throughout the Bahamaian archipelago is shown in Figure 6.

The Anchialine Environment of the Bahamas

Because islands in Bahamas are composed of carbonates, hundreds or thousands of caves are present on the islands and the surrounding banks. Some of the cave entrances occur in the ocean floor and are called blueholes. Those caves are directly influenced by oceanic factors such as reversing currents, marine salinity and the presence of marine organisms. Other cave entrances occur on land, and although they have subsurface connections to the sea, are not under direct marine influence. These caves are called anchialine caves, and are the objects of my study.

Although the present, accessible caves were formed at the top of the carbonate banks during Pleistocene low sea stands, review of data from the Deep Sear Drilling Program in the Bahamas indicates that the banks are honeycombed with numerous, older caves at great depths. That the primitive remipedes are found in anchialine caves is evidence for potential long-term availability of habitat. That the crevicular environment has been available throughout changes in sea level means that today's cave fauna could represent descendants of very old populations, unaffected by climatic changes such as Pleistocene glaciation or oceanic anoxic events.

Anchialine caves of the Bahamas typically have a small surface pool of fresh to brackish water which opens into a large cavern. Totally dark, deeper passages with polyhaline to euhaline waters may extend horizontally for many kilometers through the porous limestone. The deeper waters are characterized by very low oxygen content, in some cases less than 0.1 part per million (ppm), while waters above the density interface consistently measure 4-5 ppm. There is frequently a 2-3 m layer rich in hydrogen sulfide beneath the density interface. Most organisms collected from anchialine caves have come from the water below the density interface. These species represent a unique faunal assemblage able to inhabit an environment of total darkness, devoid of photosynthetic producers. The low oxygen waters in the aphotic passages have a high residence time which prevents a dependable allochthonous food supply. The organisms in this habitat represent a community of animals which are not found in the marine or ocean blueholes.

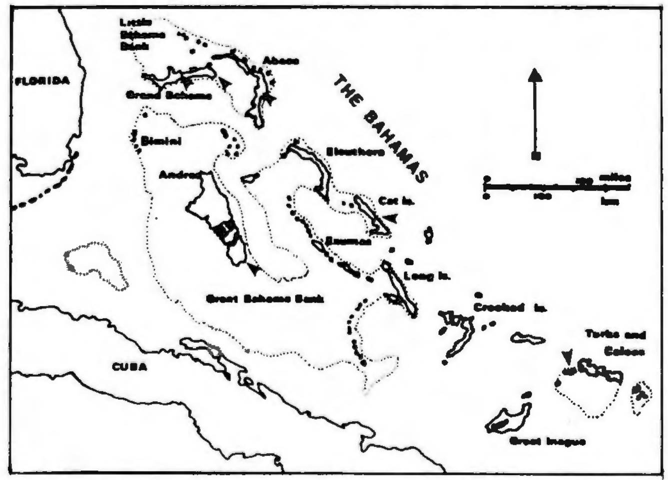

Figure 6: A map of the Bahamaian archipelago showing islands and shallow banks. Arrows indicate where remipedes have been collected.

The Karst Research Fellowship from the Cave Research Foundation supported in part my summer research in the Bahamas. It enabled me to collect additional remipede material and duplicate water analysis from a previously surveyed cave on Abaco. Several species of Remipedia were collected, including individuals representing a new genus, for which only two specimens had been previously collected. Also collected were amphipods, ostracods, isopods, nebaliaceans, shrimp, worms and leaches. The grant also enabled me to spend a week on Long Island, Bahamas. This was important because it is an area which I had not explored previously, and it represents an area in the center of the existing range of Remipedia, (Figure 5). A total of 25 caves were located and those diveable were measured for temperature, salinity, dissolved oxygen and hydrogen sulfide, at varying depths. These caves have many abiotic characteristics in common with ones previously explored, including fresh to brackish surface water, below which the salinity increased, and dissolved oxygen grops. Furthermore, several caves had a distinct hydrogen sulfide layer beneath the density interface. The faunal component resembles those in anchialine caves elsewhere in the Bahamas. The following specimens were collected: blind cave fish, crab, shrimp, ciliated protozoans, amphipods, polychaetes, thermosbaenaceans, copepods, ostracods, and parasitic isopods from the gill cavity of the blind cave fish. Some caves had very large populations of the shrimp *Barbouria cubensis*, as well as the blind cave fish. The animals collected have been sent to specialists throughout the world for identification. Several represent new species.

Despite the apparent ecological similarities, remipedes were not found in any of the Long Island caves which I surveyed. The apparent absence of these animals from caves on an island in the middle of the known remipede range is perplexing. It raises many questions about the ecology of this organism. Are remipedes always the top predators where they occur? Are remipedes excluded by larger predators? Is low oxygen a requirement or an indirect effect?

All cave diving was carried out using U. S. National Speleological Society Cave Diving Section safety standards. A strict conservation ethic is adherred to when collecting. All biological collections have been made under scientific collecting permits from the government of the Bahamas.

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Bones of the Pleistocene Ground Sloth *Nothrotheriops* in Carlsbad Cavern, New Mexico

Carol A. Hill and David D. Gillette

In late 1947, disarticulated rib, vertebrae and foot bones of a fossil vertebrate skeleton were discovered in Lower Devil's Den, Carlsbad Cavern. Most of this bone material was subsequently removed from its in situ site by Naturalists B. T. Gale and T. H. Black under the supervision of Dr. Eric Reed, Regional Archaeologist of the National Park Service. The bones were shipped on March 13, 1948 to Dr. C. L. Gazin, Curator of Vertebrate Paleontology, United States National Museum of the Smithsonian Institution, Washington, D. C., by Park Superintendent D. S. Libbey (letter dated March 13, 1948 from Libbey to the U. S. National Museum). Dr. Gazin identified the bones as belonging to the Pleistocene ground sloth, *Nothrotherium*, order Edentata, superfamily Megalonychoidea (letter dated September 21, 1948 from W. F. Foshag, Smithsonian Institution to Superintendent D. S. Libbey). Then the bones were returned by the National Museum to Carlsbad Caverns National Park on November 30, 1948 (personal communication, 1985, with paleontology collections manager Mr. Robert Purdy of the Smithsonian Institution). Bretz (1949), Black (1954) and Gale (1957) all mentioned the discovery of Nothrotherium bones in Lower Devil's Den and thought that the bones had been washed into the cave by a vadose stream.

Sometime in 1959 a large number of vertebrae, rib, teeth, and miscellaneous bone fragments were found "upstream" from the 1947 site "along a passageway to the Cave Pearl Room off the Devil's Den, Carlsbad Cavern" (Carlsbad Caverns National Park memorandum 10/20/59). These bones were collected by P. F. Spangle, J. K. Baker and George Reddy, National Park Service employees, and were identified as additional remains of the ground sloth *Nothrotherium* specie by Dr. Gazin of the Smithsonian Institution. Unfortunately, there are no known photographs of either the 1947 or 1959 collection sites.

Within the past year (1985) the sloth bones of Carlsbad Cavern have been studied relation to late-stage geologic events occurring within the cave, and the absolute ages and the paleontology of the bones themselves. The 1947 bone collection site was relocated in Lower Devil's Den near CRF survey station 3W2, but the site of the 1959 bones has not been relocated despite numerous searches "along passageways to the Cave Pearl Room off of the Devil's Den" and "upstream" from the Lower Devil's Den site.

The bones collected in Carlsbad Cavern, both in 1947 and 1959, now reside in the Carlsbad Caverns National Park museum collection. Both sets of bones are of a young juvenile of the same size, and there is no replication of bones between the two sites. Hence, while it is possible that the bones may have belonged to two separate juvenile individuals, it is more likely that they belonged to one individual whose bones became disarticulated and were carried to the two sites. Both sets of bones are badly weathered: the 1947 bones are more yellowish and clean with some calcification in the form of calcite crystals within the bone marrow; the 1959 bones appear more desiccated and bleached, with a clay coating over some parts of the bone. In each case the bones do not appear to have been tumbled, rounded or abraded by stream currents nor is there any evidence such as teeth marks to suggest that the bones were brought in by a carnivorous animal.

Since the 1959 collection site of the sloth bones has not been relocated, it was decided to concentrate on the 1947 bones including their relation to geology and to their radiometric age. The few in situ bone fragments remaining in Lower Devil's Den lie on top of deposits of orange, fine-grained, dissected silt. The bone shards rest on the downcut silt, and are scattered from 4 to 5 m around the collection site, but no further, and 70 cm above the site, but no further. The bone is clean, with no silt packed into the bone marrow cavities. These relations suggest that the deposition and emplacement of bone material either post-dated, or was contemporaneous with, the fluvial dissection of the silt. The sloth was not carried in by a free-flowing vadose stream as formerly suggested by Bretz (1949) and others, or else the bone shards would have been dispersed along the course of the stream. The few shards remaining in situ on top of the silt or a few millimeters into it, do however appear to have been gently washed, gravity-sorted and then water-laid by some type of gentle ponding effect.

The 1947 sloth bone was dated both by the Carbon-14 dating method and by the Uranium-series dating method. The C-14 date, as determined by Geochron Laboratories, was >29,700 YBP for the size sample received. The U-series date on bone material as determined by Derek Ford, McMaster University, was 111,900 years +13,300, -11,700. Calcite crystals residing within the bone marrow were U-series dated by Ford at 58,000 years +5,600, -5,400, a date which is consistent with the fact that the crystals must be younger than the bone they fill and also with the fact that the calcite crystals grew over bone marrow already badly weathered. This date of approximately 112,000 YBP is the oldest absolute date ever obtained for *Nothrotheriops* (previously named *Nothrotherium*).

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Biological Desert Under the Cap Rock

Thomas L. Poulson, Kathleen H. Lavoie and James H. Keith

There are many areas without obvious animal life in the upper level passages of the Mammoth Cave System, but only the gypsum and other sulfate areas under the cap rock seem to be truly abiotic. Unbaited pitfall traps in seemingly abiotic areas like Pohl Avenue catch itinerant sand beetles (*Neaphaenops*) and "crickets"(*Hadenoecus*); occasionally omnivorous bristletails (*Plusiocampa*) and predatory daddy-long-legs (*Phalangodes*) are observed (Poulson and Culver, 1969). Pitfall traps in gypsum areas, on the other hand, even if baited, catch nothing. Even at the borders of such areas we see only occasional crickets or beetles and they are often dead. In this report we make an initial attempt to falsify some of the hypotheses that could account for the observed absence of macroscopic organisms in upper level passages under the cap rock. If bacteria were also absent or inactive this would help to account for the excellent preservation of prehistoric remains such as paleofeces and artifacts of the preColumbian Indians.

The data presented here were collected along a transect toward the cave entrance from the edge of the cap rock in Edwards Avenue of Great Onyx Cave. The transect starts at a vertical shaft drain (Bubbly Pit) where the substrate appears to be sandy-silt and feels damp and homogeneous; the ceiling is limestone. At the abiotic end of the transect the substrate appears to sparkle, is mixed silt and gypsum shards and feels dry and gritty; the ceiling is encrusted with gypsum. The transition occurs along about 100 meters of passage and there is an associated decrease in density and frequency of macroscopic animals such as beetles, crickets, and bristletails (Table 2).

The first hypothesis is based on the presumption that there is little moisture reaching the upper level gypsum areas because of the overlaying sandstone cap rock. A partial transect of humidity in December 1972 was duplicated in June 1973 with more detail in the area of this report. The results seemed to falsify the hypothesis that moisture is limiting since the relative humidity (temperatures did not vary) ranged from 92-96% in both summer and winter and there was no trend along the transect (Table 2). Next we checked the per cent moisture in the sediment by weight loss during drying (after removal of particles bigger than 1 mm by screening). Again there was no consistent pattern from the biotic to abiotic end of the transect (Table 2). Then it was reasoned, from the fact that water is harder for plants to extract from some soils than from others, that a better measure of available moisture would be the equilibration of filter paper with moisture in the pore spaces among sediment particles. This measure does show a trend but not obviously enough to account for the biotic gradient since the biggest drop in available moisture occurs in what is already an abiotic area (Table 2). However this result does show that what occurs in the sediment is not at all what one would expect from equilibration of the sediment with atmospheric moisture as measure by relative humidity. At each site the sample was taken from the top several centimeters where the sediment ways at least 2 cm deep and loosely packed but this may not have eliminated the influence of moisture infiltrating from the surrounding bedrock. The decreasing available moisture seems to be related to increasing gypsum (taste tests were negative so epsomite and mirabilite were tentatively excluded, although no systematic study has been done during different seasons). Partitioning of sediment particle size, using standard soil sieves, shows a clear trend of less small and more large particles including obvious gypsum shards, as one moves away from the biotically-rich end of the transect.

Viable bacteria decrease from the area with many to the area with no macroscopic animals (Table 2). It is important to note that 'viable' bacteria include those that grow from inactive spores when plated on nutrient agar in the laboratory. Thus the observed trend may be mostly a reflection of how far spores have dispersed from the pit area where there may be both input of spores from the outside and from metabolically active bacteria in situ. On the other hand, the types of colonies on the agar plates indicate either a differential dispersal of the spores of antibiotic producers or a differential distribution of metabolically active antibiotic producers. The antibiotic producers are more common at the gypsum end of the transect and this could mean a low level of activity in situ for these highly competitive types. This is an area for future research. Of course the problem with this hypothesis is that there is no obvious source of organic matter for the bacteria to metabolize. A test has not been devised for per cent organic matter in the sediment that is not confounded by breakdown of gypsum and/or calcium carbonate as occurs during both weight loss on ignition at 550° C and chromic acid oxidation. An attempt to get around this problem was made by incubating an organic substrate in the cave. Strips of cellulose filter paper were placed above, at and just under the sediment surface and assayed for the metabolically active cellulose-degrading microflora. The sediment adhered to the paper and so interfered with the quantitative extraction of the dye complexed with undegraded cellulose, but a visual ranking of color was possible (the rank order by 4 colleagues agreed). On that basis there is a consistent but not striking trend of decreasing activity from the pit toward the gypsum end of the transect (intensity of color = 2, 1-2, 0-1, 0,0). The bacteria could be the basis for a restricted food chain since the present distribution of macroscopic organisms matches that of the cellulose degraders fairly well (cf. Table 2). It is interesting that the macroscopic organisms drop out sooner than the bacteria along the transect. This may reflect either less moisture limitation on the bacteria and/or their ability to subsist on lower concentrations of organic substrates. The organic input to the area might have been higher at times of past wetter climates by cricket movement from the pit connection to the surface (the alternating carbonate-gypsum deposition at the 50 m point is consistent with past variation in moisture influx from outside the cave). Or, in the even more distant past, when Edward's Avenue was in the flood zone, streams could have moved material that came down vertical shafts.

Conclusion

Some suggestions for additional research were formulated at the conclusion of this project. First, a finer scale transect with concurrent measures or organism density might show seasonal shifts. Second, it might be of interest to look in areas where mirabilite or epsomite occur seasonally since these sulfate minerals have more waters of hydration and more morphs that gypsum. This might affect either the interparticle moisture level or the particle surface osmotic potential (as suggested by Dave DesMarais). Either would affect organisms and the two modes could be separated by equilibration of filter paper in contact with the sediment (as done above) contrasted to equilibration with air that is in contact with an excess of sediment in a closed container. Bioassays might include weight loss kinetics of cricket eggs or beetles in contact with the sediment. A gradient along about 10 m has been informally noted of increasing death of cricket eggs and of late instar larvae and pupae of sand beetles in a area near shafts by Sophy's Avenue in Mammoth Cave Ridge. It appeared to be associated with a change in character of sediment similar to the one studied herein.

Table 2. Transect in Great Onyx Cave

Measurement	Bubbly Pit (biotic)	Egg-sifting Area	Step-down	Carbonate-Gypsum Speleothems	Gypsum (abiotic)
Distance (m)	0	5	20	50	110
Relative Humidity % (measured at 3 m and 1 m up from floor)	92/96	94/94	92/96	92/94	94/94
Moisture (% wt. loss with drying at 80° C)	6.1	3.1	5.1	5.5	4.7
Available Moisture (% wt. loss paper)	20.4	16.6	15.4	15.9	12.6
Sediment Particle Sizes (%)					
< 0.1 mm	<1	1	<<1	<<1	<1
0.1 - 1.0 mm	99	98	69	45	58
> 1.0 mm	<1	1	31	54	42
Viable bacteria	$>1 \times 10^6$	3×10^5	2×10^5	no data	5×10^3
Neaphaenops	abundant	abundant	common	0	0
Hadenoecus (nymphs and eggs)	abundant	common	regular	0	0
Kleptochtonius (pseudoscorpion)	regular	rare	0	0	0
Plusiocampa (bristletail)	regular	rare	0	0	0
Phalangodes (daddy-long-legs)	rare	0	0	0	0

abundant = 1 - 10/m^2 > almost every m^2 with 1 or more
common = .1 - 1/m^2 > a patchy distribution
regular = << .1/m^2 but every 50 m^2 with at least 1
rare = only occasional individuals and not in every sample period

Geochemistry and Biology of Sulphur River, Parker's Cave, Kentucky

E. A. Lisowski, R. A. Olson, W. R. Roy and D. B. Thompson

Parker's Cave, in the headwaters of the Turnhole Bend Spring drainage of the Mammoth Cave System, has five separate, subparallel streams with cross connections. One of these streams, Sulphur River, is unique because of input of sulphur water to the cave stream. An eerie white formation, termed "The Phantom" and composed of gypsum, occurs where a sulphur water tributary enters the passage near the ceiling and falls twenty feet to a cave stream. Sulphur River, downstream from The Phantom, has a strong sulphur odor and has thick white bacterial mats in the stream. The source of hydrogen sulfide in The Phantom waters is not resolved. One hypothesis is that brines and sulphur water associated with an abandoned oil well are leaking into ground water and eventually entering Sulphur River. Oilfield brines have a high concentration of sulfate ions, which are reduced to hydrogen sulfide by bacteria under anaerobic conditions. An alternate but not mutually

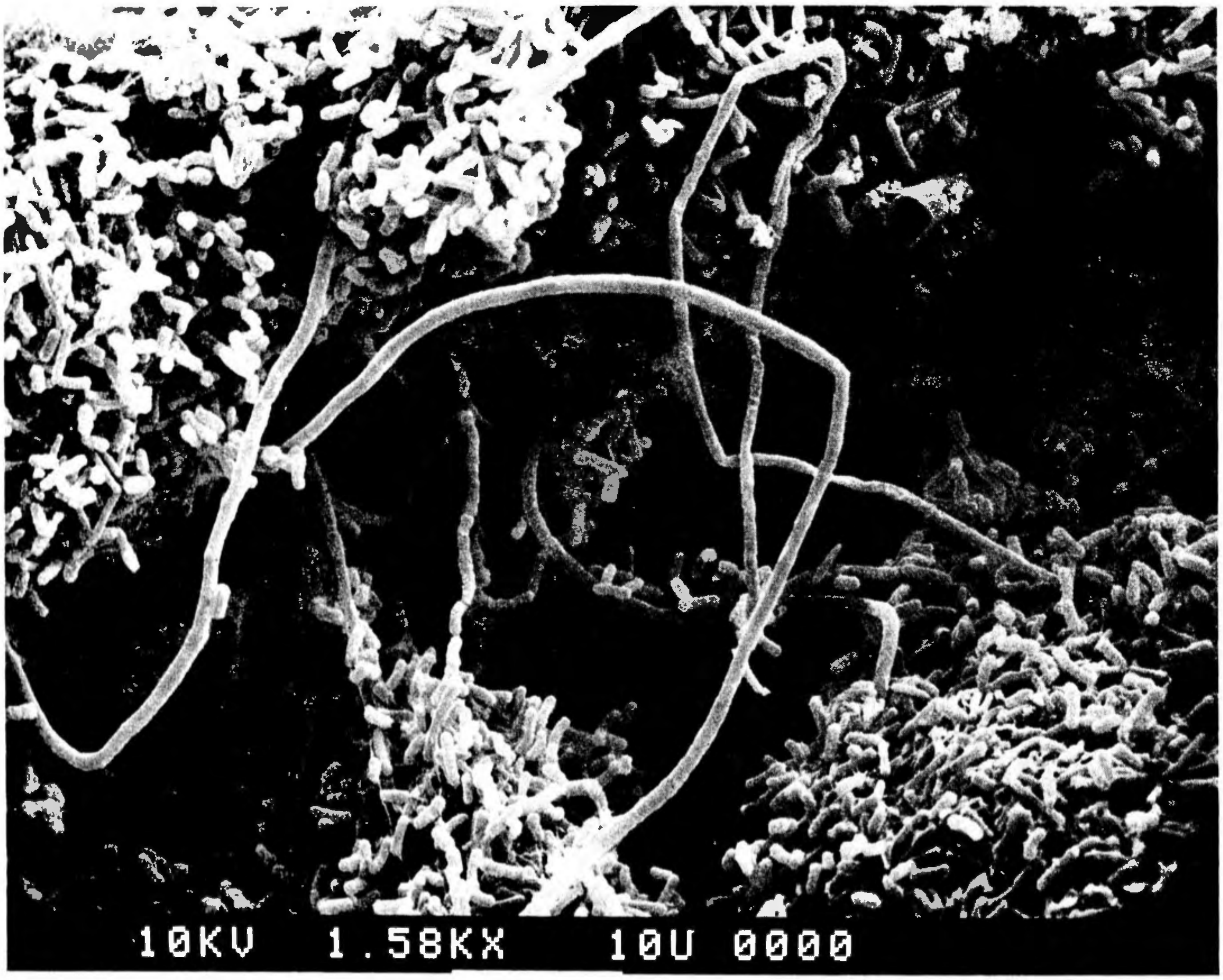

Figure 7 : Sulphur River bacterial consortium that colonized the surface of a sterile silicon wafer within a period of three days. The longer filaments, which are greater than 10 microns long, resemble *Beggiatoa*, a sulphur-oxidizing bacterium. *Beggiatoa* filaments aggregate to form visible white mats in the waters of sulphur springs and sewage treatment plants, where hydrogen sulfide accumulates. Sulphur-oxidizing bacteria oxidize sulfide to sulphur or to sulphuric acid. These sulphates, in turn, can be reduced to hydrogen sulfide by anaerobic sulphate-reducing bacteria in sediments. The identity of the smaller rod-shaped bacterial cells, between 1 and 3 microns long, cannot be determined from cell morphology.

exclusive hypothesis is that hydrogen sulfide is generated by bacterial decomposition of organic material in the stream sediments.

A study of the interaction of geochemistry and biology in Sulphur River is important not only because of the uniqueness of this ecosystem but also because of potential adverse effects of intensified oil and gas exploration in the Mammoth Cave Region. Accidental or intentional releases of oil brines or sulphur water could have major adverse impacts on ground water or on base level streams in the Mammoth Cave System.

Our descriptive study of Sulphur River has several facets. One of us (RAO) is using energy dispersive X-ray analysis to identify minerals and using scanning electron microscopy to examine the morphology of microbes that colonize artificial substrates at various points in the passage. We are also documenting the aqueous geochemistry (WRR), microbiology (DBT) and macroinvertebrates (EAL).

Preliminary results indicate that Sulphur River is influenced by connate waters, possibly a displaced brine, since the prevalent chemical character of the subterranean stream is NaCl. The stream is near neutral in pH (pH 6.3 to 6.5), and becomes increasingly reduced upstream towards The Phantom, the location where the connate waters discharge into the cavern system. Samples of the Phantom effluent were reduced (Eh<-5mV) relative to a standard Zobell solution, and contained high concentrations of chloride (up to 1.6% Cl^-) and sulfide (11 to 21 mg S^{2-}/L), and were characterized by ionic strengths exceeding 0.25 M/L. Based on available data, the composition of Sulphur River system may be generalized as $Cl^- > Na > SO_4 >> Ca > Mg > K > Si > B > S^{2-}$, Al, Fe >> As, Ba, Cd, Cr, Cu, Mn, Mo, Ni, Pb, P, Sb, Se, Sn, and V.

The microbiology of Sulphur River is strikingly different from other cave streams in the Mammoth Cave region. The substrate of the stream is covered with a white mat-like material that is several centimeters thick. This mat covers all of the substrate and is composed of bacteria with several different morphologies. Two sulphur oxidizers, *Beggiatoa alba* and *Thiotrix tenuissima* are present in the mat along with bacteria of other morphologies. The presence of two known sulphur oxidizers and a reduced sulphur source in the form of hydrogen sulfide suggest that this robust microbial community is utilizing reduced sulphur as an energy source. Water and mat samples collected over the period of several months in the fall of 1985 revealed the presence of a number of protozoa, covering twelve genera, are present. These include flagellates, ciliates and amoeboid forms. All of these protozoa are capable of feeding on the bacterial mat. In addition, two algal forms have been seen and identified. These plants most likely represent wash-ins and only transient members of the community.

The macroinvertebrate community is as diverse as the microbiological one. It includes two species of annelids, a cave snail, five species of collembolans, a psocopteran, a staphylinid, a cave carabid, a linyphiid spider and several species of mites. Many of these species are usually found in high organic areas near entrances, suggesting that most of the species are opportunistically exploiting an area of high food payoff and high risk. The only species that we saw during every visit to Sulphur River is the linyphiid spider, *Phanetta subterranea* . Water droplets collect on spiders' webs and are frequently milky white because of numerous rod-shaped bacteria. Norm Pace (pers. comm.) measured the pH of a pooled sample of the droplets and found it to be 0.13. Future work will investigate the impacts of hydrogen sulfide and sulphuric acid toxicity as well as seasonal flooding on population dynamics and distribution of these species.

Investigation of a Predator-Prey System Found in Great Onyx Cave, Kentucky

David M. Griffith

Recently, caves have been strongly advocated as ideal sites for the testing of theoretical models of modern population biology (Culver, 1982). The small numbers of species in most cave systems permits the investigator to thoroughly examine species interactions, and due to the relative simplicity of cave communities assumptions of many models are more nearly met. Of particular interest are predator-prey models, which predict oscillations in abundances of both the predator and the prey. The Lotka-Volterra model predicts that the predator "drives" the system, causing oscillations in population density. More recently, the graphical model of Rozenweig and MacArthur (1963) has proven useful for more realistically considering biological systems in nature. For example, modifications of the original model have provided insight into the role of refuges in stabilizing predator-prey interactions. These models indicate some of the parameters that need to be examined in order to determine whether the predator does indeed drive the system or whether the predator simply follows the oscillations of the prey that are due largely to environmental factors.

The subject of my study was the predator-prey system located at the end of Edwards Avenue in Great Onyx Cave. The passage is a tube averaging 2-3 m high and 9-12 m wide with a sand substrate (Poulson, 1983, p. 14). The three key species are the cave cricket (*Hadenoecus subterraneus*), the sand beetle (*Neaphaenops tellkampfi*) and an orb-weaving spider (*Meta menardi*). *Hadenoecus* lays eggs in the sand, which are eaten by *Neaphaenops*; *Meta* consumes both *Hadenoecus* and *Neaphaenops*. Since *Meta* is a recent addition (circa 1982) to the system (Poulson, pers. comm.), this report will discuss the relative impact of the spider on the *Hadenoecus-Neaphaenops* interaction.

The predation rate of *Neaphaenops* on *Hadenoecus* was measured by Kane and Poulson (1976) in 1972/1974. They obtained a high rate (88% of all eggs) in both the front and back areas of the study site. When I repeated their experiment, I included an additional measurement from the middle. I gathered data twice during the summer, with each rate measured cumulatively for one month. I obtained a negligible predation rate in the front and middle areas, and a relatively high predation rate (83.3% and 90%) in the back area. There were few *Hadenoecus* eggs (<1.0/control plot) in the front area, in contrast to many eggs in 1972/1974 (>40.0/control plot). The back area also had fewer eggs than were present in 1974. The middle area (by Bubbly Pit) had many eggs (16/control plot), but few beetles were around to eat them. The data suggest that changes in the distribution of *Hadenoecus* eggs within the cave have occurred since 1974. It also suggests that the impact of *Neaphaenops* on *Hadenoecus* may not be nearly as high as was previously believed. Heterogeneity in *Hadenoecus* egg laying may be a strategy to avoid high predation by *Neaphaenops.*

Observations of the spider during the entire summer indicate a relatively low predation rate on either beetles or crickets. Prey was observed in a spider web only three times; twice the prey was an adult cricket, and once it was a male spider (which had presumably mated with the female thus making its contribution to the population). Since the spiders have a long lifespan (>4 years) and have a relatively low metabolic rate, it is believed that despite the large growing population (181 spiders plus several egg cases were censused on June 16), the impact of *Meta* is not important. On the other hand food supply is important to the spiders as is indicated by their distribution, which corresponds to the areas of high prey density. Spiders are occasionally found in low prey density areas, but these usually take down their webs within a few days and more to another area.

Data were gathered on the foraging behavior of *Neaphaenops* in a series of behavioral experiments; however, experiments Neaphaenops and *Hadenoecus.* A mark-recapture method was used for *Neaphaenops* utilizing fluorescent dye to obtain a population estimate of 1620. The distribution and abundance of *Hadenoecus* and *Neaphaenops* were measured by censusing exhaustively in thirty 2m wide bands encircling the passage every 10 meters. This revealed a 60% reduction in the size of the adult cricket population during the month of August. Finally, sex ratio, teneral frequency and fullness (i.e. of crop) data were obtained throughout the course of the summer. The fullness data will be used to further assess the impact of *Neaphaenops* on *Hadenoecus.*

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Evolutionary Reduction by Neutral Mutations: Plausibility Arguments and Data from Amplyopsid Fishes and Linyphiid Spiders

Thomas L. Poulson

Patterns of change among the six species of Amplyopsid fish are used to argue that evolutionary reduction is based on accumulation of neutral mutations whereas troglomorphic traits are selected. Net changes, for 14 reducing and 17 troglomorphic traits, were calculated for the trogloxene-troglophile pair of species; the troglophile vs troglobite with least reduced eyes, and so on along a sequence of increasing eye reduction. The patterns of decrease for reducing traits did not parallel the patterns of increase in troglomorphic traits as expected if reduction were due to indirect selection by pleiotrophy. Pattern of change was consistent for troglomorphic traits with moderate net increase for both -xene to -phile and -phile to -bite 1 and virtually no further increase among any of the three troglobite species pairs. In contrast, patterns of decrease for reducing traits were quite variable but all showed continued high to moderate decrease among all the pairs of troglobites.

Natural experiments and calculations of energetic savings for spiders are used to argue that neither direct energy savings nor indirect material compensation are likely bases for evolutionary reduction. There is no trend with more food limitation from low to high trophic levels or from food-rich to food-poor caves at global, regional or local scales. Development, growth and maintenance cost savings for structural reduction are less than 5% of whole organism cost and much less than 1% of savings due to troglomorphic decrease in routine metabolism in spiders.

The general discussion deals with alternative hypotheses relevant to structural reduction and troglomorphy, assesses the evidence for loss of physiological compensation for environmental variation, and relates trends in morphological and genetic variation to patterns of reduction and troglomorphy.

Competition of Cave Beetles (*Ptomaphagus hirtus*) and Fungi for Dung

Julie S. Cohen

Abstract †

Three experiments were done to investigate the possible advantage for cave beetles (*Ptomaphagus hirtus*) in beginning simultaneously with fungi to use a fresh dung resource. Beetle reproduction was compared when beetles fed on resources on which fungi started ahead of or at the same time as beetles. Survival of larvae to adulthood was compared when larvae fed on a fresh resource, a resource previously used by fungi, or a choice of resources. Beetle reproduction was compared when beetles fed on resources in which fungal populations varied and in which fungi were disturbed or left intact.

Results indicate that there is an advantage for beetle larvae, in terms of survival to adulthood, in beginning to use a fresh resource simultaneously with fungi; larvae also prefer a fresh resource. There are some indications, in terms of beetle reproduction, of an advantage for beetles in starting to use a resource simultaneously with fungi. However, other variables also appear to affect reproduction. One of these variables in disturbance of fungal hyphae. Another important variable may be moisture content of the resource, which in turn is affected by time, texture of the resource and extent of fungal growth.

† Cohen, Julie S., 1985. Competition of Cave Beetles (*Ptomaphagus hirtus*) and Fungi for Dung: M. S. Thesis, Department of Biological Sciences, Univ. of Illinois at Chicago, 47 pp.

Figure 8: Woven slippers discovered *in situ*, Big Bone Cave, Van Buren County, Tennessee. (Photo by George Crothers)

Figure 9: Complete gourd container discovered in Big Bone Cave, Van Buren County, Tennessee. (Photo by George Crothers)

Archaeology Programs

CRF Archaeological Project - 1985

Patty Jo Watson

Consultation at WKU, Surface work in MCNP, the NSS Convention

On June 13 and 14, 1985, P. J. Watson consulted with the staff at the Kentucky Museum on the Western Kentucky University Campus (a new exhibit on Green River history and prehistory is in preparation there), and presented two lectures on cave and shell mound archaeology to an Elderhostel group meeting in the Museum.

From June 16 to 23, CRF archaeologists taught "Cave Archaeology" to eight students enrolled in the Summer University in the Park program (WKU and MCNP). George Crothers, Mary Kennedy and Patty Jo Watson made up the teaching staff with Ron Wilson joining us on Thursday and Friday to play his usual key role as guide in Jaguar Cave, Tennessee.

On June 23, Ron Wilson, George Crothers, Mary Kennedy and Patty Jo Watson went into Long's Cave to see the spot where the Salts Cave Mummy was exhibited shortly after its removal from "Mummy Hall" in Salts Cave in 1875. The little cabin built to house the body is still there in excellent condition, as is an abundance of historic debris from the last 100 years. We also discovered clear evidence in several places of presumably prehistoric gypsum mining, and are planning to return to these areas next spring to carry out detailed documentation.

On June 27 and 28, Crothers and Watson participated in a Cave Archaeology symposium organized by Crothers for the NSS Convention in Frankfort, Kentucky. Other participants were Ken Tankersley, Cheryl Munson, Patrick Munson (Indiana U.); Charles Faulkner, Charles Hall and Patrick Willey (U. of Tennessee); Pamela Shenian (Murray State U.); and C. Belski of Carlsbad, New Mexico. The paper by Tankersley, Munson and Munson "Middle Woodland Quarrying and Use of Aragonite from Wyandotte Cave, Indiana" received an award for the best scientific presentation at the sessions. An account by Watson of archaeological remains in Kentucky caves appears as Chapter 11 in the NSS Convention handbook (Dougherty (ed.), 1985).

On June 29, Patty Jo Watson and Mary Kennedy visited the DeWeese shell mound and found that reports of new and extensive vandalism were correct. A considerable amount of looting with attendant destruction of the deposits had occurred over the previous few weeks.

Big Bone Cave, Tennessee

On July 27, George Crothers led Mary Kennedy and Pat Watson into Big Bone Cave near McMinnville, Tennessee, where he is carrying out a Master's thesis project (Anthropology, U. of Tennessee) funded in part by a grant from the Department of Natural Resources of the State of Tennessee. He has obtained several ^{14}C dates ranging form the last half of the first millennium B.C., to the first few hundred years A.D.; hence, prehistoric activity in Big Bone Cave was at least partly contemporary with that in the Mammoth Cave System. Archaeological remains are abundant (Figures 8 and 9), although much of the pre-historic material has been disturbed or destroyed by intensive historic mining for saltpeter. Crothers assumes the aboriginal cavers were in search of gypsum or other cave minerals, but clear evidence for this remains somewhat elusive. At any rate they repeatedly visited the cave, where they worked their way through many hundreds of meters of low crawlways and several tight squeezes. The prehistoric archaeological remains were first noticed in the 19th century by Henry Mercer (who also wrote *The Hill Caves of Yucatan*, published in 1896), but were forgotten or ignored. In 1981, NSS cavers Carol Sneed, Joel Sneed and Larry Blair noticed the material and notified Pat Watson and the CRF Archaeological Project personnel.

Archaeological Reconnaissance at the Read Site (15Bt10)

On October 11, an archaeological team from Washington University (Tim Ginnett, Christine Hensley-Martin, Mary Kennedy, Adria LaViolette, Jian Leng and Pat Watson) visited the Read shell midden in the Little Bend of Green River near Morgantown. The site was excavated by WPA crews in the late 1930's at about the same time as work was going on at the Carlston Annis Mound (15Bt5) in the Big Bend. (See *CRF Annual Report* for 1977 and subsequent years for summary accounts of the Shell Mound Archaeological Project and its relationship to the archaeology of the Mammoth Cave System). Christine Hensley-Martin is doing research on the Read site material (primarily the stone tools) as a Master's these project. Our objective in visiting the site was to reconcile the old WPA map with the one made a few years ago by Bill Marquardt and other members of the Shell Mound Project. This could not be done without going to the site because there was no north arrow or other key orienting features on the WPA map to tie it to the actual terrain or to our newer map. Fortunately, however, the WPA map did include one recent cultural feature - remains of foundation stones from an early 20th century house - that we were able to relocate after some searching and with the help of three local people: Mr. Waldemar Annis (a native of Logansport, Kentucky, who owns the land where Bt5, the Carlston Annis site is located): the Bt10 landowner, Mrs. Ida Watkins (whose maiden name is Read, and whose family owned the site when it was being excavated by the WPA); and her son Mr. Wayne Watkins, who remembered the old stone foundation.

Sinking Creek Cave, Kentucky

This site (15Si9) was described in a previous *CRF Annual Report* (1983, pp. 22-23). It was badly vandalized at that time, and has now been completely destroyed by relic collectors. Our goal in returning to Sinking Creek Cave on October 12, was to examine the area just outside the cave, and to make at least a preliminary topographic map of it. There is a scatter of chert debris in the field near the entrance, and it is likely that the situation here is like that at Mill Hole near the southern border of MCNP: a permanent water supply as well as chert outcrops resulted in long-term prehistoric use of the site as a camp and stone tool workshop.

We did succeed in accumulating the data for a map (Washington U. graduate student Adria LaViolette being in charge of the transit), but found that the property has now changed hands so our future working relationship will be with Mr. Odell Sparks, the new Owner.

Cave Management Seminar at Carlsbad Caverns, New Mexico

On November 13 and 14, Pat Watson gave two presentations on cave archaeology in the NPS Cave Management Seminar at Carlsbad Caverns and at White City, New Mexico. The seminar was organized by Ron Kerbo and makes up one portion of a training program for young, Park Service management-level personnel. Emphasis was on protection and conservation, a crucial theme for cultural as well as natural resources in caves.

Prehistoric Cave Mining in Indiana and Kentucky

In the 1984 *CRF Annual Report* (pp. 30-31) reference was made to new investigations of prehistoric crystal mining (probably of selenite) in the Mammoth Cave System. Far back in Wyandotte Cave some 1500-2000 years ago, aboriginal miners removed large quantities of aragonite from a huge column now called "The Pillar of the Constitution". This Wyandotte aragonite was apparently traded relatively widely throughout parts of the Midwest where it was made into a variety of artifacts. Prehistoric selenite mining in the Mammoth Cave system is inferred from clear evidence of very intensive digging into crystal-bearing sediments at many locations in Upper Salts Cave and Mammoth Cave. This sediment-quarrying was remarked upon by the NPS archaeologist, Alonzo Pond, in accounts of his work with the Mammoth Cave mummy (Pond 1937).

Two ^{14}C dates on torch charcoal from a postulated selenite mine at survey station W21 in Flint Alley of Mammoth Cave have just been released by Dr. Robert Stuckenrath of the Smithsonian Radiocarbon Laboratory. They are:

SI-6890A	2920 ± 60, 970 B.C.
SI-6890B	2495 ± 80, 545 B.C.

Thus it appears that the mining activity on the ledge at W21 in Flint Alley took place 2500 to 3000 years ago during the Late Archaic to Early Woodland periods (the time span indicated by many of our previous dates from the Mammoth Cave system, (see Watson, ed., 1974, p. 236)), whereas the aragonite quarrying in Wyandotte Cave is Middle Woodland in age (1500-2000 years ago). Perhaps an Early Woodland demand for selenite and other forms of gypsum from Salts Cave and Mammoth Cave was superceded by increasing interest in the different exotic resources available in Wyandotte Cave and elsewhere; or perhaps the originally abundant supplies of crystals in the Mammoth Cave system had simply been mined out by the end of the last millennium B.C. Work on these and related issues of cave archaeology in the midContinental karst area is attracting increased attention from Americanist archaeologists.

Acknowledgements

The work of the CRF Archaeological Project continues to be supported and facilitated by the Superintendent and other officials at Mammoth Cave National Park, to whom we are very grateful. We also owe a debt of gratitude to dr. Robert Stuckenrath whose laboratory has dated more Eastern Woodlands cave archaeology than any other radiocarbon facility in the world.

In our research on the Green River shell mounds and related sites, we continue to benefit from the great kindness and unfailing hospitality of the local people, especially Waldemar and Ethie Annis and John L. and Kathleen Thomas. We are now and will forever be, in their debt.

We are also thankful to Mrs. Ida Watkins and Mr. Odell Sparks, respectively, for permission to visit sites on their property.

References

Mercer, Henry C., 1896, *The Hill Caves of Yucatan*: Philadelphia: Lippincott. Reprint edition: Teaneck, New Jersey and Norman, Oklahoma: Zephyrus Press and Univ. of Oklahoma Press, 1975.

Pond, Alonzo, 1937, Lost John of Mummy Ledge: *Natural History*, **39**:176-184.

Watson, Patty Jo, 1985, Archeology: In *Caves and Karst of Kentucky, Special Publication No. 12, Series XI*, edited by P. Dougherty, Kentucky Geological Survey, Frankfort, pp. 176-186.

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Cave Archaeology in the Eastern Woodlands

Patty Jo Watson

Excerpt †

Some of the oldest evidence available about the activities of our ancestors comes from caves. A million years ago, fragments of *Australopithecus*, an early form of pre-human, were deposited in the caves, pits and crevices of an ancient caverniferous landscape in South Africa. Half-a-million year old remains of *Homo erectus* have been found in a cave near Choukoutien in China. Dozens of caves in southern France and northern Spain were decorated with wonderful polychrome paintings by the people who lived there thirty thousand to fifteen years ago; and almost the entire story thus far known about the human past in Europe and western Asia comes from excavations of rockshelters and cave mouths. For thousands and thousands of years, these places were the only permanent homes our ancestors knew or needed.

When people entered the New World, some twelve thousand to fifteen thousand years ago, caves and rockshelters in North and South America similarly became depositories for the records of their lives. Russell Cave in Alabama, Meadowcroft Shelter in Pennsylvania, Ventana and Tularosa Caves in the Southwest, the caves and rockshelters of Tamaulipas and Tehuacán and the Maya area in Mexico, and several others in the Peruvian Andes and at the tip of South America provide examples of important, early and deeply stratified archaeological deposits preserved in dry caves and rockshelters. Most of these caves and, for that matter, most of the caves used by human groups are shallow, rock overhangs.

Rock overhangs are usually classed as rockshelters and differ in significant ways from caves. The famous cliff dwellings of the American Southwest were constructed under such overhangs, which, in some cases, were large enough to hold communities of several hundred rooms. Because rock shelters are overhangs and not true caves, they are illuminated by natural light. They serve as shelters from the elements, but provide enough light so that work can take place without artificial illumination. Sometimes the overhang is sufficiently protected from the elements so that deposited remains stay dry and are consequently well preserved. Other shelters, while offering useful protection from the elements, are not perfectly dry, and perishable materials left there have decayed or completely decomposed over the millennia. Most areas of the United States have few caves or rockshelters, but where they are present, those that are well lit and have fairly flat floors were often used aboriginally.

However, people also used true caves, which are completely dark and can be quite long, with multiple complex passages. It is human penetration into the remote interiors of these deep caves that is less expected. In portions of the eastern United States, within an area extending from northern Alabama to southern Indiana, is a geological region with massively bedded, underground limestone layers. This kind of geologic situation is known as a Karst landscape. In such karstic areas, water from snow and rain percolates into the limestone bedrock through thousands of sinkholes. As the water flows underground, it slowly dissolves the limestone, and over hundreds of thousands of years this process forms caves.

Ultimately, the water that forms caves emerges from the ground and feeds into nearby rivers. As the cave forms, the percolating and sometimes trickling, sometimes swiftly flowing water carves progressively deeper into the limestone, lowering the water level in the cave. Eventually this results in higher, older passages drying out and becoming stable. Thus, in some multi-level caves, upper passages may be completely dry, while there may be hidden underground rivers and other wet areas in the lower passages. It is in the upper areas where preservation of fragile, highly perishable material is extraordinary.

As a result of marrying a caver while we were still graduate students - he in philosophy and geology, I in archaeology and anthropology - I have investigated a variety of archaeological materials in a number of caves for the past twenty years. My research has included the world's longest cave, the Mammoth Cave System in Kentucky, which includes over 300 miles of passages, as well as other caves and rockshelters in this part of the Eastern Woodlands. The vast deciduous forest that once covered the entire eastern third of the United States was sparsely occupied by human groups for many millennia, and the remains of their activities are ordinarily not well preserved in he temperate climate that has prevailed here since the end of the ice age, some ten thousand years ago. But due to stable environmental conditions underground, time stands still in caves and dry rockshelters; temperatures are constant at 54° F, with no rain, no wind and no decomposing organisms. Even the most delicate leaf or fern frond will last indefinitely if not disturbed. Hence, these places are like natural museums, where even the footprints of prehistoric people are preserved in dust or damp mud for thousands of years, looking nearly as fresh as when they were first made.

In shallow rockshelters, people typically re-used the same floor space over and over. This kind of re-occupation means decades or centuries of living in the same place. As a result, deposits are laid on top of each other, with the refuse of previous years frequently disturbed and trampled by subsequent users. Such stratified deposits give a long term history of a rockshelter and are invaluable for archaeological research. While the use of deep caves was generally less common, the spaces available in the big caves were relatively more extensive. This means that many remains of human forays into deep caves were not disturbed by later occupation or other activities. Thus, not only are objects extremely well preserved, but also they lay undisturbed, exactly as they were deposited millennia ago.

Historic and prehistoric cultural remains in caves are extraordinarily diverse. They include ancient torch smudges on walls and ceilings; footprints on muddy or dusty surfaces; marks of mining or digging tools in sediment banks; wooden, vegetable fiber, bone and stone tools; prehistoric cadavers; prehistoric and historic markings on mud or stone walls; and saltpeter vats and spoil heaps. In spite of this diversity, all these items have three attributes in common: (1) they are subtle, or elusive or fragile (or all three); (2) they provide unique and valuable information about the past; (3) they pose serious documentation and conservation problems for present-day archaeologists and historians, whether left in place underground or removed to display and storage cases above ground.

Although basic methods and objectives are the same, archaeological research conducted deep underground differs in several ways from research on the earth's surface. The biggest difference is the continual need for artificial light in the perpetually dark inner recesses of a cave. The lights must provide dependable illumination lasting from three to fifteen hours, and must be sturdy and easy to carry. Battery lamps, gas lanterns and miners' hardhats with carbide or electric headlamps are all used. In addition, each person carries a flashlight, candles and matches.

Underground research is also complicated by the rugged terrain. Passages have not been cleared out and paved. Instead, in its natural state a cave is littered with piles of boulders and broken rocks of all sizes. The only way to get past most of these is by climbing over or around them. Furthermore, cave passages are so low that one must crawl long distances on hands and knees, or wriggle along on one's stomach; and many section of caves can be reached only by squeezing through extremely small openings. Another caver's technique is chimneying up and down narrow vertical passages - moving slowly by pressing one's back against one wall and one's feet against the opposite wall. My colleagues and I sometimes marvel at how skillful the ancient cave miners and explorers must have been to reach the remote ledges and crawlways where we have found their traces, especially since at least one member of each group had to use one hand to carry a torch.

† Watson, Patty Jo, 1986, Cave archaeology in the Eastern Woodlands: *Anthropology of the Americxas Masterkey*, publication of the Southwest Museum, Los Angeles, CA, 59(4):19-25, Winter edition.

CRF FELLOWSHIP AND GRANT SUPPORT

Each year, the Foundation may award up to $4,000 as a Fellowship or as one or more grants for research in karst-related fields. The truly exceptional proposal may receive a Karst Research Fellowship (limit $3,500); meritorious proposals may receive one or more karst research grants, in amounts less than $2,000, awarded to qualified students in graduate programs in the natural or social sciences. Applications are screened by a committee of scientists. The judges seek promising or innovative topics, supported by evidence that the student has command of the literature and the methodology. A detailed announcement is mailed in the late Autumn, and the deadline for the receipt of the proposal, supporting documents and letters of reference is January 30. Awards are announced by April 15. Send inquiries to:

Dr. John C. Tinsley
U. S. Geological Survey
345 Middlefield Road Mail Stop 975
Menlo Park, CA 94025

In 1985, four proposals were received and the following Grants were awarded:

1. A CRF Karst Research Grant ($1500) awarded to Ms. Jill Yager, Department of Biological Sciences, Old Dominion University, Norfolk, VA 23508-8560 for her proposal entitled "The Ecology of Anchialine Caves of the Bahamas".

2. A CRF Karst Research Grant ($1000) awarded to Mr. Donald A. McFarlane, Department of Biology, University of Southern California, Los Angeles, CA for his proposal entitled "Systematic Paleontology of a Quaternary Mammalian Assemblage, with Implications for the Biogeography of Jamaica".

3. A CRF Karst Research Grant ($1000) awarded to Mr. Richard H. Phillips, Department of Geography, University of Oregon, Eugene, OR 97403-1218 for his proposal entitled "Karstification of Mescalero Caliche, Eddy County, Southeastern New Mexico".

4. A CRF Karst Research Grant ($500) awarded to Mr. John H. Rosenfeld, Department of Chemical Engineering, University of Michigan, Ann Arbor, MI 48109 for his proposal entitled "Dissolution Kinetics of Calcite".

Research summaries and progress reports submitted by these investigators are published elsewhere in this Annual Report. Please refer to these summaries for additional details of objectives, methods and results.

INTERPRETATION AND EDUCATION PROGRAMS

Figure 10: Big Bone Cave entrance on the north side of Bone Cave Mountain, Van Buren County, Tennessee. This cave was visited frequently by pre-historic miners in search of gypsum and other minerals, then during historic times by saltpeter miners. See the article on page 31. (Photo by Charlie Hall).

Education Program

Kentucky Library Project

Margaret J. Tucker

In 1985, over 150 books were distributed to five public and 14 public school libraries as part of the Kentucky Library Project. The purpose of this project was twofold: first, to disseminate information about caving to residents near Mammoth Cave; and secondly, to give the Cave Research Foundation favorable publicity (either by word-of-mouth or printed). This dissemination was accomplished by offering area libraries free books, and sending out press releases to area newspapers afterwards.

In February, 1985, George Wood and Claire Wood helped compile an annotated bibliography of Cave Book listings. This bibliography was meant to be the selection tool used by librarians to order books tailored to their collection.

In April, 1985, letter were sent to Bowling Green Public Library, Horse Cave Free Public Library, Hart County Public Library, Green County Public Library, Edmonson County Public Library, Butler County Library, the Barren River Regional Library, the Library Coordinator of the Warren County Board of Education, Superintendent of the Bowling Green City School System, Hart County High School Library, the Glasgow High School Library and the Edmonson County school system. The Public libraries were garnered through the American Library Association *Directory*, and school libraries were contacted through school systems' offices.

A cut-off deadline of May 1, 1985 was given, although orders were received as late as June. School librarians tended to order everything on the bibliography; some public libraries ordered multiple copies. Since some books were out-of-print or were about to reach that status (*Trapped!* and *A Bat is Born*) or were probably unsuited to a library's collection, some judicious selection was applied to fulfilling the orders. Tom Brucker assisted in this delicate portion of order fulfillment.

Catalog card sets were also offered with the books in order to increase librarians interest in the collection. Unfortunately, only one-third of the books listed on the bibliography had commercially prepared catalog sets available. The sets were purchased, and books were gathered and distributed.

Press releases were written and copies were placed, along with an explanatory letter to each librarian, in each box of books. Librarians were asked to make copies of any press coverage, to return to C.R.F. Two weeks after books were shipped, the same releases were sent to the *Bowling Green Park City News*, the *Glasgow Times*, the *Glasgow Republican* and the *Morgantown Green River Republican*. Books were shipped in October, 1985, and copies of any press coverage will be sent to the President of CRF.

Publications and Presentations

PUBLISHED ARTICLES AND PAPERS

Anthropology, Archaeology, and Paleontology

Watson, Patty Jo, 1985, Archeology: Caves and Karst of Kentucky Special Publication No. 12, Series XI, (P. Dougherty, ed.): Kentucky Geological Survey, Frankfort, KY, pp. 176-186.

----------, 1985, The impact of early horticulture in the upland drainages: Production of the Midwest and Midsouth: Prehistoric Food Production in North America, Anthropological Papers No. 75 (R. Ford, ed.): Museum of Anthropology, University of Michigan, pp. 99-147.

Ecology

Cohen, Julie S., 1985, Competition of cave beetles (*Ptomaphagus hirtus*) and fungi for dung: M.S. thesis, Department of Biological Sciences, University of Illinois at Chicago, 47 pp.

Geoscience

Palmer, Arthur N., 1985, The Mammoth Cave region and Pennyroyal Plateau: in *Caves and Karst of Kentucky* (P. H. Dougherty, ed.), Kentucky Geological Survey Special Publication No. 12, pp. 97-118.

BOOKS AND PERIODICALS

Periodicals

Brucker, Lynn Weller, 1985, *CRF Newsletter*: Cave Research Foundation, Cedar Falls, IA, published quarterly.

Lindsley, Karen B. (ed.), 1985, *Cave Research Foundation Annual Report - 1984*: Cave Books: St. Louis, MO, 60 pp.

PROFESSIONAL, INTERPRETIVE AND ADVISORY PRESENTATIONS

Anthropology, Archaeology and Paleontology

Crothers, George M., 1985, The Aboriginal exploration and utilization of Big Bone Cave, Tennessee: Paper presented at the Nat'l Speleol. Soc. Convention, Frankfort, KY, June 28.

Munson, Patrick J., P. J. Watson, K. B. Tankersley and C. A. Munson, 1985, Prehistoric selenite mining in the Mammoth Cave System, Kentucky: Paper presented at the Nat'l Speleol. Soc. Convention, Frankfort, KY, June.

Watson, Patty Jo, 1985, The origins of plant cultivation in eastern North America: Paper presented at the Annual Meeting of the American Assoc. for the Advancement of Science in a Symposium on "The Origins of Agriculture in World Perspective", Los Angeles, CA, May.

----------, 1985, Prehistoric exploration of the world's longest cave: Talk given to Elderhostel Program at Western Kentucky University, June 13.

----------, 1985, The Green River shell mound archaic: Talk given to Elderhostel Program at Western Kentucky University, June 13.

----------, 1985, People and caves: Paper presented to National Park Service Cave Management Seminar, Carlsbad Caverns National Park, November 13.

----------, 1985, Cultural resource considerations: Paper presented to National Park Service Cave Management Seminar, Carlsbad Caverns National Park, November 14.

Ecology

Lisowski, Edward A., 1985, Ecological correlates of terrestrial cave dwelling invertebrates in large river passages in Puerto Rican caves: Paper presented at the biology session, Nat'l Speleol. Soc. Convention, Frankfort, KY, June 24.

Poulson, Thomas L., 1985, Evolution and ecology of cave animals: Talk given to Mammoth Cave National Park guides, March 1.

----------, 1985, Participant in invited international symposium on Regressive Evolution (abs.): Nat'l Speleol. Soc. Convention, Frankfort, KY, June.

Geoscience

Hill, Carol A., 1985, Lecture presented on "cave minerals" to the University of New Mexico PE Caving Class, April.

----------, 1985, Guest speaker on "cave minerals of the world" at the seminar of the New Mexico Tech Department of Geoscience and New Mexico Bureau of Mines and Mineral Resources, September 12.

----------, 1985, Lecture presented on "cave minerals of the world" to the University of New Mexico PE Caving Class, October.

Palmer, Arthur N., 1985, Origin of caves and karst: Invited Lecturer to the Dept. of Geology, Franklin and Marshall University, Lancaster, PA, January.

Tinsley, J. C., 1985, Origins of Caves: Presented to 4th grade Lyceum, Los Gatos, CA., (November).

----------, and J. Sowers, 1985, Paleoclimatic signals from caves: Poster session presented at Geological Society of America, Penrose Conference, "Stratigraphic Evidence of Climatic Change", Lake Havasu City, AZ, (April).

Watson, Richard A., 1985, The adventure of the cave: Lecture presented to Experience, Inc., University Club of St. Louis, MO, November 20.

SERVICE

Hill, Carol A., 1985, Consultant to Cave of the Winds, Colorado Springs, CO on the cleaning and restoration of speleothems in the tourist parts of the cave, and on the resource potential of the wild parts of the cave, September 1-2.

----------, 1985, Acted as an Instructor and presented a talk on the "resource management of cave minerals" at the National Park Service Cave Management Seminar, White City, New Mexico, November 13-18.

Lisowski, Edward A., 1985, Participant in the Biology Short Course offered during the Nat'l Speleol. Soc. Convention, Frankfort, KY, June 25.

----------, 1985, CRF representative on the Special Mammoth Cave Excursion during the Nat'l Speleol. Soc. Convention, Frankfort, KY, June 26.

Palmer, Arthur N., 1985, Contributor to the short course in Karst Geology: Nat'l Speleol. Soc. Convention, Frankfort, KY, June.

Poulson, Thomas L., 1985, Participant in workshop on "biology of cave organisms": Nat'l Speleol. Soc. Convention, Frankfort, KY., June.

----------, 1985, Editing contribution of diagrams and clearing house for photo contributions to interpretive booklet for Mammoth Cave National Park (Mammoth Cave, by J. L. Wagoner and L. D. Cutliff, Interpretive Publications, Inc.).

Watson, Patty Jo and C. Wesley Cowan, 1985, Organizers of a Symposium on "The Origins of Agriculture in World Perspective": Annual Meeting of the American Association of the Advancement of Science, Los Angeles, CA, May.

Cave Books

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

The sale and distribution of Cave Books' publications materials, wholesale and retail, is being managed by:

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

Cave Books created a publishing initiative in 1983 with the goal of publishing one new cave book each year. Funding and management of this publishing effort will be handled independently of other internal publication efforts. The personnel managing publishing include:

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

Initial funding for publishing was provided by $10,000 in donations from thirty Foundation personnel. The first book in the series, The Grand Kentucky Junction, was released in the spring of 1984. Revenue from its sales will support the cost of a second book, and so on,thereby providing self-sustaining funding for each following publication. A new book, Yochib: The River Cave by William Steele, should be in print by the summer of 1985.

Publications represents a major and growing effort in the Foundation. We continue to solicit manuscripts and add new items to our inventory. Revenue from this effort provides primary support for many Foundation programs, including the Annual Report. Books published by Cave Books (Intl. Standard Book Number ISBN9 prefix-0-939-748-) 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 general address for Cave Books is 756 Harvard Ave., St. Louis, MO 63130 USA. A complete listing of books and maps available through Cave Books may be obtained by writing to this address.

Bibliography of Cave Books Publications to Date

Conn, Herb and Jan Conn, 1981, *The Jewel Cave Adventure*: Cave Books, St. Louis, MO, (illus.) 240 pp.

Crowther, P. P., C. F. Pinnix, R. B. Zopf, T. A. Brucker, P. G. Eller, S. G. Wells, J. F. Wilcox, 1984, *The Grand Kentucky Junction*: Cave Books, St. Louis, MO, 96 pp.

Daunt-Mergens, Diana O. (ed.), 1981, *Cave Research Foundation Personnel Manual*: Cave Books, St. Louis, MO, 3d ed., (illus.), 155 pp.

Lavoie, Kathleen H. (ed.), 1984, *Cave Research Foundation Annual Report - 1983*: Cave Books, St. Louis, MO, (illus.), 45 pp.

Lindsley, Karen B. (ed.), 1984, *Cave Research Foundation Annual Report - 1981*: Cave Books, St. Louis, MO, (illus.), 55 pp.

__________, (ed.), 1985, *Cave Research Foundation Annual Report - 1984*: Cave Books, St. Louis, MO, (illus.), 60 pp.

Moore, George W. and G. Nicholas Sullivan, 1981, *Speleology: The Study of Caves*: Cave Books, St. Louis, MO, (revised ed., illus.), 163 pp.

Noswat, Erd, 1976, *Maws, a Parody*: Cave Books, St. Louis, MO, (illus.), 36 pp.

Palmer, Margaret V. (ed.), 1981, *Cave Research Foundation Annual Report - 1980*: Cave Books, St. Louis, MO, (illus.), 51 pp.

__________ and Arthur N. Palmer (eds.), 1983, *Cave Research Foundation Annual Report - 1982*: Cave Books, St. Louis, MO, (illus.), 45 pp.

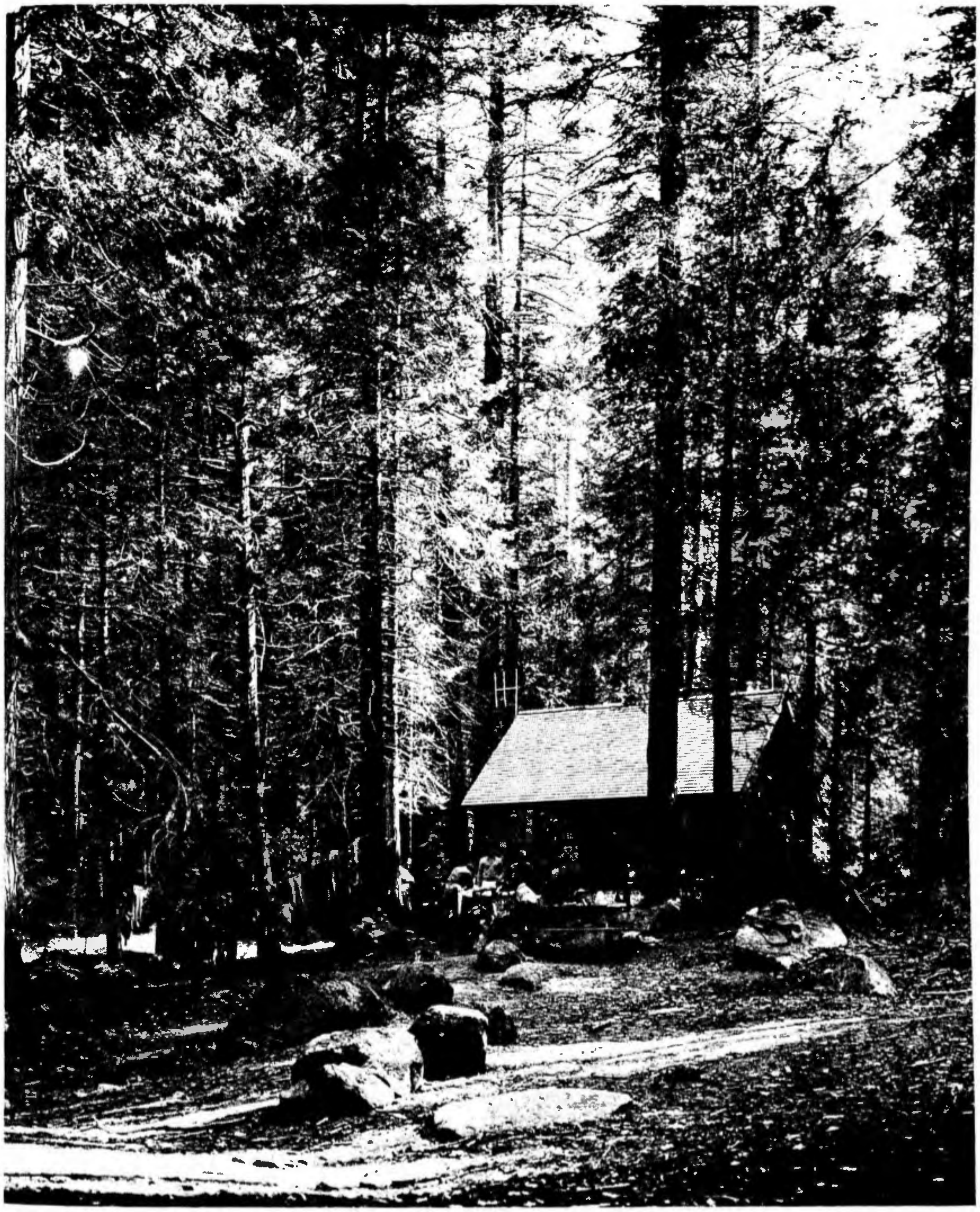
Poulson, Thomas L. and Bethany J. Wells (eds.), 1981, *Cave Research Foundation Annual Report - 1979*: Cave Books, St. Louis, MO, (illus.), 74 pp.

Steele, C. William,1985, *Yochib: The River Cave*: Cave Books, St. Louis, MO., (illus.), 176 pp.

Watson, Richard A. (ed.), 1981, *Cave Research Foundation: Origins and the First Twelve Years: 1957-1968*: Cave Books, St. Louis, MO, (illus.), 495 pp.

__________, (ed.), 1984, *Cave Research Foundation: 1969-1973*: Cave Books, St. Louis, MO, (illus.), 290 pp.

__________, (ed.), 1984, *Cave Research Foundation: 1974-1978*: Cave Books, St. Louis, MO, (illus.), 366 pp.



THE CAVE RESEARCH FOUNDATION

Figure 11: The Lilburn field station used by CRF during expeditions held in Sequoia and Kings Canyon National Park, California. (Photo by William Frantz)

CRF Management Structure 1985

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Sarah G. Bishop	John C. Tinsley
Rich Wolfert	Richard B. Zopf

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Operations Manager	Paul Blore
Chief Surveyor	David Hoffman
Project Cartographers	Gary R. Schaecher
	Jack Regal
	John P. Brooks
	Robert L. Taylor
Newsletter	Pete Lindsley
Sylamore Operations Manager	Thomas A. Brucker
Sylamore Cartographer	Doug Baker

OPERATING COMMITTEES

The Foundation has established four permanent committees to help conduct its business. All Committees are chaired by a Director of the Foundation.

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

John C. Tinsley, Chairman	Beth Estes	Arthur N. Palmer
E. Calvin Alexander	John W. Hess	Margaret V. Palmer
William P. Bishop	Carol A. Hill	Thomas L. Poulson
Nicholas Crawford	Francis Howarth	Patty Jo Watson
David J. DesMarais	Kathleen H. Lavoie	Ronald C. Wilson

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

Finance Committee : Drafts Foundation budgets, provides advice to treasurer and seeks sources of funds to support Foundation programs. The Cave Research Foundation is a non-profit, tax-exempt organization recognized by theInternal Revenue Service under IRS Code, Sec. 501 (c)(3) and assigned Federal Number 31-6052842. The primary source of funds for operation of the Foundation is derived from gifts, bequests and other private contributions. Revenue from the Foundation endowment Fund, established in 1974, is used to support a Grants/Fellow ship Program to support research in karst-related disciplines. Other sources of income are obtained from the sale of publications and limited contract projects. The Foundation is maintaining good financial stability with the growth and subsequent increased revenue from our Publications affiliate, Cave Books, and the Endowment Fund.

Roger E. McClure, Chairman/ Treasurer	Roger W. Brucker	L. Kay Sides

Publications : Provides policy guidance and direction on all Foundation publication matters, proposes publications initiatives, assists individuals/groups in accomplishing their publication goals, reviews/coordinates all proposed publications, insures all publications meet desired quality and format standards and represent the Foundation in a favorable manner. Publications activity has become a major force in CRF operations over recent years, primarily through the Foundation's publishing affiliate, Cave Books. The effort has been two-fold: first, to provide a service to CRF and the caving community; and second, to produce revenue to fund Foundation activities.

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

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COMPUTERS AND ANNUAL REPORTS

Each of the past several years of publishing the CRF Annual Report has brought us closer to complete computer processing of the materials that goes into one of these reports, and this year is no exception. In the 1970's the process involved gathering the material, sometimes typing the hard-to-read hand manuscripts, placing the material in some sort of order, and mailing it all off the the "Printer". The "Printer", also acted as typist, typesetter, spelling checker, intermediate editor, layout and artistic designer, final copy editor, printer and publisher. Occasionally, the editor was familiar with most of this process and the materials would fit right in. But usually, the editor was most skilled at just the painful extraction of materials from the contributors and relied on the "printer" to make the stack of submitted material look like the Annual Report that is expected today from the Foundation.

The next level of report preparation implemented small computer word processors for the first typing. The ability to easily provide copies for review by the CRF science committee staff was welcomed. The advantage was that both errors and editing changes could be marked on the paper hard copy and later incorporated into the computer disk file. But then, the "Printer" had to re-keyboard the whole thing which tended to introduce additional errors in the text. You might think this problem was easily solved when the Printer placed a computer on his photo typesetting machine. We soon discovered that computers don't all speak the same version of 1's and 0's and that you certainly can't expect the disk formats to be compatible. Last year's 1984 Annual Report was a good attempt at eliminating the re-keyboarding problem. The text was entered on an Apple 2 using the Wordstar word processing program. Then, the text was transferred to a KAYPRO disk. The Printer then went from the KAYPRO format to the one of many TRS-80 formats which controlled the typesetter. EACH line had to be checked by the Printer for the extra line feeds that had been introduced by Wordstar and used by "normal" dot matrix printers. The end result did not include any significant time saving.

Two technology breakthroughs contributed to the success of the 1985 Annual Report. First, a "standard" typesetting language became popular to the extent that computer typesetting services were more widely available. Adobe Systems Incorporated (not the same as Adobe Press) designed the PostScript language that talks to both laser printers and even higher resolution typesetting equipment. Second, the price of sophisticated computer graphics hardware and the necessary page layout software came within the range of personal computer owners and provided an easy path to the PostScript machines. We believe that the Foundation is on the leading edge of a new wave of Desktop Publishing techniques that will revolutionize the printing industry as it existed prior to 1984.

The 1985 Annual Report was edited and published with the help of the following computer hardware (and software):

Hardware	Software
Apple][e Computer	(Wordstar, Xmodem)
Apple MacPlus Computer	(Microsoft Word, MacSpell+, Red Ryder, PageMaker)
Apple LaserWriter Printer	(PostScript).

So what's left for 1990? The halftone illustrations and some of the line work are still done by the old methods. At the present time the hardware that converts photographs to computer images is not of adequate quality. In the 1990's we may still not have all of the longest cave in the world on a single wall map, but I predict we will have computer pictures of the cave in the Annual Report!

Pete Lindsley