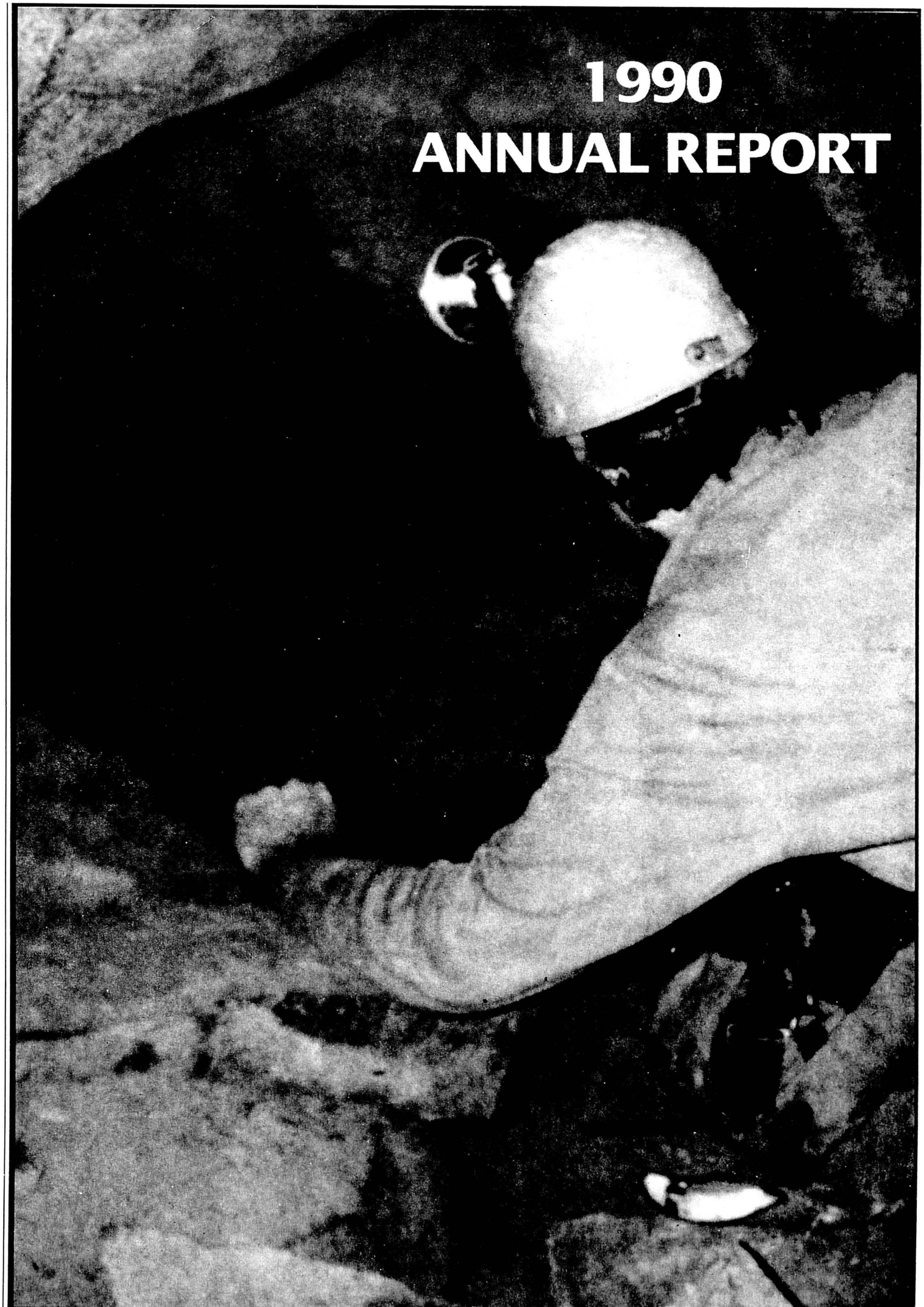
1990 ANNUAL REPORT



Cave Research Foundation

Annual Report 1990

Cave Research Foundation

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.

EDITOR
Karen Bradley Lindsley

EDITORIAL STAFF
R. Pete Lindsley

Cover photo: Kevin Neff exploring in McGown Way, Mammoth Cave. (*Photo by Scott House*).

ISBN 0-939748-33-9

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

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 Also, many of the processes that formed the cave passages we travel are no longer active in these areas.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 heir 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.

HIGHLIGHTS OF 1990

While the Cave Research Foundation has been involved in several projects and contracts in cooperation with the U. S. National Forest Service, it was not until this year that the foundation entered into a national Memorandum of Understanding with the Service. It is hoped that this increased cooperation will provide for better management and study of the cave resources administered by the National Forest Service.

This year saw the Foundation move its Mammoth Cave base of operations from Flint Ridge to the Maple Spring Ranger Station north of the Green River. There has been a time of adjustment for the way expeditions are being administered. While the facility is certainly adequate, the Board of Directors are formulating plans for the creation of a first class research facility that is located closer to the underground laboratory.

Several CRF scientists continue to be intimately involved in the pre-development environmental studies of Kartchner Cavers, Arizona. These scientists are performing contract work for Arizona Conservation Projects, Inc. (ACPI) who are doing the studies for the State of Arizona. The CRF Science Committee has been reviewing all draft reports prepared by ACPI.

A mapping and baseline biological inventory was initiated in Missouri in cooperation with the Mark Twain National Forest. This baseline study will be of vital importance if the area is opened to proposed lead mining.

The Guadalupe Escarpment Area of the Foundation entered into contracts with both the National Park Service and the Bureau of Land Management. Carlsbad Cavern National Park issued a contract that will allow for the completion of a precision survey in Lechuguilla Cave that will extend from the entrance to the E-F Junction. The Bureau of Land Management provided a contract for the survey of gypsum caves in the Chosa Draw area just to the southeast of Carlsbad Cavern.

A CRF-sponsored reconnaissance team located numerous large river caves in Guizhou Province, China. This team laid the groundwork for a second major CRF expedition to China that should take place in 1991 or 1992.

Rondal R. Bridgemon
Cave Research Foundation President

Contents

INTERPRETATION AND EDUCATION PROGRAMS

Intrepretation

Education

CARTOGRAPHY PROGRAM

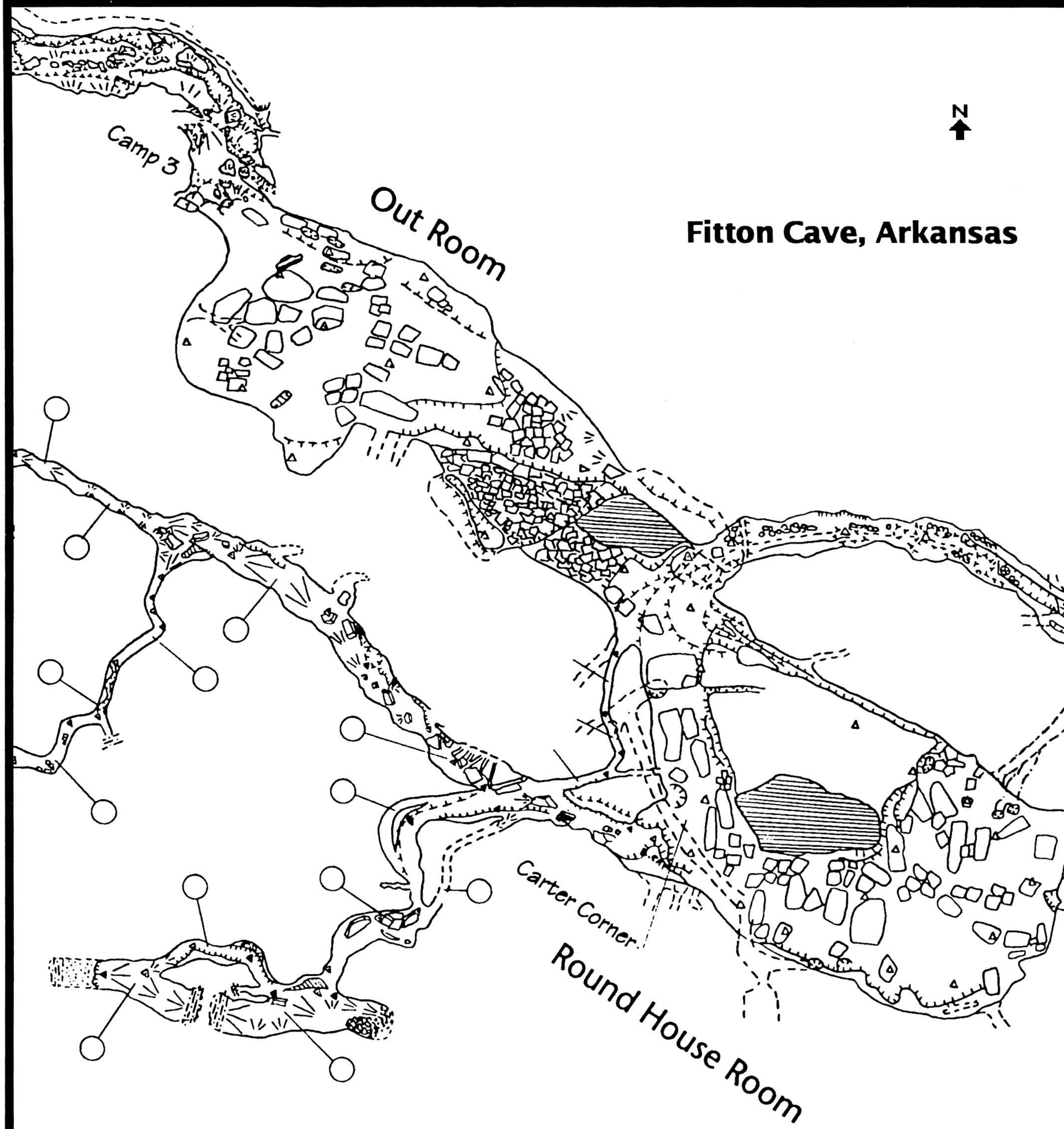


Figure 1: A portion of one of the quadrangle maps of Fitton Cave in Buffalo National River, Arkansas. The blank circles show where the project cartographers will add passage heights. Line maps are being generated using a computerized loop-closure program (CMAPS) – see the article and map on pages 15 and 16.

CARTOGRAPHY

General Resource Cave Inventory at Lava Beds National Monument

by Janet Sowers and Bill Devereaux

Lava Beds National Monument contains over one hundred lava tube caves. The objective of the general resources inventory is to provide Lava Beds managers with a method for gathering basic data on the caves, and then to gather this data on a selected group of caves. Inventory data will be used by Lava Beds managers to evaluate the significance and vulnerability of specific caves and make appropriate management decisions. We expect the inventory procedure to be used by Lava Beds staff in future years to gather information on additional caves as the need arises.

The inventory form, after two years of revisions, trials, and further revisions, was finalized this spring. The form is nine pages long and includes sections on cave location, history, entrance description, biology, geology, hydrology, atmosphere, cultural resources, visitor impact, access, and management. Information gathered will go into a computerized data base structure developed by NPS staff.

To assist CRF personnel and Lava Beds staff with consistent data gathering, an inventory handbook was prepared. This handbook includes item-by-item instructions for completing the form, as well as reference pages of keys to biologic species, geologic and cultural features, and a description of the resources rating scheme used to evaluate the caves. A copy of this handbook is available to accompany each inventory team in the cave.

A list of 24 caves to be inventoried was prepared in February, in cooperation with then Resources Manager, Charisse Sydoriak. The incoming Resources Manager, Patrick Toops, will review and make any necessary changes to the list while the work is in progress. The list includes caves that are especially significant and a selection of representative caves.

At our Thanksgiving expedition we held a half-day inventory training session. Thirteen joint-venturers participated in the training. These people will likely form the core of our inventory teams for the next year.

The inventory project is a cooperative one between the monument and CRF, and Lava Beds contributed substantial hours to the inventory this summer. A Student Conservation Association summer volunteer took on the task of gathering location, historic, and entrance description data for all 24 caves. This work has saved us countless hours, ensured that these data were consistently gathered, and allowed us to now concentrate our time inside the caves.

To date, field work is complete on the interior of nine caves. Additional work is in progress to check, correct, and finalize these inventory forms. In the coming year we expect to complete inventories of the remaining thirteen caves.

We have found the cave inventory process to be an enlightening one in many ways. Rarely in speleology do we have the opportunity to spend time moving slowly through a cave recording such a wide variety of attributes. Rarely, too, do we have the opportunity to collect data which will allow us to compare such a variety of attributes in a quantitative way among many different caves. This project will likely make significant contributions to science as well as to management. For example, this small sample of inventory data shows that Valentine Cave and Crystal Cave are strikingly different in geologic history, atmosphere and biology.

Feature	***Valentine***	***Crystal***
Intact passage	1726 ft	202 ft
Breakdown passage	61 ft	2319 ft
Number of levels	1	4
Ice floor	0 sq ft	10,050 sq ft
Slime (bacteria coating)	976 sq ft	0 sq ft

Cave Mapping at Lava Beds National Monument

by Mike Sims and Bruce Rogers

The objectives of this project are to survey and map the caves that are expected to be of most significance for purposes of cave inventory and cave management. Caves more than 100 feet in length or that have significant contents or features will be mapped. A minimum of twelve caves were originally to be mapped in the scope of this project.

To date, twenty-five caves have been surveyed as part of this project. Twenty-two of these are drawn up, some in final form, others in sketch form awaiting a final field check. Final drafts will be drawn in 1991 and reproducible copies transmitted to the National Park Service at the close of the mapping project in 1992.

Lilburn Cartography Project 1990

by Peter Bosted

This year was again fairly productive for the survey of Lilburn Cave. About 1.0 miles of new passage was surveyed by 19 survey parties during six expeditions. A total of 499 survey stations were set, making the average shot length just over 10 feet. Most of the passages surveyed were side passages off of the major trends, with no major discoveries made to extend the boundaries of surveyed cave. A complex maze of crawls was found in the East Stream area, several new rooms and crawls were found off of the Blue Passage, progress was made in mapping the complexity in the vicinity of the Mirabilite Room, the 1 by 10 Complex was extended, and a surprising number of side passages were found leading from the Enchanted River. Some of the leads from Hog Heaven were pushed, leading to a additional canyon, but several interesting leads remain for next year in this new part of the cave.

Very dry conditions allowed a party to survey from the Upstream Rise to the White Rapids. Bill Farr then dove upstream from The Rise, penetrating about 350 feet in a passage that gradually descended to a depth of 56 feet, where he turned back. The passage continues deeper, but there was only about ten inches between the ceiling and the sand floor. This exploration dashed hopes that a dive might easily lead to the hypothesized Great North Cave which should underlie the two miles of sinkholes dotting the surface of Redwood Canyon between Lilburn Cave and the uppermost sinkpoint for Redwood Creek.

Two trips continued the surface survey along the road as far as the stream crossing. A third trip made another map of the new sink at Pebble Pile Creek, so that its evolution with time can be documented and studied. The 20-feet-per-inch (1:240 scale) map of the cave has been updated with the 1990 surveys, and progress continues to be made on producing a set of quadrangle maps, also at a scale of 1:240. A map using different gray tones to depict corresponding subsurface levels in the cave (for the plan), or for different distances from the viewer (for the profile) was produced; this map is entirely computer-generated. All algorithms used for smoothing the walls (spline fits were used), solving the hidden line problem, and dealing with splay shots and the definition of rooms were written by the author.

The current surveyed length of Lilburn Cave is 12.36 miles (19.9 km), making it apparently the longest cave survey west of the Continental Divide (see Figure 18 in the center of this book).

Pre-Development Studies at Kartchner Caverns, Arizona

by Robert H. Buecher

The CRF Board agreed to provide assistance to Arizona Conservation Projects, Inc., (ACPI) in their baseline environmental study of Kartchner Caverns. CRF's direct assistance has been in the form of surveying equipment and providing for the review of the draft reports prepared by ACPI's scientific team. Several CRF scientists are principal investigators for this team. Robert Buecher, former CRF director, is the Project Manager for ACPI.

Introduction

To prepare for the public opening of Kartchner Caverns in an environmentally sensitive manner, Arizona State Parks has contracted with ACPI for a two year pre-development study of the cave.

The purpose of the pre-development studies now being conducted is to provide a framework of basic knowledge about the geologic and environmental conditions of Kartchner Caverns. The studies will document existing conditions and provide information critical to the sound development and management of the cave for public viewing.

Without such a study, the delicate environment of Kartchner Caverns could be exposed to hazards that could ruin it as an attraction and as a pristine natural wonder.

The studies focus on four main aspects of the cave environment: (1) cave climate and meteorology, (2) geology, (3) hydrology and (4) biology. This article will serve as a brief overview of the principle studies as well as an introduction to the team of experts ACPI has assembled.

Cave Microclimate

Of all the studies, cave microclimate and meteorology will be the most critical in designing an environmentally sound cave development and management plan.

Arizona State Parks intends to maintain humidity, temperature and air flow in the cave in order to preserve the unique features of the cave. The contrast between the moist interior of the cave (over 95% relative humidity) and the dry desert above make Kartchner Caverns particularly vulnerable to damaging changes. Large parts of the cave are still "live". In the live areas, calcite is still being deposited and speleothems are forming. Changes in airflow, temperature or humidity caused by improper development could quickly dry out the cave, halt speleothem growth, and diminish the cave's beauty.

Other parameters being investigated in this study include evaporation rates, air quality, drip rates and surface meteorology. A total of 22 micrometeorological monitoring stations have been installed throughout the cave.

To better understand the relationship between the cave climate and outside weather data is being collected on surface conditions. A surface meteorological station has been installed which includes instruments for recording temperature, relative humidity, air pressure and rainfall.

Cave climate studies are being performed under the direction of Thomas Aley, director of the Ozark underground Laboratory.

Geologic Studies

The geological studies include investigations of the surface geology, subsurface geology, speleothems (cave decorations), mineralogy, speleogenesis and a geophysical survey. Overall direction of the geologic studies will be performed by Dr. Edgar J. McCullough, Jr., Dean of the Science Faculty at the University of Arizona.

The objectives of the surface and subsurface geological investigations are twofold: (1) to provide a detailed understanding of the geological setting and speleogenesis of the cave and (2) to provide geological engineering information critical to the evaluation of potential visitor access points. Geologic mapping and interpretation will be performed by Dr. Kenneth Thomson. Underground mapping and speleogenesis will be performed by David Jagnow.

Speleothems and Mineralogy – Secondary mineral deposits within Kartchner Caverns give it much of its beauty. The speleothems decorating the cave are composed primarily of calcite. The inventory and assessment of the cave minerals will be conducted by Carol Hill.

Geophysics - The primary purpose of the geophysics is to determine if additional large, unknown cave chambers are located within the Park boundaries. Another objective is to aid in the placement of surface facilities to minimize impact on the cave. The geophysical investigations will be conducted by Art Lange, Manager of Operations for the Geophysics Group.

Hydrology

Kartchner Caverns was formed by the reaction of the limestone rock and the ancient water table. Even today the presence of water in the cave and elsewhere in the park plays a vital role in maintaining the conditions in the cave. The hydrologic studies aim to understand the relationship between the cave and the surrounding groundwater. As a part of this study frequent measurements are taken at each of several water wells located on the Park. The impact of surface flooding on the cave and proposed visitor facilities will also be assessed.

The hydrology studies are headed by Charles G. Graf, of the Arizona Department of Environmental Quality.

Biology

The most visible sign of biological activity in the cave are the bats. Kartchner Caverns is the summer migratory and maternity home for about one thousand Cave bats (*Myotis velifer*). The bats begin arriving from their winter range in Mexico in May, have young about the third week of June (which begin flying the first week of August), and leave by mid-September.

Bats occupy a vital niche in the cave ecosystem, therefore much effort is being devoted to understanding their habits and requirements. Bat studies are under the direction of Rhonda Sidner, a bat ecologist and mammalogist with eight years of experience studying the bats in southeast Arizona.

Invertebrates make up the majority of all known cave organisms, but tend to be overlooked during cave inventories. The dark, generally nutrient-poor habitat of caves gives rise to interesting invertebrate-dominated ecosystems and unique cave-limited species. Invertebrate studies will be performed by Dr. Warren C. Welbourn.

Other Studies

The potential of the cave to support algae and moss growth is being studied. Such growth is a common problem in electrically lighted caves. A notable example of the problems that can be caused is Lascaux Cave in France. There algae began to grow over prehistoric cave paintings. As a result, the cave was permanently closed to the general public. Catherine Aley will conduct the plant growth studies. She has previously been involved in studies on controlling plant growth at Carlsbad Cavern and Blanchard Springs Caverns.

Additional studies being performed as part of the pre-development studies include (1) a history of the discovery and exploration of the cave, (2) a program of systematic photos to record existing conditions and monitor changes in cave features, producing maps of the cave in support of the other studies, (3) a study of the small animals that utilize the cave, and (4) constructing a model of the cave.

MISSOURI CAVE INVENTORY AND MAPPING

by Scott House

Inventory and survey projects on state and federal lands in Missouri began in 1980 as a project of Southeast Missouri Grotto and the Missouri Speleological Survey; these projects have been under the auspices of the Cave Research Foundation for the last several years. These projects are performed under volunteer agreements signed with three agencies: the Missouri Department of Conservation, Ozark National Scenic Riverways (National Park Service), and Mark Twain National Forest (United States Forest Service.) Much of the field work done over the past year has been on Mark Twain National Forest lands.

Mark Twain National Forest

The survey of Still Spring Cave (Douglas County) continued with four trips taken in 1990. One major stream inlet was mapped to its termination, other leads were completed, and one major lead opened up into virgin walking passage. This is the longest cave on MTNF land and it just keeps getting longer. In the same area, a survey of Davy Crockett Cave was begun at the request of the Forest.

In Washington County, three trips were required to finish 250' long Hazel Creek Cave. Clearcuts, energetic beavers, and bad weather all contributed to a very difficult survey. Nearby, two trips were taken to Brazil Pit Cave which is nearly finished.

In Iron County two trips were taken to continue the survey of Cave Hollow Cave which shows no sign of ending. In the same general area a small cave located within Bell Mountain Wilderness was mapped.

Most of the work done in 1990 was on a project in a lead drilling permit area. For each cave within the study area the following are needed: a map, a geologic/hydrologic characterization, and a baseline biologic inventory. The area in question is a heavily disguised karst area; a thick mantle of residuum conceals sinking streams, sinkholes, springs, and even caves. With lead prospecting and the possibility of lead mining in the area it is important to have a complete inventory of what we know; the catch is that so much karst is hidden that what we don't know about is far greater. Three survey trips were taken to Kelly Hollow Cave (Oregon Co.) to finish that lengthy cave; three trips were also taken to Barrett Spring Cave in the same immediate area. Barrett Spring is a typical Ozark spring cave where an almost impenetrable spring entrance leads to a good amount (more than a half mile) of very large passage. Other caves within the study area that were surveyed include Pipe Spring Cave, Hurricane Creek Bear Cave, Cascade Spring Cave, Mine Hollow Cave, and Bockman Spring Cave. One cave (Blue Spring Cave) that lies just out side of the defined area was also mapped.

Ozark National Scenic Riverways

Several small shelters and short caves along the Jacks Fork were surveyed in 1990. In addition, work continued on two large projects. Powder Mill Creek Cave is on land within the ONSR that is actually owned by the Missouri Department of

Conservation. Six trips were taken there in 1990 with good results. Most of the work done is either up the Third Watercrawl or in a major side passage known as Hellhole. Large passage has been discovered in Hellhole and many leads exist. The Third Watercrawl is becoming something of an endurance challenge now that it is several thousand feet long. Allens Branch Cave, on private land just outside of the boundaries, is another wetsuit endurance cave. Trips going to the end of the surveys can expect one full mile of watercrawl to get there. The lead mining area project in the MTNF is also of considerable interest to the management of the waters of the ONSR; Big Spring, one of the largest single outlet springs in the United States, drains much of the study area and the National Park Service has requested Sole Source Aquifer status for the entire region.

Missouri Department of Conservation

Two projects were worked on in 1990. One is the aforementioned Powder Mill Creek survey project (both an ONSR and an MDOC project.) The other is the continuing survey of Great Scott Cave in Washington County. This year's survey trip turned up another 1000 feet of new survey. Only one trip a year is permitted; the cave is both a hibernaculum (winter) and a maternity site (summer) for endangered Indiana and Gray bats.

Personnel

Much of the above work was coordinated by Mick Sutton or Doug Baker. Others leading trips, coordinating work or drawing maps include Scott House, Bob Osburn, Paul Hauck and Jim Kaufmann.

Missouri Long Caves List

by Scott House and Doug Baker

An ongoing effort has been made to accurately track the length of the longest caves in Missouri. Interesting statistics crop up. The 100 longest mapped caves together add up to a total of 216 miles (110 miles less than the Mammoth Cave system in Kentucky.) Of that 216 miles the 20 longest caves in the state account for 135 miles. 93 of the 216 miles comes from one county (Perry) which has an intensely developed karst area somewhat generically referred to as the Perryville sinkhole plain. Of the 100 longest caves fifteen are in Perry County along the Mississippi River in southeastern Missouri, thirteen are in Pulaski County in central Missouri, seven are in Shannon County in south-central Missouri, and seven are in Washington County in eastern Missouri. Incidentally, this generally parallels the actual occurrence of cave entrances; Perry, Pulaski, and Shannon are the counties with the highest number of caves in the state. Five of the top twenty caves are owned by a government agency; three others are show caves.

Familiar names abound as many people associated with CRF were responsible for quite a few of the above projects. Paul Hauck and Bob Osburn led the way in the exploration and mapping of Crevice Cave, Paul drew up the Moore system map and coordinated all the work and did the cartography on Meramec Caverns. David Hoffman was chiefly responsible for the mapping of Carroll Cave over the past many years, Doug Baker has been coordinating the work in Still Spring Cave and Powder Mill Creek Cave while Mick Sutton and Sue Hagan are leading the effort in Great Scott Cave. Scott House coordinated the mapping of Piquet Cave, Cameron Cave, and Mark Twain Cave. Much of the field work has been done by cooperators of the Missouri Speleological Survey.

Most of the length information was obtained by the authors through personal communication or from files maintained jointly by the Missouri Department of Natural Resources and the Missouri Speleological Survey. Some of the lengths had to be figured by using a map wheel on a published map.

Table 1: Twenty Longest Caves in Missouri

Position	Cave	County	Miles	Kilometers
1	Crevice Cave	Perry	28.2	45.4
2	Moore Cave System	Perry	16.5	26.6
3	Mystery Cave System	Perry	15.8	25.5
4	Rimstone River Cave	Perry	14.0	22.6
5	Carroll Cave	Pulaski	11.3	18.1
6	Devils Icebox	Boone	5.6	9.1
7	Piquet Cave	Pulaski	4.9	7.8
8	Powder Mill Creek Cave	Shannon	4.6	7.4
9	Cameron Cave	Marion	4.6	7.4
10	Meramec Caverns	Franklin	4.0	6.5
11	Hot Caverns	Perry	3.1	5.0
12	Cathedral Cave	Crawford	2.9	4.8
13	Mark Twain Cave	Marion	2.8	4.5
14	Great Scott Cave	Washington	2.7	4.4
15	Maple Leaf Cave	Perry	2.5	4.1
16	Zahner Cave	Perry	2.2	3.6
17	Meisner Crevice Cave	Perry	2.2	3.5
18	Still Spring Cave	Douglas	2.2	3.5
19	Indian Creek Caverns	Stone	2.1	3.4
20	Mertz Cave	Perry	2.1	3.4

Fitton Cave Survey Project

by Pete Lindsley

The primary goal of this special survey project is the systematic precision survey of Fitton Cave, Arkansas. Located in the Buffalo National River, access to the cave is controlled by a permit system managed by the United States National Park Service. (Cavers other than CRF use the same permit system for access to the cave.) The initial milestones of the Project, a survey of the major trunk passages in the cave and a preliminary release of the draft map quadrangles were completed in 1989.

Jack Regal (Siloam Springs, Arkansas) took over as Project Operations Manager from Gary Schaecher in October, 1989. Gary will continue as the Chief Project Cartographer. Only two expeditions were fielded during 1990 (others were canceled due to wet weather, which limits field station access). The majority of survey work was centered on the Tennouri section of the cave including the Tennouri Room and Tennouri Helictite passage.

Survey data is archived and analyzed using computers. As the cave is surveyed by field teams, the survey data is entered into a database program. To date we have used Omnis 3 and FoxBase+ (Macintosh) and dBase 3 and FoxPro (PC compatible) programs as our "front end". These database programs are used to export the survey data to an

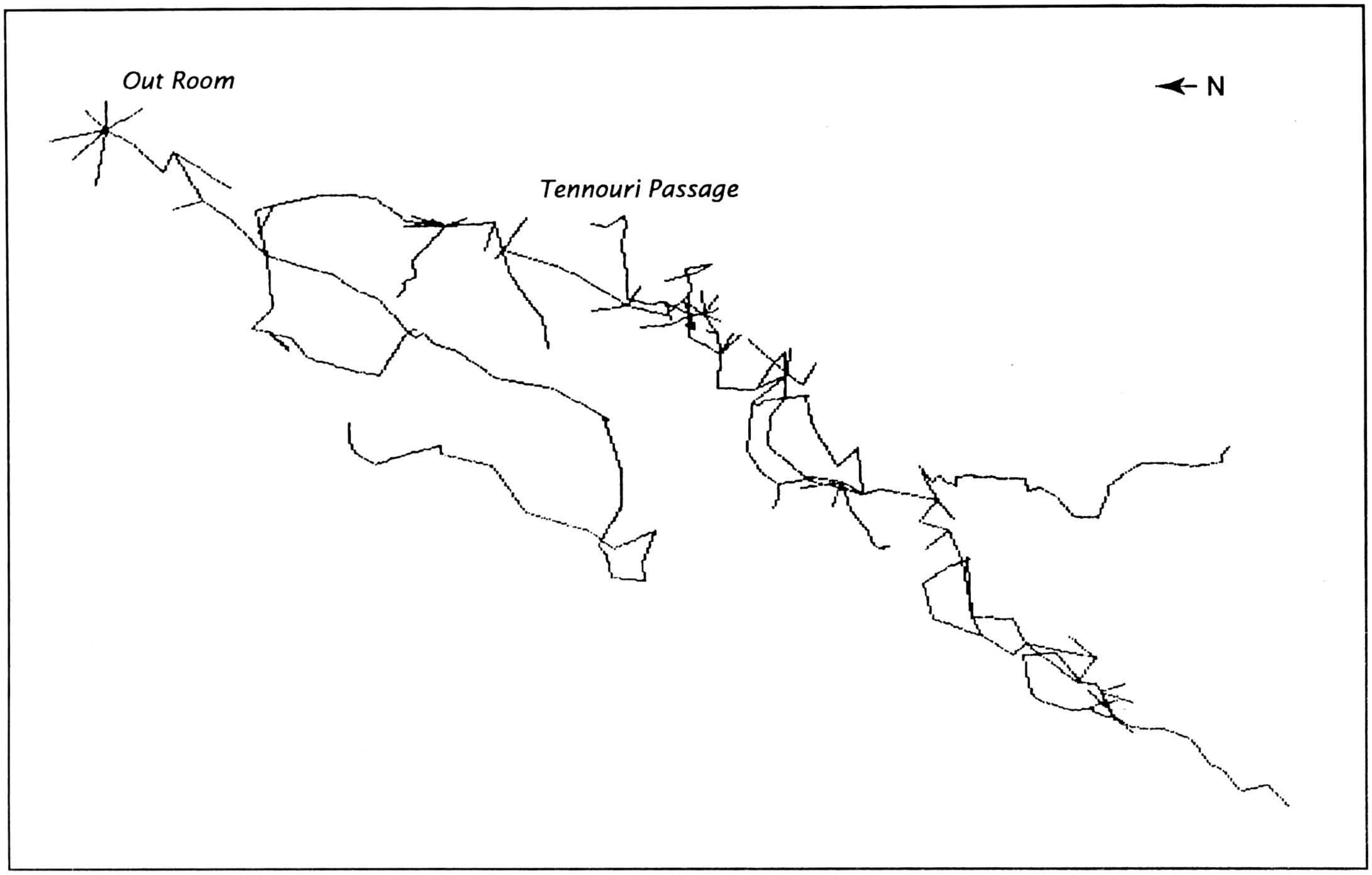


Figure 2: A line drawing of a segment of Fitton Cave, Arkansas compiled using CMAP computer programs.

ASCII file which can be edited with a word processor. Additional processing is performed using Robert Thrun's CMAP suite of programs. CMAP is used to compute closures and perform survey adjustments on loops. CQUAD7A is used to convert the CMAP data to plot files at the desired scale and orientation. PGDEP33 is used to output the line map plot files on an MX-100 dot matrix printer. ACROSPIN, a graphics utility program, is used to display the line maps on a color screen and provides rotational and zoom features. Figure 2 illustrates a typical dot matrix output of the Tennouri Passage area receiving emphasis during 1990.

Planning was completed in 1990 for continuation of the survey work in the cave during the 1990's as well as initiation of scientific studies. Near term survey objectives will center on the New Maze, Tennouri Helictite, and Lost Passage areas. Wall detail and passage cross sections on existing and future maps will be emphasized. Future work is expected to start in Bat Cave Passage, Lower East Passage and Fitton Spring areas. With a good baseline quadrangle map set in hand, CRF is now in a position to support additional scientific work on this "little Mammoth" cave in the Ozarks. There are several potential projects including mineralogy, geology, hydrology and biology that will be of interest to qualified scientists and researchers. Interested primary investigators should contact Pete Lindsley, Project Manager, or Jack Regal, CRF Fitton Project Operations Manager, for additional information.

Survey, Exploration, and Cartography of the Cave of Mammoth Cave National Park

by Scott House

The Mammoth Cave cartography program continues to make great strides along several parallel paths. Data reduction and manipulation tools continue to be more effective and integrated; survey efforts have improved in both quality and quantity; and traditional detailed map-making is moving along nicely.

FIELD WORK

Mammoth Cave Ridge

Work continues to support the 1:600 map series. We continue to resurvey passages that are not up to modern standards and 3.7 miles of passage was replaced in 1990. Over two miles of new passage was surveyed in a variety of areas. Some of these passages had been known at one time but forgotten over the years. About 1200 feet of new survey was put into upper levels of the Alberts Domes (Figure 3) and Henrys Dome areas with many leads left. Over 1000 feet was surveyed in the Emily's and Sitgreaves Avenues areas, Flint Alley and Jessup Avenue yielded over 500 feet of new survey, Solitary Cave begrudged us another 400 feet while Lower Robertson and West Bransford gave up another 400 feet. Upper levels of Woodbury's Pass led to some 800 feet of new passage; similarly, a push on the upper levels of Sansoms Domes discovered over 1100 feet of new passages. The biggest piece of new survey came from the rediscovery of a long-lost passage off of the Fox Avenue area. Found by guides more than fifteen years ago it had never been surveyed by CRF and thus far has given up nearly a half mile of crawls, canyons, and climbs.

Major resurveys were done of Emilys Avenue, Sitgreaves Pass, Thorpes Avenue, Stevenson's Avenue and Burleys Way. Other resurveys were done in East Bransford and the Henrys Dome area.

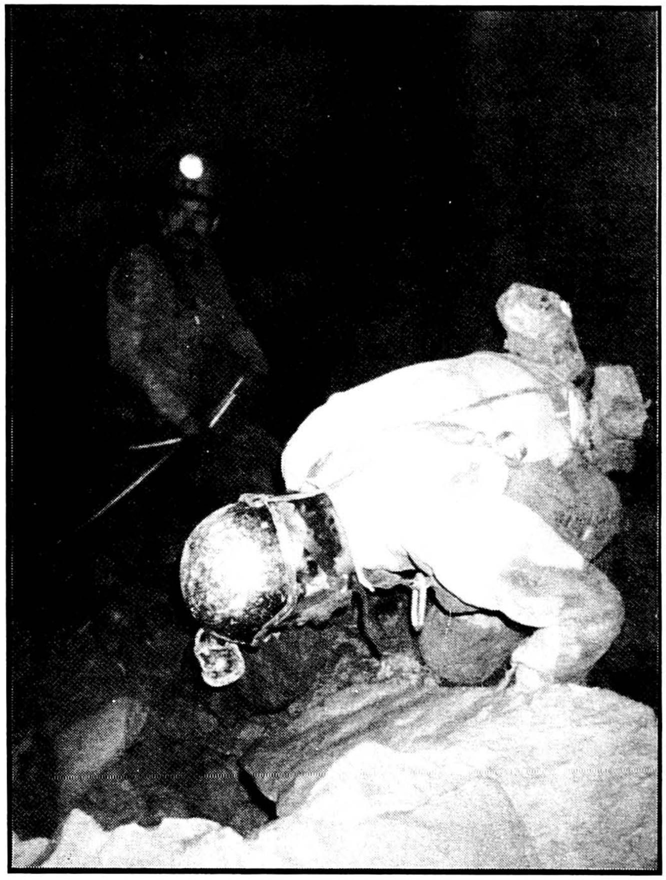


Figure 3: Tom Brucker and Steve Gentry at the top of the lobe of Alberts Dome. *(Photo by Scott House)*.

Hawkins River Area

Once again the weather played havoc with efforts up the river; rainfall patterns demonstrated an unusually high correlation to scheduled expeditions. Nonetheless over a half mile of new survey was put in - nearly all of which was located up the L survey. 1991 will see more efforts at surveying the many leads in this area. Travel time to the best leads is 4 - 6 hours from the Doyel Valley entrance. Some resurvey of the river trunk was done as well as new survey of side passages and flood routes along the river.

Flint Ridge

The major emphasis continues to be fixing the survey net of the Colossal/Salts complex; this involves a fair amount of resurvey. 2.8 miles of major passages were resurveyed in 1990 with about 1400 feet of new survey also done. Most of the passages resurveyed were connecting passages; for instance, several thousand feet of Grand Avenue was redone.

In Unknown Cave work centered on completing the Union Shafts and Textbook Shafts areas. 1700 feet of new survey was put in along with 1200 feet of replacement survey.

Surface Surveys

The Flint Ridge surface survey line (theodolite and EDM) was continued from the Salts entrance area down the boundary road and then to a benchmark at the Frozen Niagara entrance for a distance of over two miles. Two side shots, one of which was over 8000 feet in length, tied this survey to a benchmark on Toohey Ridge enabling another surface tie to the Roppel Cave section (Figure 4).

Figure 4: Scott House and Jim Borden at a theodolite station on Toohey Ridge. (*Photo by Patti Howe*).

Smaller Caves

Over 2000 feet of survey was done in several smaller caves in and around the park. New surveys are in progress of Indian and Long Caves and more survey was accomplished in Smith Valley Cave. Three small caves, Sturgeon Cave, Sloans Crossing Cave #1, and Crow Cave, were surveyed. Surface hunting located new caves, however, and this keeps us perpetually behind.

DATA REDUCTION

Progress continues to be made in the development of Cave Map Language (CML), CRF's universal data interpreter developed by Mel Park. Through its parsing abilities and translator programs CML can make use of virtually any type of ASCII code that we have available. Currently it is able to utilize the mainframe Crowther/Mann data of the 1970's, the Ohio CPM data from the early 1980's, the Missouri Apple ProDOS data from the late 1980's, and ASCII dumps from the present widely-used SMAPS program.

Presently CML is primarily used as an archival tool but it is a very fast data processor as well and closure routines are being developed at this time. Additionally, CML can be used to create list of station ties which can be turned into schematic form. Lastly, CML will probably be used as a data base for extracting a great deal of incidental information about surveys, surveyors, compasses, etc. CML is written in C and runs on Macintosh and MS-DOS machines.

Currently most of the new data is being entered through the latest version of SMAPS to make use of its editing and graphics features (Figure 5). Concerns over SMAPS' closure routines and file storage system limits its use at present; although these are being worked on it remains to be seen whether or not SMAPS continues to be used.

A very useful tool is the database of survey books which contains basic information about the area of the cave, amount of survey and resurvey, date, survey letters, etc. From this we can extract trivial bits of information (did you know that 177 feet of resurvey was done in Great Onyx Cave in

1967?) or more important types of information such as the length of the cave system. Maintenance and improvement of this database has taken a great deal of time but provides us with many important types of information. We even keep track of the location of xerox copies of survey books through this database (Bob Osburn currently has right at 150 books.) According to this database the length of the cave system at the end of 1990 was over 327 miles. This is a conservative figure and the true total is probably at least a couple of miles longer.

Cave	**Miles**	**Kilometers**
Crystal Cave	14.13	22.73
Colossal Cave	29.19	46.98
Salts Cave	13.39	31.21
Unknown Cave	45.15	72.65
Flint Ridge total	107.86	173.57
Proctor Cave/River	32.13	51.71
Mammoth Cave	128.69	207.11
Roppel Cave	59.16	95.21
System Total:	327.84	527.60

CARTOGRAPHY

System maps are drawn at a scale of 1:600 (1"=50' or 1cm = 6m) in pencil on 3 mil gridded mylar. Final maps are inked on 4 mil single-matte mylar. Maps of smaller caves are normally pencilled on paper and inked on mylar at a variety of scales depending on the nature of the cave. Final inked versions of system maps await a stopping point which has not been reached on any of them despite the best attempts of survey crews. The Kentucky Avenue map is being inked at this time and will hopefully be finished within the year. Maps of five smaller

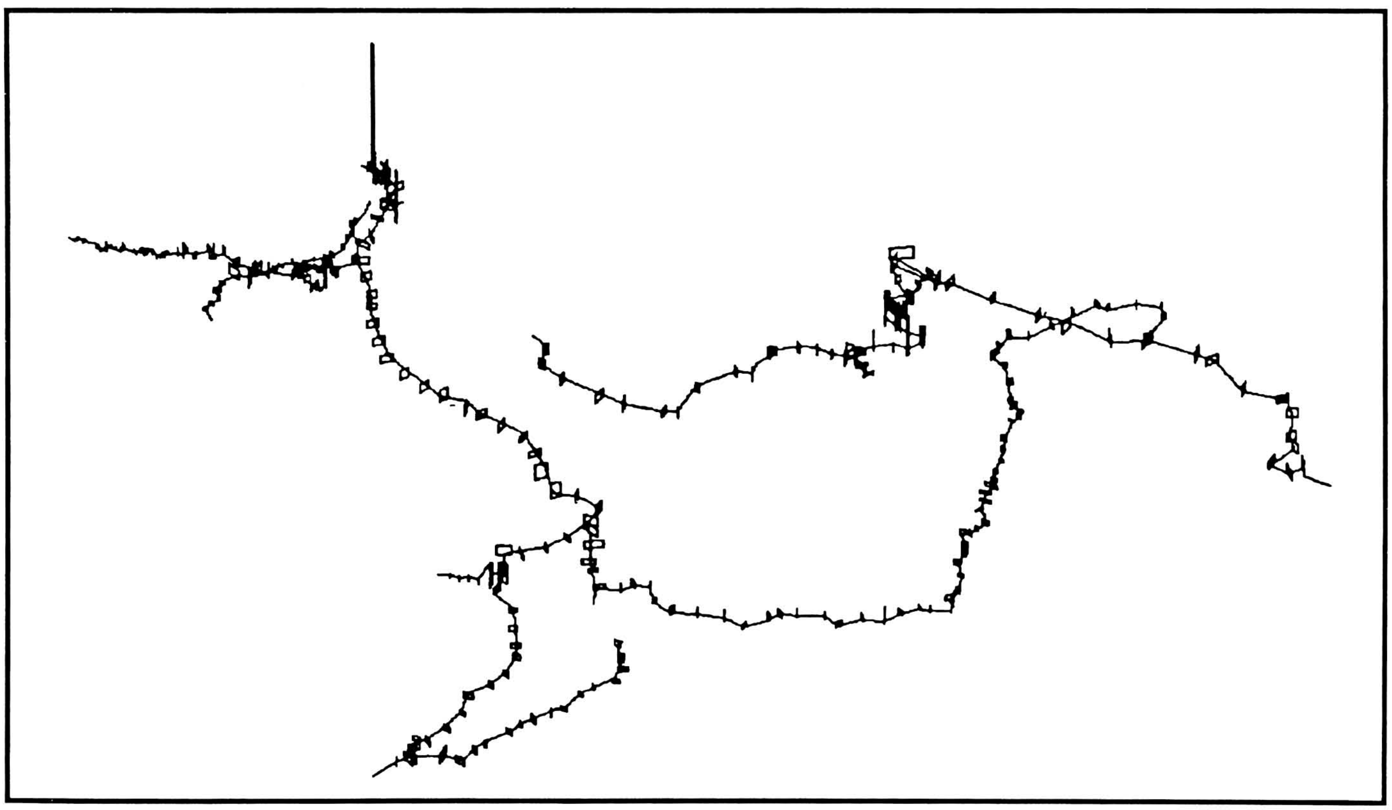


Figure 5: A SMAPS-generated oblique view of the Shelly Avenue/Cutliff Way area of Mammoth Cave.

caves were finished this year: White Trail Cave, Rubble Cave, Little Beauty Cave, Jim Cave, and Hunts Sink Pit. Copies of these are available through Cave Books.

The following 1:600 sheets are in pencil/mylar status accompanied by the names of the cartographers:

Crystal Cave (2 sheets) .... Art Palmer
Unknown Cave, Pohl Avenue .... Paul Hauck
Mammoth Cave:
  Frozen Niagara (2 sheets) .... Scott House
  Kentucky Avenue .... Mick Sutton
  Cathedral Domes .... Scott House
  Bishops Domes .... Kevin Downs
  Cleaveland Avenue .... Doug Baker
  Marion Avenue .... Bob Osburn
  Blue Springs Branch .... Roberta Burnes
  Mick Sutton
  Main Cave .... Scott House
  Alberts Domes .... Scott House
River System (2 sheets) .... Bob Osburn

In preliminary (pencil on paper) form are the following:

Colossal Cave (3 sheets) .... Jim Borden
River System (2 sheets) .... Bob Osburn
Unknown Cave:
  Mather Avenue .... Scott House
  Brucker Breakdown .... Scott House
  Gravel Avenue .... Mick Sutton
  Northwest Passage .... Mick Sutton

The following sheets are in planning: Mammoth:

Historic .... East Bransford
Cocklebur Avenue .... Upper Salts
Mystic River .... Lower Salts
Echo River ....

The following maps of smaller caves are currently being drafted:

Smith Valley Cave .... Tim Schafstall
Long Cave .... Tim Schafstall
Sloans Crossing Cave .... Kevin Downs
Running Branch Cave .... Eric Compas
Lawton Cave .... Jim Greer
Little Proctor Cave .... Jim Greer
Curd Cave .... Jim Greer
E.L. Morrison Cave .... Jim Greer
Dry Prong Cave .... Stan Sides
Rigdon Pit .... Bob Osburn
Dickey Pit .... Bob Osburn
Church Talus Cave .... Tom Brucker
Mouse Cave .... James Sturbenz

Crow/Hackett Caves .... Scott House

THE SCIENCES

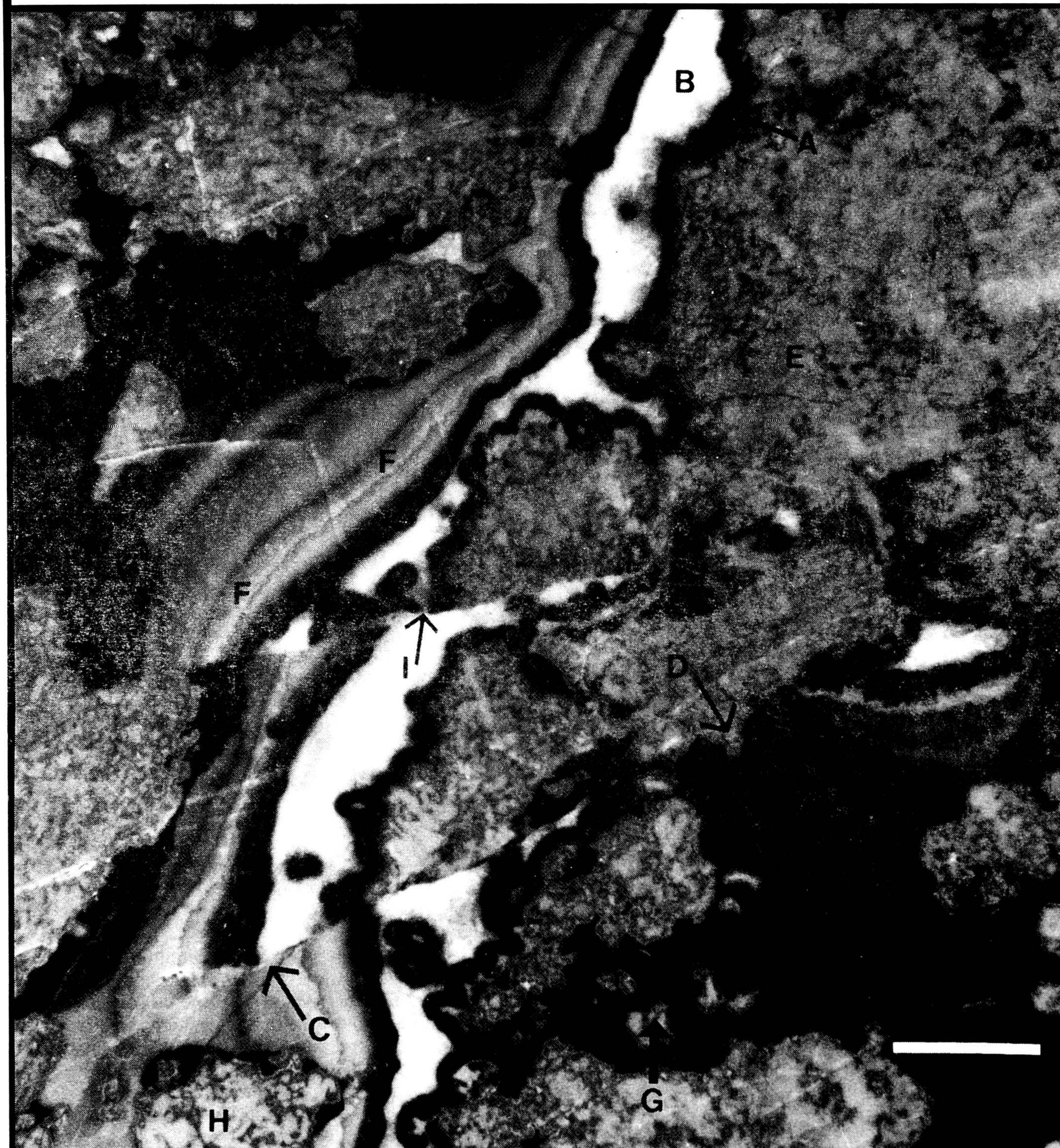


Figure 6: Photograph of a hand sample illustrating early diagenetic (lowland, supratidal karst) dissolution features and microarchitecture from the Late Proterozoic Beck Spring Dolomite of Eastern California. Dissolution features include, A) multiple, consecutive phases of isopachous rim cement around secondary fenestrae (bladed and equant forms typical of phreatic zone neomorphic calcitization); B) clean pore-fill, sparry (coarse-grained) calcite cement in secondary fenestrae; C) post lithification microfaulting; D) carbonate pendent (gravitational) fabrics (microstalactitic); E) algal marine microstructures (?); F) complex internal micritic (fine-grained) sedimentation; G) dark, small-scale recrystallization micrite with floating relics (variably patchy in grain size); H) pseudo breccia (patchy secondary mosaic of irregular-shaped carbonate) in pale gray micritic matrix; I) early geopetal fabric (partial infilling at the bottom of a cavity). Scale bar is 1 cm (*Photo No. 4509A by Ray Kenny*).

GEOSCIENCES

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

by John Tinsley

INTRODUCTION

Sinkholes and Sinkhole Sediments

Colluvial and alluvial processes which transport earth materials from slopes to sinkholes and caves are important in the evolution of karst basins; however, opportunities to estimate rates of soil erosion and slope degradation in karsts of the western United States under conditions of natural vegetation are seldom realized. Into the nearly pristine drainage basin of Redwood Canyon, a 700-year old silicic volcanic ash was erupted from the eastern Sierra Nevada and subsequently blanketed the mantled karst; this tephra deposit forms a discrete horizon in selected sinkholes and provides a stratigraphic basis for calibrated, volumetric estimates of post-tephra sediment eroded to the sinkholes (Tinsley, 1983). The study includes about 38 of the 60 sinkholes mapped in the karst; the results presented reflect a simple yet effective means of obtaining estimates of this karst-related process.

The sinkhole sediments are composed chiefly of gravel, sand, silt and clay derived from the granitic and metamorphic rocks which frame the canyon, and from alluvial terrace deposits along Redwood Creek and its tributaries. Drainages tributary to Redwood Creek typically sink at or near the contact of Redwood Canyon's marble and the adjacent granitic and non-carbonate metamorphic rocks. The white, powdery tephra, identified by its distinctive trace element chemistry as a product of the Deadman Dome vent in the Inyo Craters volcanic chain located south of Mono Lake in eastern California (Wood, 1977), is easily recognized in the field using soil augers or shallow slit trenches.

About 700 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 central California. 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, 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 such sinkholes preserve little if any record of the ash. Sinkholes located on terrain where slopes measure less than about 8 degrees did not receive tephra or sediment rapidly, and processes of bioturbation active on the forest floor commonly have obliterated the tephra layer. Most favorably, sinkholes that are floored with sand and silty sediment lack efficient conduit-related drainage and are permeable to water. Seepage of water through the sediment-plug effectively traps air- and water-borne sediment, including tephra; the trapped sediment is accreted vertically to that sinkhole's sedimentary record. In instances where the sinkholes have not developed collapse or stratigraphic leaks into the cave during the post-tephra time, the tephra is isochronous, having been erupted, transported, and deposited within a very short span of geologic time, and establish age equivalence among deposits in widely separated localities. The Redwood Canyon karst is a convenient laboratory wherein rates and processes of slope erosion can be appraised, owing to the tephra "clock" preserved in many sinkholes.

Methods

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. The respective volumes of tephra and post-tephra sediment are estimated using standard isopach mapping techniques. The quotient of the tephra volume (or post-tephra sediment volume) divided by the area of the 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. Of course, a key assumption is that the sinkhole has behaved itself by having trapped sediment and has not leaked appreciable tephra or post-tephra sediment into the subjacent cave system. Sinkholes floored with sediment composed chiefly of sand-sized and finer particles function as a natural filter, permitting water to percolate through to the cave, but effectively trapping the sediment. Sinkholes which contain open or active swallets, evidence of active collapse, or which contain boulders and cobbles simply are not useful for this study. Swallets and active collapse indicate by-passing of sediment directly to the cave and concomitant loss of signal; cobbles and boulders are intrinsically poor filter media and also are impenetrable to the soil auger. As the number of sinkholes suitable for this study is small, compared to the number of sinkholes in the karst, the number of geomorphic variables which can be evaluated from the process standpoint will be smaller than I had hoped for at the outset of this study. Initially, I had expected to compare 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. However, only 10 or 12 sinkholes are likely to be truly useful; most sinkholes are "leaky", probably owing to the intrinsic perversity of Nature. The estimated erosion rates would be applicable to the mixed coniferous forest ecosystem under conditions of present climate which prevailed during the past 700 years. Only by comparing results from the well-plugged sinkholes can we obtain stable estimates of sediment yield for further analysis.

Results

Forty-five sinkholes have been examined and ten sinkholes have been augered as of 12/31/90, with emphasis being placed on the array of sinkholes located west of the trail where it crosses Redwood Creek. Small basins and sinkholes characterized by basin hillslope declivities of less than 8% to 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 of root penetration and burrowing animals. In this instance, the stratigraphic record is diffuse or intermittent, and uncertainties in the results increase. 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. These sinkholes give the best results and are easiest to work with in the field, as the rate of sedimentation typically exceeds the rate of bioturbation within the sink. 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 during the past 700 radiocarbon years.

References

Tinsley, J. C., 1983, Tephrochronology of sinkhole deposits in the Redwood Canyon karst, Sequoia and Kings Canyon National Parks, California: Palmer, M. V., ed., *Cave Research Foundation 1982 Annual Report*: St. Louis, Missouri, p. 23-25.

Wood, Spencer H., 1977, Distribution, correlation, and radiocarbon dating of late Holocene tephra, Mono and Inyo Craters, eastern California: *Geological Society of America Bulletin*, v. 88, p. 89-95.

Dust Monitoring and Sedimentology of Selected Caves at Lava Beds National Monument

by John Tinsley, Ken Miller, and Bob Johnson

Objectives

Lava tubes at Lava Beds National Monument, northeastern California, appear to be impacted by deposition of clastic sediment within and around the caves. Sediment transport occurs in result of natural processes and may also reflect impact of human visitation in unexpected ways. Among the sedimentological features of interest in this study are deposits of sediment that obscure features of the lava near tourist trails, deposition of clastics in ice deposits in ice caves, owing to sediment borne on the footgear of visitors, and sediment plumes near cave entrances that mantle floor features to depths of as much as 20 to 30 centimeters. We have undertaken a study of aspects of the sediment dynamics of a few of the caves, in order to elucidate the relative importance of natural dust sources versus contributions of sediment stemming from recreational use of the caves—an issue also of interest to resource management at Lava Beds National Monument (LABE).

Appraisal of the human-wrought effects on the lava tubes using a sedimentological approach is the principal goal of this research. Study of the distribution, composition, rate of deposition, and geologic circumstances of sedimentation in selected caves of the Monument is intended to provide an objective basis for evaluating sediment deposition within the caves. In result of this study, the resources management staff will have a locally-tested methodology and protocol to follow for evaluating dust accumulation and sediment deposition in the Monument's caves, should additional monitoring become advisable. On the basis of the initial two years' study, we will also be deciding if certain in-cave monitoring protocols might be profitably continued in order to gather data over a more extended time within the caves selected for the pilot studies in conjunction with this project.

Initial Results

In 1989, three aerosolic dust traps were deployed, one near Skull Cave, one near Valentine Cave, and one near the Monument's weather station. The dust traps are patterned after a design employed by Dr. Marith Reheis of the United States Geological Survey, who is monitoring the composition and influx rates of aerosolic dust across the southern Great Basin in conjunction with a regional study of soil genesis. Each Reheis-type apparatus consists of a 6-foot T-type steel fence post which is driven into the ground and stabilized against the elements by guy wires—sometimes a sporting venture in a young lava flow. The trap proper is an angel-food cakepan that demurely perches atop the fencepost. The cake pan contains a mesh (hardware-cloth) platform which supports 400-500 spherical marbles, the role of which is to keep winds from eddying through the pan and blowing out the accumulated dust. Semi-annual or annual forays are required to rinse the marbles, mech, and pan of accumulated dust and recover the sample. Dividing the mass of the trapped dust by the cross-sectional area of the trap yields an estimate of the dust flux expressed as grams per unit area per unit time. Samples recovered to date have been on a semi-annual basis are small; consequently, an annual visitation program is planned for 1991 and beyond.

Within the caves, the doughty researchers encountered some surprises. At At Valentine Cave, a lava tube noted for its well-preserved features of flowing lava displayed within the tube, and at Skull Cave, a large cave exemplary of the size that the conduits may attain under proper conditions, illustrates the problem. Pieces of smooth lava were placed in semi-concealed areas along the trails to serve as accumulation points for dust. Visitor dynamics were such that our efforts at concealment were insufficient. More than half the collectors were later recovered from bizarre locations, having been hurled from their places of concealment. It seems that anything small enough to throw will be picked up and thrown. On Labor Day weekend, bloodied but unbowed, Ken Miller directed the re-deployment of traps at Skull Cave at a point somewhat further into the cave, where life is a darker reality and where the traps may not be noticed by frustrated paleolithic types. The success of this tactic remains to be evaluated.

Skull Cave provided an interesting initial finding. The entrance passage at Skull Cave contains a wedge-shaped deposit of sediment that measures about 20 cm thick near the entrance and thins caveward until the flow features of the pahoehoe lava floor of the cave are no longer obscured by the sediment. We had hypothesized that the sediment plume merited study to determine the rate of growth as a measure of human impact or as a record of interplay among human-wrought and natural processes. Two of us (Miller and Tinsley) decided to determine how much dirt might be getting tracked into the cave under present conditions. We dutifully washed off and dried our boots and walked from the parking lot to the cave, and then washed and dried boots again. Several sorties later, we had an idea of how much sediment per visitor might be reaching the apex of the sediment cone near the cave entrance. As a final check, we conducted an additional survey of foot-borne sediment flux within the cave, by initially cleaning our boots, taking a tour of the cave, and returning to the entrance and re-cleaning the boots once more, taking care to capture the sediment signal leaving the cave.

It turns out that the sediment plume is quite dry, owing to a rather fissure-free ceiling near the entrance, yet the interior of the cave is rather moist. Moist footgear readily acquires particulates from the floor, and we discovered that the dust leaving the cave outweighs that arriving at the cave by orders of magnitude. The sediment plume thus is shrinking owing to visitation—not growing, under the prevailing moisture regime. There are also some additional aspects of the history of the cave which are pertinent. The cave was discovered in 1933, on Valentine's Day, hence the cave's name. The parking lot and pathways to the cave entrance were paved with asphalt in the middle 1960s. The paved condition of the parking lot and entrance trail means that for 25 years or so, human-borne sediment would not have the effects of vehicular traffic and the unpaved trail-tread as a source for the sediment plume at the cave entrance. Thus, the probability emerges that the sediment plume may be a dwindling, paleo-feature, gradually disappearing in the present day.

1991 Plans

We plan to excavate the Valentine Cave sediment plume in an archaeological manner, to examine the sedimentological characteristics of the deposits. We hope to determine if there is evidence that can be developed to indicate the age of the plume. If Valentine Cave's sediment plume is a pre-1965 feature, perhaps even dating from the development phase shortly following the opening and widening of the entrance in the 1930s, then the sediment may not contain abundant synthetic fibres from the clothing of the human visitors. One imagines that wool or cotton would be in sediment from pre-WWII years; one also imagines that bacteria could make a pretty good living off of any such natural textile fibers.

Presuming that the survival rate of our in-cave sediment traps improves, we should be able to relate dust flux to position relative to the trail. The available data from observations and from a few surviving traps indicates that the trail tread is the source of the sediment, and that footfalls of tourists is the principal means of suspending the particles in the air, whence they settle out upon surrounding rock surfaces.

Geology and Mineralogy of Lava Tube Caves in Medicine Lake Volcano, California

by Bruce W. Rogers and Patricia H. Rice

Medicine Lake volcano lies in the north-east corner of California, just south of the California-Oregon border. This Pleistocene to Holocene volcano is located in the southeastern portion of the Cascade Geomorphic Province. The volcano has developed as a large shield over 33 km in diameter which attains an elevation of 2417 m. The north slope of the mountain is covered with bunch grasses and sage at the lower elevations adjacent to highly alkaline Tule Lake. Further up slope a mixed sage and pinyon juniper woodland is present while a ponderosa pine forest covers the upper third of the volcano. The southern slopes of the mountain are cloaked in mixed ponderosa and hardwood forest. Except for Medicine Lake, a caldera lake, and short-lived ephemeral streams, the volcano lacks permanent surface water. The eruptive rocks range in composition from basalt to rhyolite. More mafic flows and breccia comprise the bulk of the volcano with a thin covering of more silicic pumice, ash, and obsidian flows. The basaltic lavas have compositionally changed throughout their eruptive history such that the earliest lava is more silicic (approximately 53% SiO_2) and the latest more mafic (approximately 47% SiO_2). This results in lava fields which change composition along their length.

In a zone on both the northern and southern flanks at approximately 1370 m in elevation are many cinder and composite cones from which long, tube-bearing lava flows emanate. A wealth of volcanic features of special interest to speleologists and cavers are present in these areas. Many of the tube system's roofs failed shortly after their draining. The resulting landforms can be divided into three types of collapse features: long, sharp-edged collapse trenches; shallow sagged, partially collapsed, partly squeezed down tube-cum-trenches; and alluviated trenches. The sharp-edged trenches have clean walls and partially preserve cave passage profiles under overhanging trench edges and in reentrants. The shallow sagged trenches have not undergone chaotic collapse but have plastically sagged, either closing or leaving very low passages. Alluviated trenches are uncommon. These features have had their floors thinly veneered with sediments and subsequently vegetated. These trenches appear to be either sharp-edged or sagged in origin. Spatter cones or rootless vents (hornitos) are present along the axes of portions of the tube systems. These hornitos range up to 20 m in diameter and 10 m high and, in some cases, allow access to otherwise sealed cave segments.

Approximately 18% of these tubes are preserved as accessible caves. The slope along the length of many of these caves commonly averages 3 degrees although sudden drops over the controlling underlying topography are present. Over 300 caves are known from these flows. The caves range from short grottos under 10 m long to braided systems nearly 7 km long. Passage sizes range from 0.25 m high crawlways a meter wide to "dirigible passages" up to 25 m in diameter. Vertical pits up to 20 m deep are common where passages either stopped their way to the surface or collapse between overlying levels occurred. While breakdown is pervasive, small to large areas of original pahoehoe floors with differing surface textures are found in nearly every cave. Wall and roof decorations of lava glaze are very common even in the smallest of surface tubes. However, in many of the moderate- to large-sized caves consecutive collapse of the linings have removed most of the tube's original glaze. Hardened cascades and lava falls are common in the caves as are frozen lava lakes and pools. Rafted blocks of lava and lava balls encased in the pahoehoe floor are scattered along the length of many tubes.

Fourteen minerals, mineraloids, and rocks identified by x-ray diffraction are found as speleothems in the tubes. These include: ice – H_2O (common, especially seasonally), goethite – $FeO{\bullet}(OH)$ (rare), pyrolucite – MnO_2 (rare), romanechite – $BaMn^{+2}Mn^{+4}{}_8O_{16}(OH)_4$ (rare), gypsum – $CaSO_4{\bullet}2H_2O$ (uncommon), barite – $BaSO_4$ (rare), calcite -$CaCO_3$ (very common), two unnamed sulfite and sulfo-carbonate salts – $Na_2SO_3{\bullet}7H_2O$ and $Na{\cdot}SO_4{\bullet}CO_3{\bullet}nH_2O$ (rare), cristobalite – SiO_2(very common), silhydrite – $3SiO_2{\bullet}H_2O$ (rare), amorphous silica – SiO_2 (moderately common), and basalt and andesitic basalt (ubiquitous). The sources of these minerals are varied. The silicates appear to have been leached from the unstable pumice and glassy ashes. The calcite, gypsum, barite, and unnamed salts have drawn their carbonate and sulfate from the wind-blown dust derived from the largely carbonate lake margins. The oxide and hydroxide minerals (exclusive of ice) have been derived by weathering of the relatively deeper soils of the upper, well-watered and vegetated slopes of the volcano. Ice is present as permanent deposits in at least 20 caves and appears as seasonal decorations in a great number of caves. There is a rough zonation controlled by elevation of the secondary mineralization in the lava tubes. This zonation appears to follow the availability of ground water, soil composition, and vegetation patterns. On the flanks of the volcano, the less mobile oxide, hydroxide, and miscellaneous "minerals" form in the caves higher on the volcano where soils are well developed and ground water abundant. The more mobile silicate, carbonate, and sulfate minerals are found further down slope in areas of thinner soils and less ground water. Ice and basalt speleothems are found throughout the elevational range of the caves studied.

This manuscript benefited greatly from discussions and reviews from Julie Donnelly-Nolan, Aaron Waters, and Edward Helley of U. S. Geological Survey, Gary Hathaway and Charisse Sydoriak of the U. S. Park Service, and Mike Sims of the Cave Research Foundation, for which we are grateful.

References

Anderson, C. A., 1941. Volcanos of the Medicine Lake Highlands, California, Univ. Calif. Publ., *Bull. Dept. Geol. Sci.*, v. 25, no. 7, pp.347-422.

Baer, R. L., 1973, *Petrology of Quaternary Lavas and Geomorphology of Lava Tubes, South Flank of Medicine Lake Highlands, California*, MS Thesis, Univ. of New Mexico, 120 p.

Donnelly-Nolan, J. M., 1987, Medicine Lake volcano and Lava Beds National Monument, California, *Geol. Soc. Am. Centennial Field Guide-Cordilleran Section*, pp. 289-94.

Donnelly-Nolan, J. M., and D. E. Champion, 1987, Geologic map of Lava Beds National Monument, northern California, U. S. Geol. Survey Map I- 1804, scale 1 :24,000

Donnelly-Nolan, J. M., D. E. Champion, C. D. Miller, and D. A. Trimble, 1989, Implication of Post-l 1,000 Volcanism At Medicine Lake Volcano, Northern California Cascade Range, in Workshop XLIV, Geological, Geophysical, and Tectonic Setting of the Cascade Range, *U. S. Geol. Survey Open-file Report 89-178*, pp. 556-80.

Greeley, R., 1987, The Role of Lava Tubes in Hawaiian Volcanos, in Volcanism In Hawaii, *U. S. Geol. Survey Prof. Paper.* 1350, pp. 1589-1602.

Rogers, B. W., 1990, Mineralogy of Lava Tube Caves in Medicine Lake Volcano, California (abs.), *Natl. Speleo. Soc. Convention at Yreka, California, Program with Abstracts*, pp. 33.

Waters, A. C., 1981, Captain Jacks Stronghold (The geologic events that created a natural fortress), *U. S. Geol. Survey Circular 838*, pp. 151-61.

Waters, A. C., J. M. Donnelly-Nolan, and B. W. Rogers, 1990, Selected Caves and Lava Tube Systems In and Near Lava Beds National Monument, California, *U. S. Geol. Survey Bull. 1673*, 102 p.

General Geology and Development of Lava Tubes in New Mexico's El Malpais National Monument

by Bruce W. Rogers

The El Malpais area of New Mexico is one of the newest National Park Service units. It is located in northwest part of the state near the town of Grants at an elevation of approximately 2200 m. The El Malpais, (Spanish meaning "bad country") is a high, lightly forested grassland surrounded with typical southwest mesa topography. A mix of open juniper-ponderosa pine woodland covers the bare to thinly soil covered lava areas whereas a bunch grass-sage-rabbitbush vegetation mantles the deeper soil covered areas. A three agency cooperative agreement has resulted in U.S. Forest Service wilderness and Bureau of Land Management special management areas surrounding the Park Service monument core .

Deformed preCambrian metasedimentary rocks and flat-lying Mesozoic sedimentary rocks underlie the monument. A series of Pliocene- to Holocene lava fields overlie the older rocks. The basaltic lavas have compositionally changed throughout their eruptive history such that the older basanites and alkali-olivine basalts range between 45 to 48% SiO_2 while the younger olivine basanites, basalts and mugearites range from approximately 46 to 51% SiO_2. This has resulted in lava flows which change composition along their length. Scattered throughout some of the lava units are both deep crustal olivine and pyroxene and partly melted Mesozoic quart-rich sedimentary rock xenoliths. The oldest and youngest flows containing the known caves have been dated at 1.3 to 0.75 million years old by potassium-argon methods and 1000 to 400 years old by archaeological methods.

In the major cave area, five approximately kilometer-diameter volcanos with Spanish names such as El Calderon (The Caldron) and La Teatra (The Teapot) have disgorged lava flows containing tubes in varying states of preservation. Many of the tube system's roofs failed shortly after their draining. The resulting landforms can be divided into three types of collapse features: long, sharp-edged collapse trenches; shallow sagged, partially collapsed, partly squeezed down tube-cum-trenches; and alluviated trenches. The sharp-edged trenches have clean walls and partially preserve cave passage profiles under overhanging trench edges and in reentrants. The shallow sagged trenches have not undergone chaotic collapse but have plastically sagged, either closing or leaving very low passages. Alluviated trenches are scarce but have been thinly veneered with sediments and subsequently vegetated. These trenches can be either sharp-edges or sagged in origin. One of the main cave forming flows, the Bandera Crater flow, is 45 km long and contains 28 kms of identifiable tube, most of which is collapsed or sagged trench. This and the other major flows contain dozens of caves ranging from SO m long natural bridges to 3-400 m long caves and over kilometer-long systems. Tube sizes generally are large with many caves having 8 m wide and 12 m high passages but several of the caves contain passages up to 15 m in diameter. As is common with other lava tube terrains, most of the caves have areas of extensive roof and wall lining collapse. As a result, a substantial portion of the caves have few primary wall and floor surfaces intact. Where the tube interiors are intact, the pahoehoe walls and floors show a variety of features and textures. Rafted blocks are present in several of the caves. Many of the caves are braided or dendritic in pattern, however, unitary tubes are present.

Ten minerals and rocks have been identified by x-ray diffraction as speleothems in the Monument's caves. These include: ice – H_20 (common, especially seasonally), gypsum – $CaS0_4 \cdot 2H_20$ (very common), epsomite $MgS0_4 \cdot 7H_20$ (uncommon), mirabilite – $Na_2S0_4 \cdot 10H_20$ (rare), thenardite - Na_2S0_4 (rare), calcite – $CaC0_3$ (very common), trona – $Na_3H(C0_3)_2 \cdot 2H_20$ (rare), burkeite – $Na_6(S0_4)_2(C0_3)$ (rare), cristobalite – SiO_2 (uncommon), and basalt (ubiquitous). The sources of the minerals is varied. The gypsum, epsomite, mirabilite, thenardite, calcite, trona, and burkeite appear to have drawn their carbonate and sulfate from wind-blown dust derived from weathering of the Mesozoic sedimentary rocks. The cristobalite appears to have been leached from the unstable pumice and glassy ash. Ice is present as permanent deposits in at least 4 caves and appears as seasonal decorations in a great number of other caves.

Native Americans utilized the caves quite extensively, leaving cultural remains in many caves. Spaniards, Mexicans, and gringos apparently did not make great use of the lava tubes except U.S. Army troops quarrying ice from Bandera Ice Cave, thus left little record of their passing in the caves. This manuscript benefited greatly from discussions with and reviews from Ken Mabery, Cindy Ott-Jones, and John Morlock of the U. S. Park Service, Edward Helley and Julie Donnelly of the U. S. Geological Survey, and T. M. Duke McMullen of the Sandia Grotto, National Speleological Society.

References

Baldridge, W. S., F. V. Perry, and M. Shafiqullah, 1987, Late Cenozoic volcanism of the southeastern Colorado Plateau: I. Volcanic geology of the Lucero area, New Mexico, *Geol. Soc. Am. Bull.* 99, pp. 463-70

Carden, J. R., and Laughlin, A. W., 1974, Petrochemical Variations within the McCartys Basalt Flow, Valencia County, New Mexico, *Geol. Soc. Am. Bull.*, v. 85, p. 1479-84.

Mabery, K., 1990, personal communication. Maxwell, C. H., 1986, Geologic Map of El Malpais Lava Field and Surrounding Areas, Cibola County, New Mexico, U. S. Geol. Survey Map I-1595, scale 1 :62,500.

Rogers, B. W., 1990, General Geology and Development of Lava Tubes in New Mexico's El Malpais National Monument: Confirming Epsomite in the Field by Taste Testing, Natl. Speleo. Soc. Convention at Yreka, California, Program with Abstracts, p. 29.

Rogers, B. W., 1990, The Earth Shook, The Sky Burned, and All The Bunny Rabbits Ran Away ... Part 13: Four Windows Cave, *Cave Research Organization of South Africa Bulletin*, in press.

Fossil Microorganisms in Karst Environments

by Margaret V. Palmer and Arthur N. Palmer

Fossil bacterial and algal filaments, though rarely observed elsewhere in the fossil record, are well preserved in cave deposits and paleokarst zones associated with former sulfates. The science of microbiogeology is not a new one, but it has rarely been applied to cave studies. It shows great promise for interpreting the environmental conditions in which caves and karst features formed.

Our first encounter with the subject was unexpected. Examination of carbonate breccia in thin sections of wall rock from Jewel Cave, South Dakota, showed a tangle of obviously organic filaments growing from iron oxide bodies in the calcite matrix. An example is shown in Figure 7. These were of particular interest because they are of Mississippian age, more than 300 million years old. They are by no means the oldest known fossil bacteria, but they are among the best preserved. These microfossils appear to be undetectable by scanning electron microscope (SEM), which probably accounts for the fact that they had not been previously discovered. We have tentatively identified them as iron-fixing bacteria similar to the modern *Leptothrix* and *Cronothrix*. The filament diameters are about one micron, larger than those of typical bacterial filaments, because the filament sheaths are coated with iron oxide (probably hematite), which was apparently originally deposited as iron hydroxide. Similar iron-hydroxide-coated bacterial filaments are seen where anoxic groundwater rich in dissolved ferrous iron encounters oxygen where it emerges at springs or in wells, forming a slimy yellow gunk. Clusters of cells surrounded by yellow sheaths are also clearly visible, similar to the modern bacterium *Siderocapsa*. A rather neutral pH is most favorable for the growth of both types of bacteria. Internal structures are obscured in most of the filaments in calcite but are well preserved in local patches of quartz.

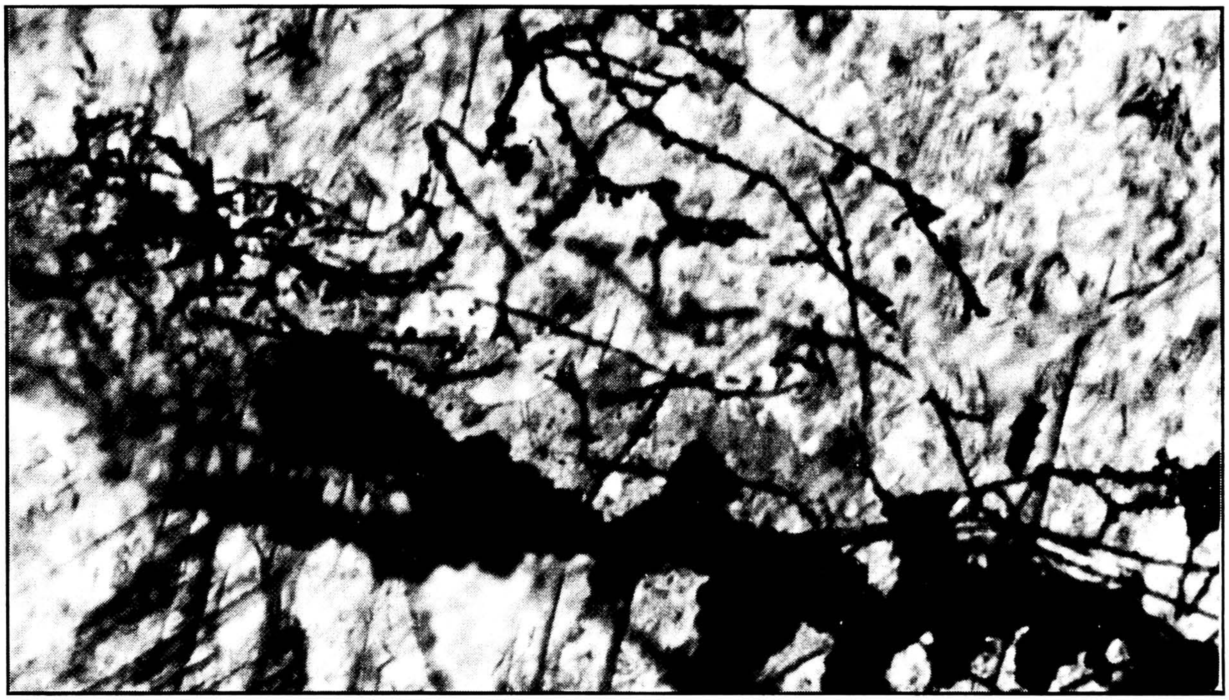


Figure 7: Bacterial filaments coated with iron oxide in Mississippian calcite breccia matrix, Jewel Cave, SD. The large opaque blob is inorganic hematite. Filaments are about one micron in diameter. (*Transmitted-light photomicrograph by A. Palmer*).

The fossil bacteria occur only in a certain orange-yellow calcite that forms the matrix of the carbonate breccia in the Black Hills. It is identical to the very thin calcite veins that protrude as boxwork from the walls of the Black Hills caves. We have interpreted the breccia and boxwork to be the product of now-vanished evaporites (Palmer and Palmer, in press). The vein calcite is a replacement of gypsum. The microfossils show that the process took place at rather neutral pH at the interface between anoxic water and fresh oxygen-rich water infiltrating from a nearby surface.

In many places in the Black Hills caves the bedrock walls are deeply weathered to a multicolored powder. Examination of striking dark-brown, very friable bedrock in the boxwork zone of Wind Cave showed that much of the color is produced by iron-oxide-rich microfossils (Figure 8). These are much larger in scale than the bacterial filaments, and their rambling blob-like patterns suggest blue-green algae (cyanobacteria). They appear to have grown in the bedrock, but it is uncertain whether they are Mississippian features related to evaporite paleokarst, as were the bacteria in Figure 7, or contemporary with Tertiary cave origin. Their apparent association with the cave is misleading, because many of the cave features (e.g., the boxwork and friable sandy wall textures) are inherited from the Mississippian.

At various times in their complex origin, caves in the Guadalupe Mountains, New Mexico, have experienced reduction and oxidation of sulfur and iron compounds, so it is not surprising that bacterial microfossils should appear there as well. In Lechuguilla Cave, Pleistocene or Holocene filaments line the inner walls of stalactite-like growths (Figure 9). Accretion of iron oxide has enlarged them to several tens of microns in diameter, far beyond the normal range of bacterial filaments. In transmitted light their internal structure is visible and the color stands out as a vivid translucent red. SEM photomicrographs show much more surface detail (Figure 10) but are of course unable to show internal detail. These and much smaller filaments

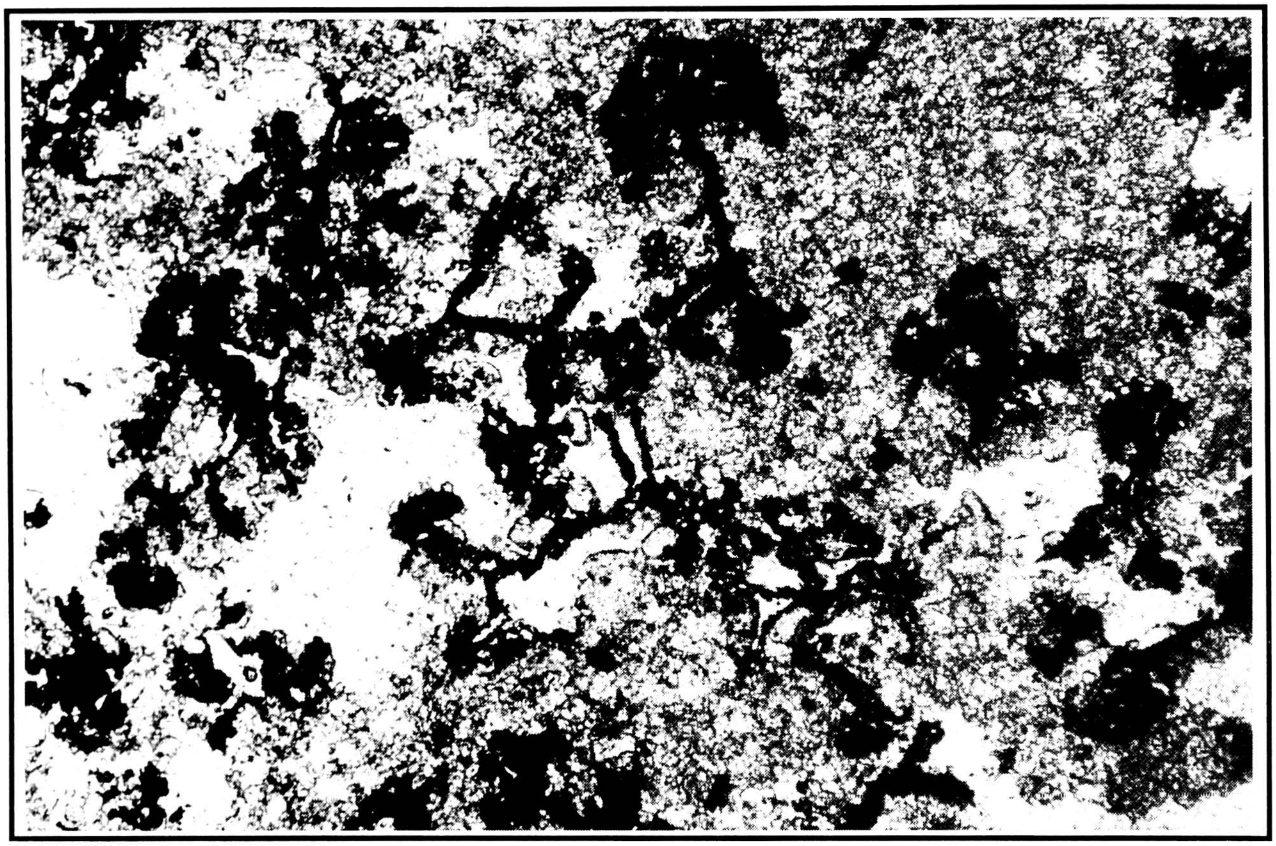


Figure 8: Algal (?) structures in porous bedrock, Wind Cave, SD. Long dimension of photo is about 1.5 mm. (*Transmitted-light photomicrograph by M. Palmer*).

(0.25 microns diamteter) are found in other areas of the cave in finger-like "U-loops" of subaqueous origin. Bundles of filaments have adhered to each other and to adjacent calcite protrusions, forming bridges and networks that are now encased in calcite (Davis and others, in press). As in the case of the calcite spar in South Dakota, the iron-fixing bacteria help to identify the environment in which the speleothems grew.

Chenille spar may have a similar organic origin. It is a calcite deposit consisting of parallel vertical fingers hanging from shelfstone in present or former pools. In the New Mexico Room in Carlsbad Cavern, the tips of chenille spar in a certain pool have flexible filaments up to a centimeter long hanging from them. These have been examined under SEM by Rick Olson of the University of Illinois, who discovered them to be bundles of filaments of unknown affiliation, with fenestrate sheaths that contain elongate holes similar to those in the desiccated stalk of a dead ocotillo cactus.

More complete descriptions and interpretations of the South Dakota and Lechuguilla microfossils are included in the papers cited below. Even these merely scratch the surface of what promises to be a vast and promising field – the geomicrobiology of caves and karst.

References

Davis, D. G., M. V. Palmer, and A. N. Palmer, in press, Extraordinary subaqueous speleothems in Lechuguilla Cave, New Mexico: *National Speleological Society Bulletin*.

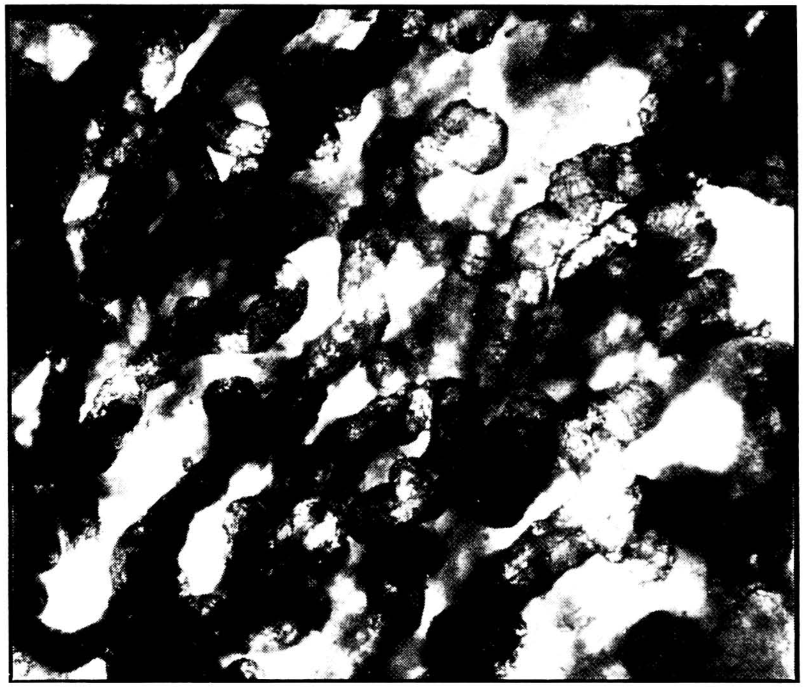


Figure 9: Bacterial filaments in an iron-oxide-rich speleothem from Lechuguilla Cave, NM. Maximum diameter of the oxide-coated filament sheaths shown here is about 15 microns. (*Transmitted-light photomicrograph by A. Palmer*).

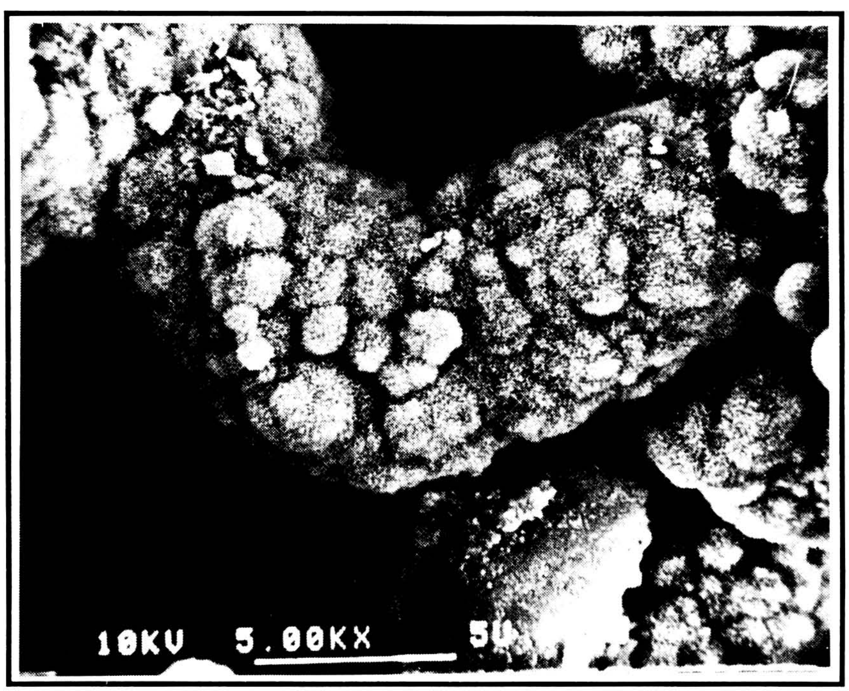


Figure 10: Sheaths of bacterial filaments coated by iron oxide and calcite, from the speleothem in Figure 8, Lechuguilla Cave, NM. White bar = 5 microns. (*SEM photomicrograph by R. Olson*).

Palmer, A. N., and M. V. Palmer, in press, Geologic history of the Black Hills caves, South Dakota: *National Speleological Society Bulletin*, v. 51.

Karst on the East Fork of the Obey River, Tennessee

by Ira D. Sasowsky

OVERVIEW

A study currently in progress within the drainage basin of the East Fork of the Obey River, Fentress County, Tennessee, seeks to date cave formation, and from this better understand drainage basin growth on the Cumberland Plateau margin. The East Fork of the Obey River (EFO) is a northward flowing tributary of the Cumberland River and is deeply incised into the Cumberland Plateau of north- central Tennessee. The Cumberland Plateau, a gently rolling upland at an elevation of 1700 feet (570 meters), is underlain by flat-lying rocks, with a slight regional dip to the East. Basin area above the U.S.G.S. stream gage is 520 square kilometers. A significant karst is developed in the valley walls, including the Xanadu, Zarathustra, and Mountain Eye Cave systems with combined lengths exceeding 75 kilometers. The caves are multi-storied systems of abandoned trunk passages, with currently active lower levels near the elevation of the river. The higher level passages have significant sediment fills, making the area well suited for construction of a paleomagnetic stratigraphy, and allowing minimum age dating of the caves. Correlation of cave passages with surficial features may allow quantification of basin growth rates; a unique application of karst to a geomorphic problem.

Hydrology

The upper reaches of the drainage net run upon sandstones, shales and conglomerates, and are unremarkable in their behavior. Upon reaching the uppermost limestone, the Bangor, the streams commonly sink, and resurge at the top of the Hartselle Sandstone, which acts as a thin confining bed in this area. The Monteagle Limestone is directly beneath the Hartselle, and it is here that the spectacular hydrology of the EFO begins. The EFO sinks in its river bed at the base of a 5 meter waterfall (Figure 11). This sinkpoint is overrun by water only at discharges greater than 3.4 cubic meters per second; at all other times the riverbed is dry below this point for the next 10 kilometers. The resurgence of the "underground Obey" is Enchanted River Spring (Figure 12). This is believed to be the longest reach of dry stream due to karst piracy in North America.

At high discharges, when the sinkpoint is overflown, the surface channel becomes active, and water flows down the valley, frequently in a flash-flooding manner. A stage rise of 3 meters within 2 hours was noted on November 11, 1988, which turned an ankle deep stream into a muddy torrent 20 meters wide and impossible to cross.

Most of the caves are significantly above the current water table, and no longer play a strong role in water transport. The exception to this is the lower level of the Mountain Eye System, which carries at least some of the water from the East Fork Sink. Development of an extensive karst beneath the river is indicated by numerous springs, but is inaccessible due to perennial flooding.

Hydrochemistry

Understanding the current hydrochemistry is essential to interpreting the past of the basin. A sampling program is underway which determines major constituents at 10 critical points within the basin. Interpretation of the chemistry has been complicated by the presence of acid-mine-drainage (AMD) in the basin. The result of strip-mining for coal, this AMD accounts for measured stream pH's as low as 2.5 within the basin. Discharge, conductivity, temperature, and pH are measured in

Figure 11: View upstream of the sinkpoint of the East Fork of the Obey River. Fall is approximately 5 meters high, and is formed where the stream breaks through the Hartselle Sandstone. Discharge is 3.4 cubic meters per second, and is completely swallowed through a breakdown choke at the base of the falls into the subsurface flow system.

the field at each sampling point as part of the program to characterize current geochemistry of the system.

Dating

A minimum age for cave passages is being determined by paleomagnetic analysis of clastic sedimentary deposits within the caves. By collection of a sufficient number of samples at various levels and locations, a paleomagnetic stratigraphy can be constructed, and correlated with the known paleomagnetic time-scale. Since deposition of the sediments must post-date the formation of the cave passage, a minimum age of the passage can be determined.

Samples are taken in a small, oriented, plastic cube, and then brought to the lab for measurement of the natural remnant magnetism. Alternating-field de-magnetisation is used to remove over-printed magnetic signals. All samples analyzed thus far have had a normal polarity, indicating that they are either less than 730,000, or more than 900,000 years old.

Figure 12: Enchanted River Spring, resurgence of the "Underground East Fork". Caver is sitting just outside the entrance to this water-filled maze cave, which is traversable for several tens of meters in low-water conditions. The water rejoins the main surface channel of the East Fork within 35 meters; ten kilometers from where it sunk.

Early Development of Karst Systems: Preliminary Simulation Modeling Results

by Christopher G. Groves

Much of the work that has been done in order to understand the nature of karst has been concerned with the large scale, explorable segments of these flow systems. However, for a more complete understanding we must also consider events that occur at scales precluding direct observation. Solutional processes that determine the outcome of competition between very small initial flow paths, for example, may ultimately determine location and morphology of major conduits within an aquifer. Computer simulation of such processes can serve asa tool with which to peer into these tiny places. Important recent advances in this area have been made by Dreybrodt (1990) and Palmer (1991).

A new model (Karst Aquifer Research Simulation Technology) that couples hydrodynamics of flow through small limestone conduits with dissolution kinetics is currently under development. This VS FORTRAN program features subroutines which calculate rates of calcite dissolution assuming both surface reaction rate kinetic control and diffusion control using mass transfer theory. Under any geologically reasonable set of fluid flow and chemical conditions (assuming presence of carbonate species only) rates are calculated by the two models, and the slower, or limiting,rate chosen. In this way kinetic controls under varying conditions during early flow system development are investigated. A third kinetic model, assuming control by CO_2 hydration, is currently being added. Such control may be especially important in the earliest stages of conduit development (Curl, 1965; Dreybrodt, 1990).

For model validation, laboratory dissolution experiments on limestone blocks (Rauch & White, 1977) have been simulated by the code and early results are quite encouraging. Holes were drilled in very pure limestone blocks and carbonic acid solutions at a PCO_2 of about one atmosphere were circulated at a Reynolds number of about 1850, just below the laminar-turbulent threshold assumed by the program of 2300. A laminar flow/ mass transfer rate limiting model predicts the evolution of calcium concentrations in the circulating fluid within a factor of about two (Figure 13), and pH and bicarbonate concentrations are similarly close. Although the surface reaction limiting

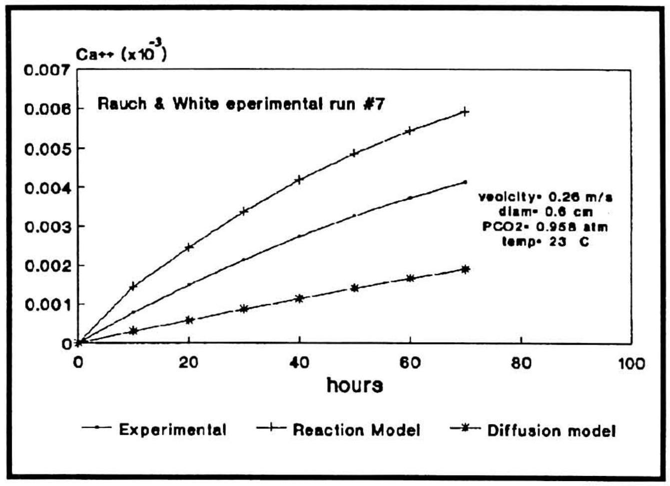


Figure 13. Calculated vs. experimental results of circulating fluid within a small limestone conduit. Experimental data from Rauch & White (1977).

model also shows good agreement, the program predicts that diffusion should control kinetics under these conditions, as this is the slower calculated rate. In reality, this flow probably occurs in the laminar-turbulent transition zone in which mass transfer rates may be somewhat enhanced. Other repeated simulations assumed increasing Reynolds numbers, but otherwise under similar conditions to the Rauch & White experiments. Higher Reynolds numbers are obtained by simulating increased head drops across a constant conduit length. Results suggest that upon reaching turbulent flow conditions, diffusion is found to hand over kinetic control to surface reaction rate and dissolution rates increase about one order of magnitude (Figure 14). This is in general agreement to earlier theoretical work by Buhmann & Dreybrodt (1985).

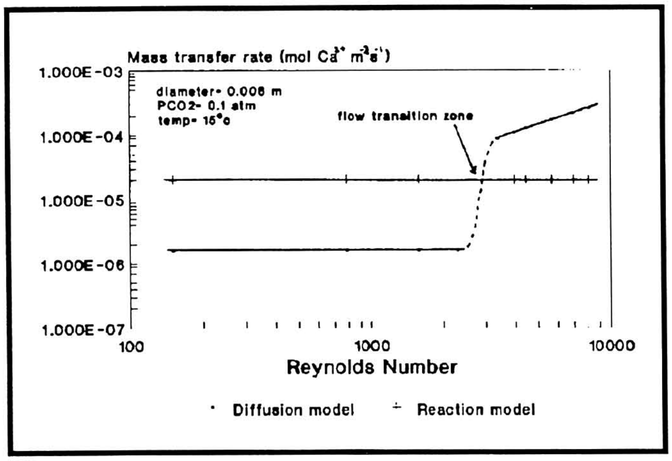


Figure 14. Diffusion and reaction limiting model mass transfer rates vs. Reynolds number.

Another feature of the program is that longitudinal changes in diameter can be simulated. This will allow investigation of the effects of constrictions on early passage development. In addition to shedding light on the important morphological effects of varying kinetic controls under different physical and chemical conditions, the model should prove useful in understanding the relationships between variations in these conditions and early conduit growth rates. This is a critical step toward further understanding of growth competition in these early passages.

Acknowledgements

This research is being conducted as a Ph.D.dissertation under the direction of Dr. Alan D. Howard for the Dept. of Environmental Sciences at the University of Virginia and many of the ideas have been developed by Alan and I together. Appreciation is especially expressed to Deana Groves, Carol Wicks, Janet Herman, and Steve Kraemer for assistance with this project. Financial support is being provided by the Cave Research Foundation, the National Speleological Society, and the University of Virginia.

References

Curl, R. L., 1965, Solution kinetics of calcite: *Proc. 4th Int. Congress Speleol.* (Ljubljana), Vol. 3, pp. 61-66.

Dreybrodt, W., 1990, The role of dissolution kinetics in the development of karst aquifers in limestone: a model simulation of karst evolution: *Jour. Geol.*, Vol. 98, pp. 639-655.

Dreybrodt, W. & D. Buhmann, 1985, The kinetics of calcite dissolution in geologically relevant situations of karst areas 1. Open System: *Chem. Geol.*, Vol. 48, pp. 189-211.

Palmer, A.N., 1991, The origin and morphology of limestone caves: *Geol. Soc. Am. Bull.*, in press.

Rauch, H.W., and W.B. White, 1977, Dissolution kinetics of carbonate rocks. 1. Effects of lithology on dissolution rate: *Water Resources Res.*, Vol. 13, pp. 381-394.

Hydrogeology of the Sierra Juarez, Oaxaca, Mexico

by James H. Smith, Jr.

Introduction

Since 1988, karst hydrological and geological field studies have been conducted in the Western Hemisphere's most complex know vertical drainage systems located in the Sierra Juarez Geologic Subprovince in the state of Oaxaca, Mexico (Figure 15).

It is the goal of this research to study the hydrogeology of the Sistema Huautla Karst Groundwater Basin. Research has involved: a) defining the drainage basin, b) finding the resurgences of two karst groundwater basins, c) dye tracing of unconnected deep caves into Sistema Huautla, d) relating structural controls to groundwater flow, e) defining the stratigraphic horizons in which caves are found, f) collecting water samples for water chemistry, and g) developing a regional model for speleogenesis. The main re-

Figure 15: Sistema Huautla and Sistema Cuicateco karst groundwater basins.

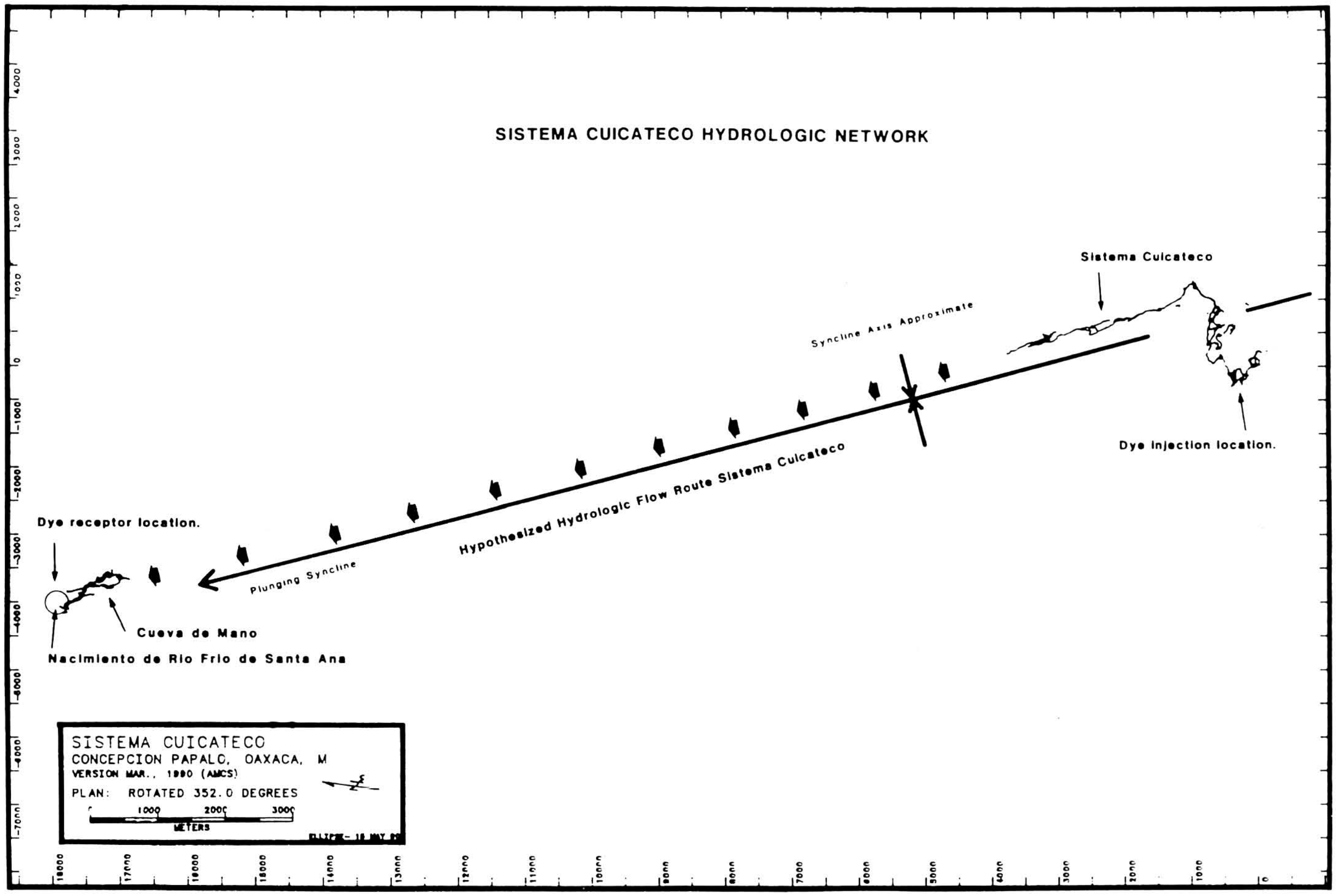


Figure 16: Sistema Huautla drainage has formed along the eastern limb of overturned strata to the west and it flows along a N-S strike and down the plunge to the south.

search emphasis has been on Sistema Huautla using nearby Sistema Cuicateco as a comparison. This research will culminate in a Master's thesis advised by Dr. Nicholas C. Crawford, Director for the Center for Cave and Karst Studies, Western Kentucky University.

Karst Hydrology

Geologic field mapping has determined that the karst groundwater basins of Sistema Huautla and Cuicateco are narrow and elongate corresponding to the configuration of the folds. Drainage within the aquifer to discharge point is controlled by the plunge of the fold. Sistema Huautla drainage has formed along the eastern limb of overturned strata to the west and it flows along a N-S strike and down the plunge to the south (Figure 16).

Sistema Cuicateco has formed on the western limb of a syncline which dips to the east. Conduit flow is to the east until it reaches the trough of the syncline and then it flows along a NW-SE strike and follows the plunge to the north (Figure 18).

Hydrologic Field Research

To study groundwater flow direction, qualitative dye tracing was performed in the Sistema Huautla Karst Groundwater Basin in 1988 and 1990. Stone (1984) located springs on both sides of the Rio Santo Domingo. For Sistema Huautla, a single perennial outflow on the north wall of the Rio Santo Domingo (Sistema Huautla Resurgence) was established by a dye trace injected into a cave stream. The dendritic vertical drainage system of Sistema

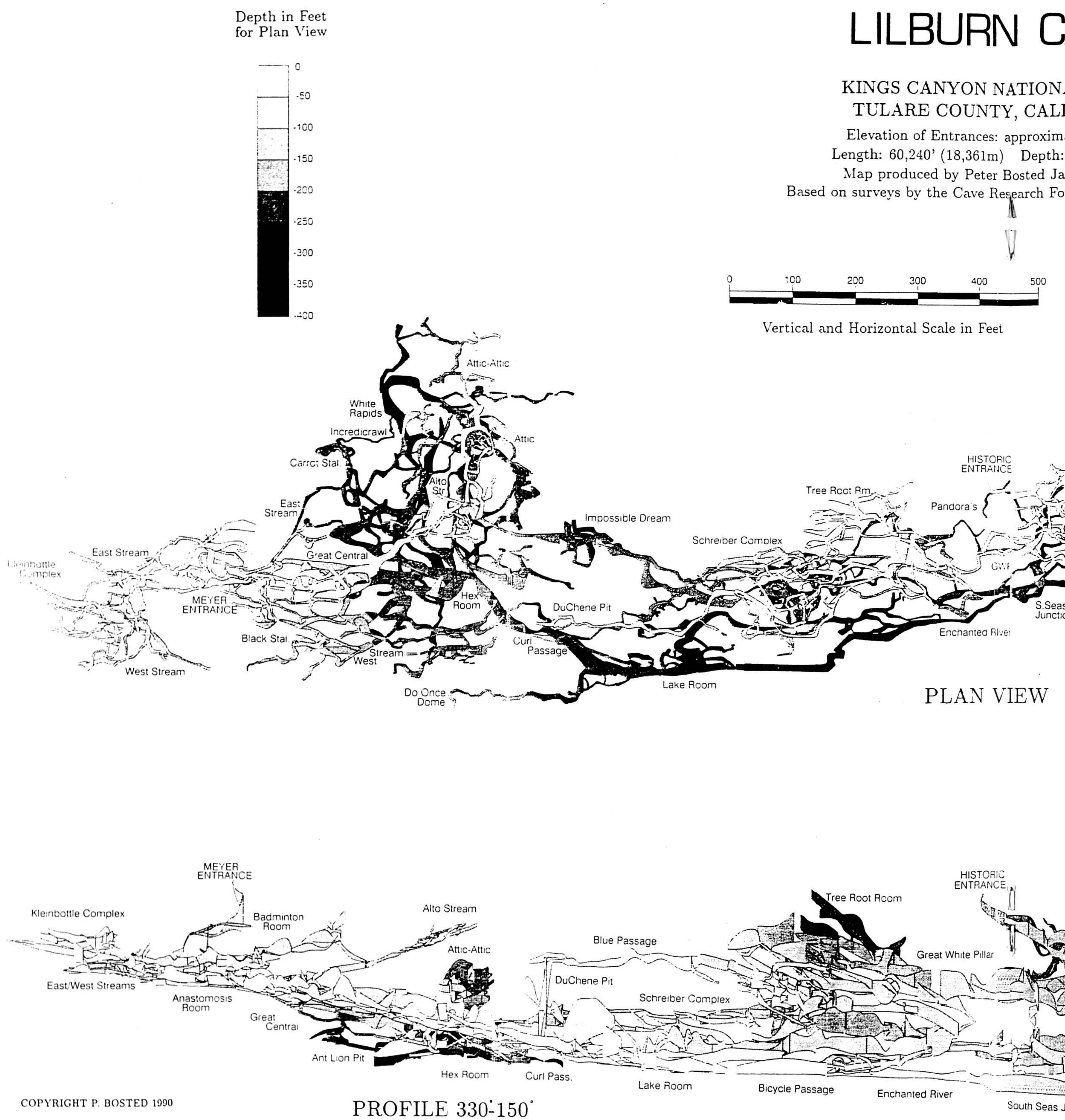
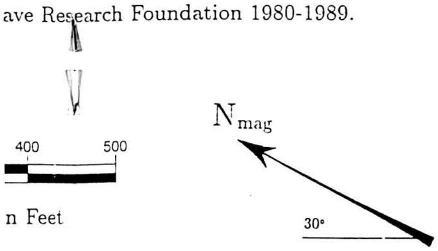


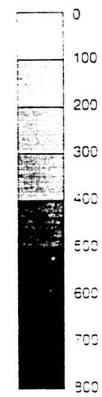
Figure 17: Computer-generated maps of Lilburn Cave in California. Different gray tones depict corresponding subsurface levels in the cave (plan view) or different distances from the viewer (profile view).

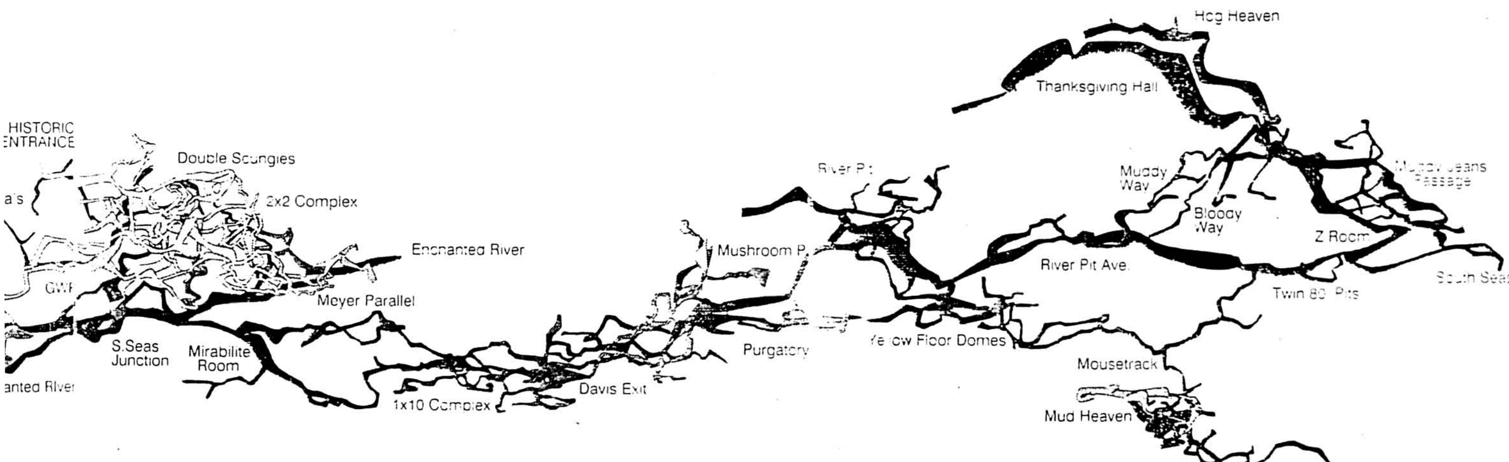
RN CAVE

ON NATIONAL PARK
UNTY, CALIFORNIA
ınces: approximately 5200'.
361m) Depth: 404' (123m).
Peter Bosted January 1990.
ave Research Foundation 1980-1989.

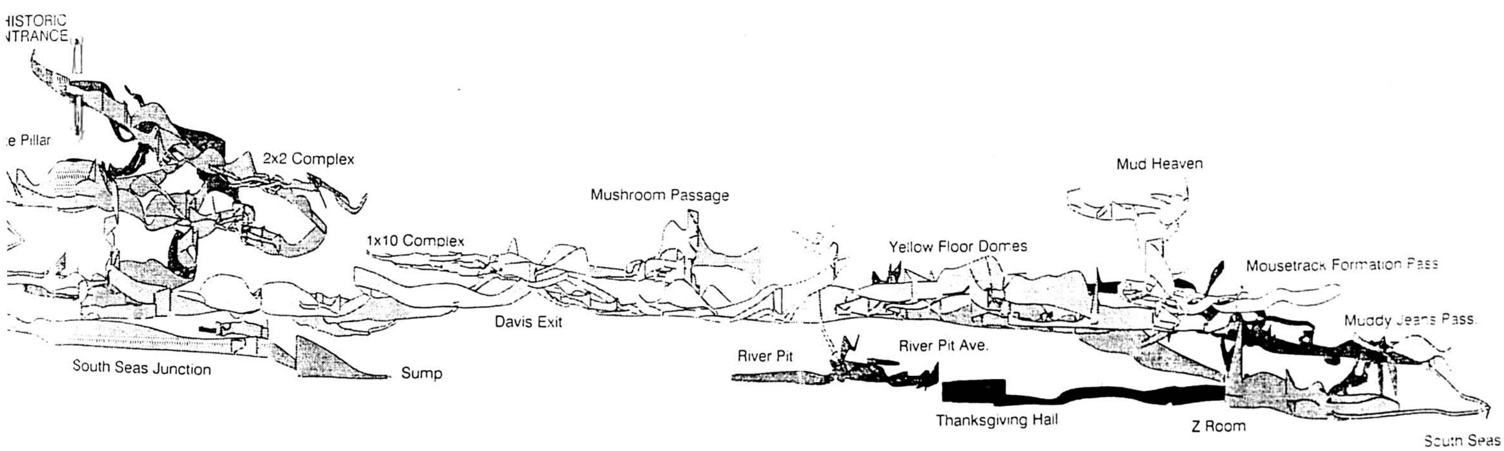


Distance from Viewer
in Feet for Profile





N VIEW



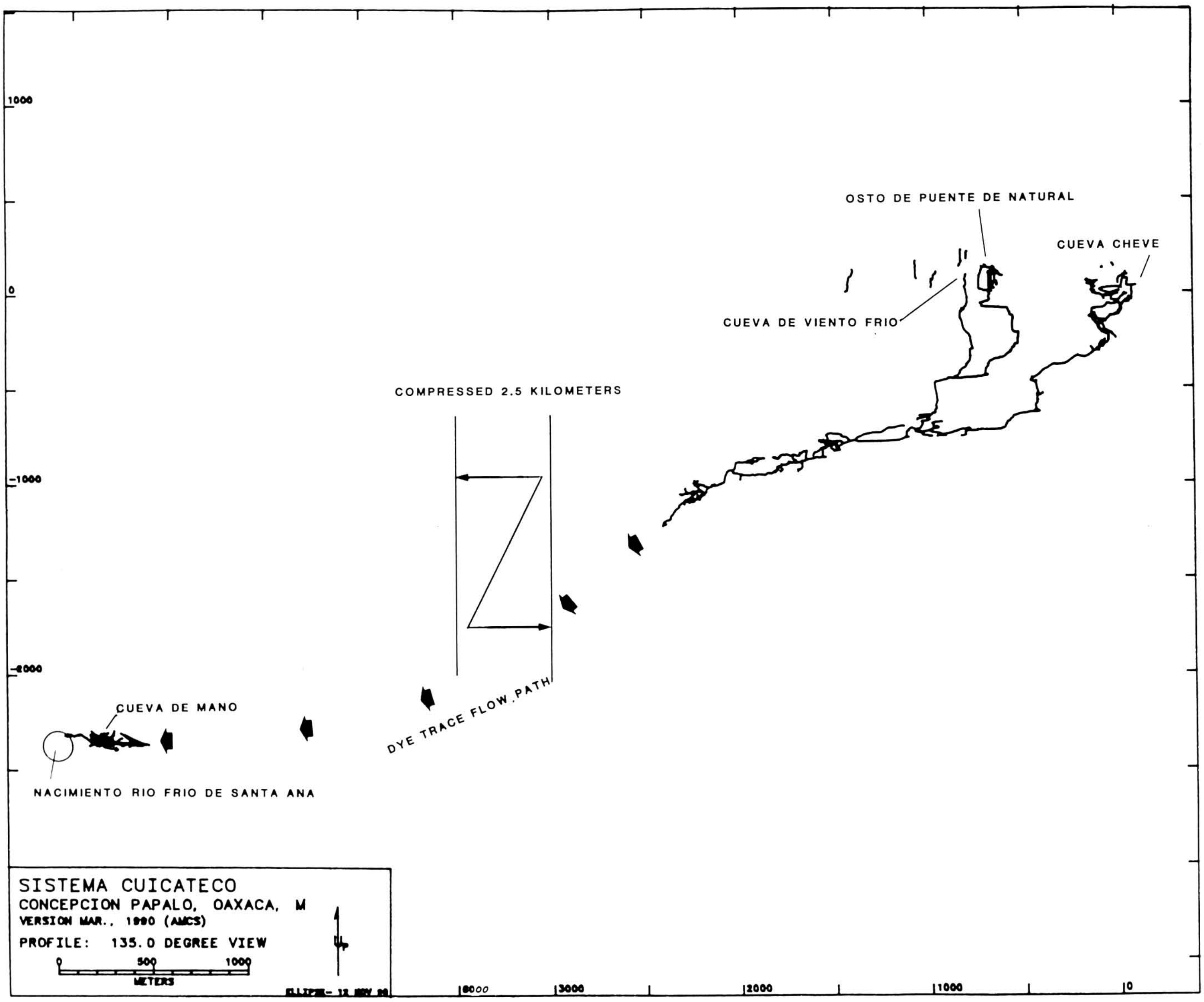


Figure 18: The conduit flow of Sistema Cuicateco is to the east until it reaches the trough of the syncline and then it flows along a NW-SE strike and follows the plunge to the north.

Huautla was proven to have a vertical relief of 1770 meters. The linear drainage of the karst groundwater basin is approximately 17 kilometers.

Similarly, a dye trace was conducted in 1990 at Sistema Cuicateco's Cueva Cheve entrance to the Nacimiento de Rio Frio de Santa Ana. The input is located at 2720 meters elevation and the resurgence is a single spring at 300 meters. The 2420 meter-deep dye trace is currently the world's deepest. The proven vertical hydrologic extent is 2580 meters. The elongate drainage basin has a minimum linear drainage of 21 kilometers along the syncline.

During 1990, the stream caves Cueva de Congrueo and Cueva de Agua Carlota were dye traced to the Sistema Huautla Resurgence. The dye from Carlota took almost a month to exit. It was observed in Cueva de Agua Carlota that dye was impounded by potholes and slowly released into cave streams. It is further hypothesized that dye was also impounded in deep sumps in phreatic loops under low flow conditions at a base level with low gradient. The dye from Sistema Cuicateco exited after eight days indicating a steady gradient along the base level with perhaps brief impoundments.

Conclusions

Research and the formulation of ideas concerning the geology, hydrology and speleogenesis of these vertical drainage systems are continuing. Based on research to this point the following conclusions are presented: a) Sistema Huautla and Sistema Cuicateco karst groundwater basins are formed in and controlled by elongate synclines, b) springs for the karst groundwater basins occur down the plunge of the synclines, c) hydrologic flow patterns are controlled by the structural geology, d) both karst groundwater basins have single perennial springs as discharge points.

New Studies on San Josecito Cave, Nuevo Leon, Mexico

by Joaquín Arroyo-Cabrales

San Josecito Cave is a locality that has demonstrated the greatest potential for a detailed Late Pleistocene record in the southernmost section of the Southern Plains. It is located on the western flank of the Sierra Madre Oriental in southern Nuevo León, México, at the edge of the Mexican Plateau; and is about 1km south from Ejido San Josecito, at 23°57'21" latitude north, 99°54'45" longitude west. The elevation is approximately 2250m.

The cave is a single drop, multi-entrance fissure that occurs in folded Late Jurassic limestone. Between 1935 and 1941, personnel of the California Institute of Technology (Cal Tech), under the direction of Dr. Chester Stock, quarried the uppermost chamber and recovered a rich vertebrate fauna.

The San Josecito Cave fossil fauna includes one species of amphibian, two species of iguanid lizards, two species of snakes, more than 43 species of birds, and more than 45 species of mammals (Arroyo-Cabrales *et al.*, 1989). At least 30 extinct taxa occur, 12 of which were described based on fossil specimens from this cave, including the well-studied great-footed extinct turkey (*Meleagris crassipes*) and the Pleistocene vampire bat (*Desmodus stocki*). The fauna may be from different times throughout the Late Pleistocene. However, in most studies, the San Josecito Cave fauna has been viewed as a single time-related entity. Prior stratigraphically-controlled analyses have not been done and radiocarbon dates are not available. Taxonomic studies of particular taxa form the primary research base with the assemblage.

From a review of the available documentation referring to Stock's excavation, it appears that the cave was divided into five north-to-south blocks. In each block, workers shovel-excavated in 5 ft. levels (1.5m), removing all the sediments from the upper levels. At the 65 ft-level (19.8m), a test pit (2x2m unit, 4.5m deep) was excavated in the southern portion of the chamber where Stock's crew had encountered the heaviest bone deposit corresponding to the area below the major entrance that could constitute a trap.

During the 1989 reconnoiter of the cave, our sidewall cleaning of Stock's pit indicated well-stratified deposits with large quantities of small bone throughout the 4.5m exposure. Stock's interest in the cave apparently decreased when the large bones began to be rare.

The previous information provided the basis for proposing our project objective, the study of the San Josecito Cave fauna and its bearing on the Late Pleistocene ecosystems of the Mexican Plateau and the Southern Plains.

The first of three steps of the project was to locate and explore the area around San Josecito

Cave. We visited the cave on three occasions, bringing in preliminary vertical and horizontal control, collecting specimens of the present flora and fauna, and mapping the other caves located downslope from San Josecito Cave (Figure 18).

During our reconnoiter of the cave, a sketch map was made that shows the only room (ca. 25x11m) lit by three skylights, two of them 30m above the floor and one large upper opening that probably served as a trap for the fauna and was above Stock's final pit (Figure 18). An access tunnel descends 41° from the east to a 7m drop or very steep climb down to the floor of the main room. Backdirt from the early paleontological excavations was stacked or piled behind dry-laid rock walls on most of the main room with some spilling south into a passage that goes down by about 60m. From Stock's correspondence, that passage was said to be excavated by the local people looking for a "treasure" prior to the paleontological excavations.

Attempts were made to match the views from photographs taken during Stock's excavations with marks and other features currently visible on the cave walls. This procedure has helped to locate within a stratigraphic section some of the fossils that have recorded data.

The second step of the project was the examination of the fossil material and corresponding documentaiton from Stock's excavation of San Josecito Cave. Material and documentation were on deposit at the Natural History Museum of Los Angeles County.

The cave reconnaissance and the collection data reanalysis constituted the foundation of the next step of our study, that of renewed, stratigraphically-controlled excavations of San Josecito Cave. The objective of the excavation was to recover high-resolution data, both stratigraphically and taphonomically, that would contribute to the paleoenvironmental reconstruction of the ecosystem(s) preserved in San Josecito Cave.

The first excavation season was undertaken with a six-week field season from March through April, 1990. Final results based on the renewed excavation are not yet available as the processing of materials is still being done in several laboratories in México and the United States.

The San Josecito Cave fauna study is a building block towards the understanding of Late Pleistocene paleoenvironments, climates, and faunal communities in the Mexican Plateau and the Southern Plains. Once San Josecito Cave is better understood, its fauna can be compared with other faunas from contemporaneous sites on the Mexican Plateau, like El Cedral in San Louis Potosí, and in the southernmost part of the Southern Plains to form a more detailed paleoecologic framework for that part of the region. The research project is a joint venture between U. S. and Mexican researchers.

References

Arroyo-Cabrales, J., Johnson, E., and Ralph, R. W. 1989. An Initial Reappraisal of San Josecita Cave and its Late Pleistocene Fauna. *Current Research in the Pleistocene*, v. 6, p. 63-65.

Volcanospeleological Pseudokarst in Micronesia: An Overview

by Bruce W. Rogers

In 1984, the Pacific Basin Speleological Survey (PBSS) embarked upon a project to compile a preliminary listing of the known caves in the island nations of the Pacific Basin. Previous American, Australian, French, and British work in Melanesia and portions of Polynesia was a matter of record so Micronesia was selected as the focus of the PBSS' working area. Pohn Pei, Kosrae, Chuuk, and Yap States of the Federated States of Micronesia;

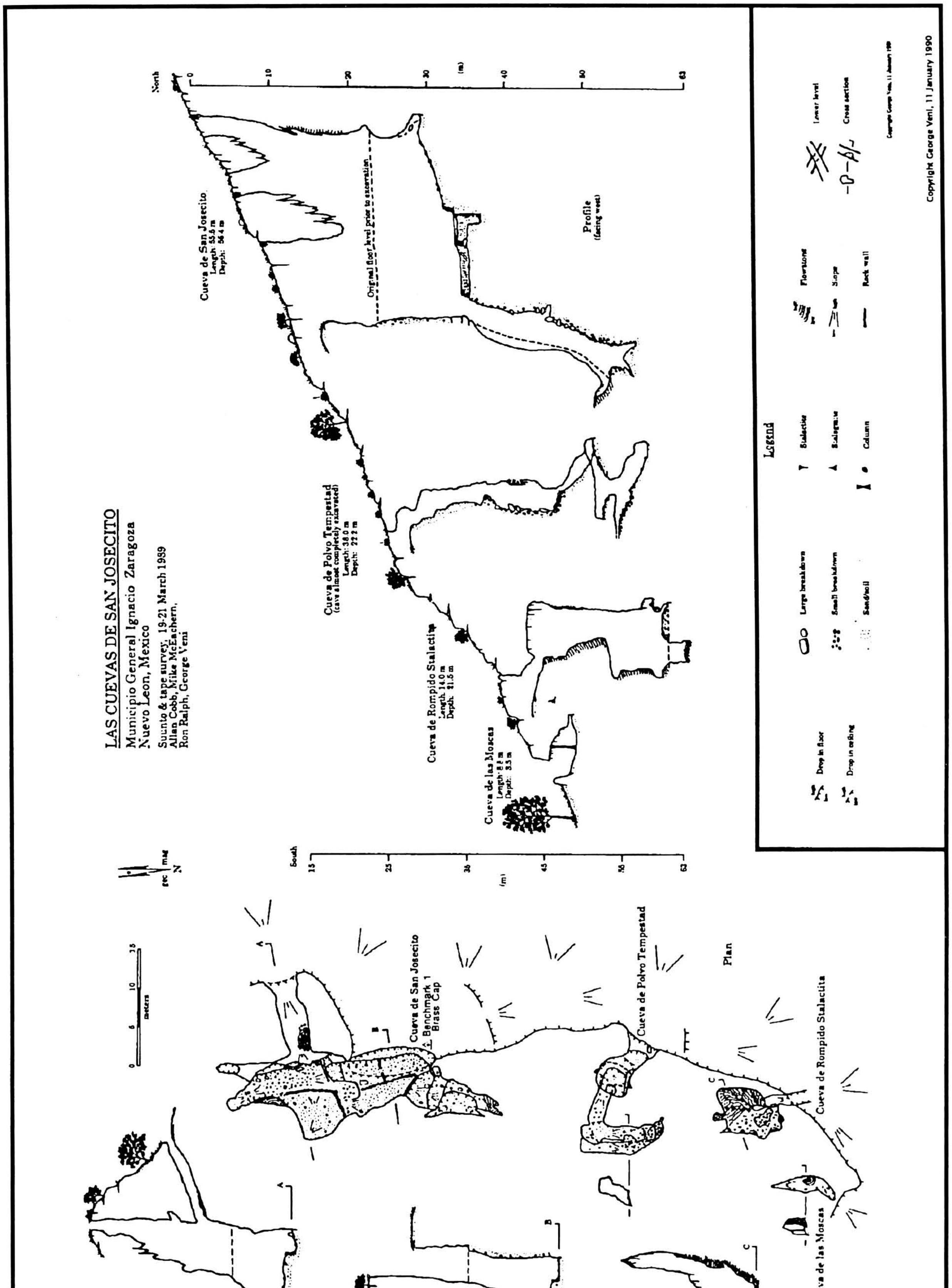


Figure 18: Map of San Josecito Cave and other nearby caves.

Agrihan, Pagan, Saipan, and Rota Islands in the Commonwealth of Mariana Islands; the Territory of Guam; and the Republic of Belau were visited. Extended expeditions to these areas in 1984, 1986, and 1989 have found a small but significant sampling of volcanic speleological features to be investigated.

Pohn Pei Island

On the island of Pohn Pei rock shelters up to SO m wide and deep and 30 m high have formed in vertical cliffs in the middle elevations of the island. These shelter caves have their origin in the differential weathering of breccia beds intercalated with massive basaltic flows. Small rock shelters formed either by collapse of basaltic rock outcrops or failure of lava tube segment roofs and containing large amounts of rock art have been found on the uppermost slopes of the island. Some of these sites are prominent in indigenous peoples religious beliefs. In the walls of construction material quarries where Pohn Peians have removed both columnar basalt "logs" and crushed rock for over 800 years, many large, lava-filled tubes are exposed. On the lower slopes of the volcanic island are many outcrops of olivine basalt showing kluftkarren development. The origin of these solution forms is poorly understood but may be due to the fact that silicate minerals are unstable in the presence of water high in dissolved carbon dioxide and organic acids common in warm, humid climates.

Kosrae Island

Kosrae State has at least one large lava tube developed in olivine (?) basalt in the middle slopes of the central massif. The cave is approximately 10 m in diameter, is floored with deep deposits of both bird and bat guano, and extends for an unknown distance. Two large colonies of both Sac-wing(?) bats and cave- dwelling swiftlets occupies the cave.

Chuuk Islands

In the main island grouping of Chuuk State several volcanic pseudokarst features are found. On the Pata peninsula of Tol Island a 30 m long and 10 m in diameter lava tube in an 8.2 m.y. old olivine basalt lava has been utilized by local inhabitants for many hundreds of years. A local legend attributes the origin of the tube to industrious sea turtles assisting an imprisoned local chief. The Japanese Army also used the cave as a munitions bunker during W.W. II. On the upper slopes of the island two 4.6 m.y. old melilite nepheline basalt and nepheline basalt lava flows are surfaced with a meter-high kluftkarren field as a result of the extreme - up to 10 m deep - weathering common to these islands.

Yap Island

There are several reports of small sea caves eroded into the western shores of Yap Island in Yap State. These have formed in basalt and andesite flows of Cretaceous age which have been later metamorphosed by subduction into garnet-bearing green and blue schist and amphibolite.

The islands of Saipan, and Rota in the Commonwealth of the Northern Marianas Islands, the Territory of Guam, and the Republic of Belau are largely comprised of elevated Miocene to Holocene reef limestones. These islands, however, have large areas of exposed Paleocene to Eocene volcanic basement rocks. found on these islands are important to both the local development of groundwater and cultural resources. Intercalated basaltic and andesitic lavas and tuff beds in many these carbonate terrains have channeled ground water which produced solution caves. These beds also allow perching of the local water table thus producing flashy springs, some of major magnitude. Volcanic agglomerates also are the hosts to many small sea caves in the littoral zones of Guam, Saipan, and Belau. These volcanic rocks also have been important sources of tough rock from which the Chamorro, Yapese, Kosraean, Chuukese, Pohn Peian, and Belauan peoples fashioned tools and carved a great variety of megalithic sculptures over the last 3500 years. Farallon de Pajaros (Uracas), Maug, Asuncion, Agrihan, Pagan, Alamagan, Guguan, Sarigan, and Anatahan Islands in the northern Marianas Islands are Miocene to Holocene volcanos. All have reported lava tubes and other non-solution caves but little is known of their extent or contents.

Agrihan Island

Agrihan Island is a Quaternary volcano of basaltic and andesitic composition. As recently as 1917 volcanic activity included lava flows down the slopes of the central volcano but little is known of the extent or contents of the resulting lava tubes.

Pagan Island

Pagan Island is the only island in the northern "inner arc" Mariana Islands which has a well known volcanic history. It is a Late Miocene to Holocene composite volcano. Major eruptions in 1872, 1909, 1917, 1923, 1925, 1929-30, and 1982 have been recorded. While most of the basaltic to andesitic lavas have been erupted as aa flows or pyroclastic deposits, there are moderate-sized areas of pahoehoe flows. In these flows on the west, east, and especially the south flanks of Mount Pagan are concentrations of caves of differing types. Lava tubes up to 10 m in diameter, collapse trenches over 13 m deep; eruptive fissures, vents, and hornitos deeper than 20 m; and many 1.5 m diameter surface tubes have been reported. Some tubes have been utilized repeatedly with tube-bearing younger flows emanating from the older tube's mouths. Only one series of tubes, however, has been correlated with a documented eruption; that of the February to May, 1925, eruption of Mount Pagan. During this eruption an olivine augite basalt pahoehoe flow descended the west slopes of Mount Pagan at 4 am on March 11 and formed a series of lava tubes. Many of these caves are still active fumaroles, emitting hot air and steam. The extent and composition of secondary deposits in these and the other known older tubes are unknown; however, inferences of sulfur and carbonate deposits are found in the literature.

Inland from many of the steep, rocky headlands are areas of fissure caves up to 10 m deep formed by separation of basalt blocks from the headlands and resulting slow seaward creep. Along the east and northwest coasts of Pagan are deep sea caves formed by littoral excavation of loose clinker. The caves have roofs and floors of massive basalt flow units.

The constant volcanic activity, civilian and military construction during the 1914-45 Japanese occupation, and 1950's U.S. Marine and Navy war games activities have all but erased evidence of Pagan Island's earliest inhabitants, thus we know nothing of their utilization of the island's caves. The Spanish and German occupiers of the island left little record of their activities but we do know that they mined sulfur from various sites in the inner crater of Mount Pagan. The Japanese mined the same(?) deposit as well as deposits discovered near the summit of the south cone of South Volcano during 1917 and 1934 but the amounts of sulfur obtained were small, the labor considerable, and both operations were abandoned. During the 1982 eruption of Mount Pagan, inhabitants of Lagona Village sought shelter in lava tubes for several days until evacuated by ship. Only incidental observations of spelean biology have been made, however, reports of large populations of cave-dwelling insectiverous and fruit (?) bats have been made as well as forest-dwelling flying foxes.

Rota Island

The island of Rota derives its water supply from a large karst spring perched on the island's andesitic basalt pile. A small cave in agglomerate has developed at the island's Sabana District summit. Other deposits of fine-grained andesite and andesitic basalt exposed on the southeast coast were utilized as sources of stone for tools.

Saipan Island

On the island of Saipan in the Sabana Dan Dan area are small soil pipe caves which have developed in tuffaceous siltstones and sandstones of the Eocene Hagman Formation. In the Eocene andesitic volcanic rocks of the Hagman Formation exposed on the Hagman Peninsula are several small caves at sea level. Deep fissure caves in up to 10 m square creeping blocks of tuffaceous sandstone and conglomerate are also present. Other small sea and fissure caves in the Hagman sandstones and conglomerates are located along the sea level areas of Punta I Naftan. Andesite and dacite from the Eocene and Eocene(?) Densinyama, Hagman, and Sankakuyama Formations were locally quarried for tool making.

Guam Island

On the island of Guam are several areas of badland topography including small soil pipe caves developed in tuffaceous shale of the Eocene to Oligocene Alutom Formation. Along the southwest coast of the island are small sea level caves developed in the basalt and basalt breccia of the lower Miocene Umatac Formation .

Palau Islands

In the northern volcanic islands of the Republic of Belau short sea level caves have developed in Eocene to Oligocene basaltic andesite, andesite, and dacite flows and breccia of the Babeldaop, Aimeliik, and Ngeremlengui Formations. Large slabs of andesite also furnished material for the extensive megalithic sculpture tradition and for tools used in the islands.

References

Cloud, P. E., Jr., R. G. Schmidt, and H. W. Burke, 1956, Geology of Saipan, Mariana Islands, part 1, General Geology, *U. S. Geol. Survey, Prof. Paper 280-A*, 126 p.

Corwin, G., L. D. Bonham, M. J. Terman, and G. W. Viele, 1957, *Military Geology of Pagan Island, Mariana Islands*, U. S. Army Corps of Engineers, Intelligence Division, Headquarters, U. S. Army Pacific, 259 p.

Daly, R. A., 1916, Petrography of the Pacific Islands, *Geol. Soc. Am. Bull.*, v. 27, pp. 325-44.

Emery, K. 0., 1962, Geology of Guam, Mariana Islands, part 2, Marine Geology, *U. S. Geol. Survey Prof. Paper 403-B*, 76 p.

Epp, D. 1978, *Age and Tectonic Relationships Among the Volcanic Chains On the Pacific Plate*, (PhD. dissert.), Honolulu, Univ. Hawaii, 199 p.

Keating, B. H., D. P. Mattey, J. Haughton, and C. E. Hensley, 1984, Age and Origin of Truk[sic] Atoll, Eastern Caroline Islands: Geochemical, Radiometric Age, and Paleomagnetic evidence, *Geol. Soc. Am. Bull.* v. 95, pp. 350-56.

Mattey, D. P., 1982, Minor and Trace Elements Geochemistry of Volcanic Rocks From Truk [sic], Ponape [sic], and Kusaie [sic], Eastern Caroline Islands: Evolution of a Young Hotspot Trace Across Old Oceanic Crust, *Contributions to Mineralogy and Petrology*, v . 80, pp. 1 - 13.

Stark, J. T., 1958, *Military Geology of Truk[sic] Islands, Caroline Islands*, U. S. Army Corps of Engineers, Intelligence Division, U. S. Army Pacific, 205 p.

Stark, J. T., 1963, Geology of Guam, Mariana Islands, part 3, Petrology of the Volcanic Rocks of Guam, *U. S. geol. Survey Prof. Paper 403-C*, 32 p.

Stark, J. T. and R. L. Hay, 1963, Geology and Petrography of the Volcanic Rocks of the Truk Islands, East Caroline Islands, *U. S. Geol.Survey Prof. Pap. 409*, 41 p.

Tracey, J. I., Jr., S. 0. Schlanger, J. T. Stark, D. B. Doan, H. G. May, 1963, Geology of Guam, Mariana Islands, part 1, General Geology of Guam, *U. S. geol. Survey Prof. Paper 403-A*.

ECOLOGY

Bat Survey and Monitoring, Lava Beds National Monument

by J. Mark Perkins

The bat survey project at Lava Beds National Monument is almost complete. Many individuals connected with CRF and the monument had valuable input. We surveyed about one half of the named caves winter and summer for roosting bats.

Plecotus Townsendii

Surveys revealed approximately 600 *P. Townsendii* (Townsend's Big-Eared Bat) using eight caves, three in summer and five in winter. Summer nursery colonies numbered two. The larger maternity colony appears to stage (meet early) in an obscure side passage of a moderately well known cave from about May 1 to June 15, or until the colony is disturbed. The colony then moves to a nearby cave. Disturbance at this second cave appears to be minimal, since the general public and most cavers are not aware of the cave location.

The smaller maternity colony attempts to roost at Ovis Cave in the Cave Loop area, a popular area with Lava Beds cave visitors. Initial staging appears to occur in Thunderbolt and Blue Grotto Caves, also within the Cave Loop area. Delay in posting Ovis this year resulted in these bats being disturbed. They then moved to downslope passages of Thunderbolt, adding caves and passages administratively closed to the public. Counts by summer personnel and myself indicate Cave Loop population levels are similar to those noted by E. Pierson in 1988 (125 total females). The larger colony appeared to number only about 250 adult females this year, down from over 400 counted by E. Pierson in 1988.

Several single males were noted roosting in Cave Loop caves during the summer of 1990. No male roost sites with more than two or three individuals were noted or reported. The location of the majority of the male population in the summer is presently unknown. I did find one male in a a cave just outside the monument in May 1990.

Other bats

Steve Cross led a large contingent to count and photograph emerging *Tadarida brasiliensis* (Mexican Free-Tailed Bats) at the maternity cave for this species. Numbers seem to be about what they were before (125,000).

Mike Sims reported a *Myotis* sp. colony in a nearby cave during a late summer survey trip. Efforts will be made to visit the cave in summer 1991 and verify the species.

Mist netting at Heppe Cave (a water source) expanded our knowledge of resident bat species. Despite the cold (ice in water), we netted over 30 bats and noted at least 5 species not known to congregate colonially within the monument.

Recommendations for seasonal closure of several caves to protect the resource will be made. Summer closures will begin prior to Memorial Day and continue through Labor Day. Winter closure recommendations for the two most significant hibernacula will be Oct 1 through April 1. Other winter sites will be recommended for closure November 1 through April 1.

A computer data base and maps with roost sites, bat distribution and populations at each site are being prepared.

Isotopic and Micropaleontologic Study of the Proterozoic Beck Spring (California) and Mescal (Arizona) Formations: Evidence for Precambrian Land-based Photosynthetic Communities

by Ray Kenny

Isotopic analyses of carbonate from the Beck Spring Dolomite (~0.8 Ga.) define two systematic diagenetic alteration trends on a $\delta^{18}O$ - $\delta^{13}C$ diagram (Figure 20). The upper trajectory has relatively invariant $\delta^{13}C$ and ranges from 31‰ ($\delta^{18}O$ smow), 5‰ ($\delta^{13}C$ pdb) to 9‰ ($\delta^{18}O$), -1‰ ($\delta^{13}C$). This trend is interpreted to result from early to late diagenetic and hydrothermal alteration and is in agreement with marine values reported by earlier workers (Zempolich *et al* 1988; Tucker, 1983). The lower trajectory ranges from 31‰ (d1 8O), 5‰ ($\delta^{13}C$) to 18‰ ($\delta^{18}O$), -5‰ ($\delta^{13}C$). The alteration trend toward low $\delta^{13}C$ occurs in samples associated with filled solution cavities, breccias, and recemented chert "lag" deposits near the top of the sedimentary unit. These coupled ^{13}C and ^{18}O depletions could have occurred as a result of one of the following equilibrium conditions:

1) oxidation of marine organic matter deposited on a near-shore, subaerial exposure surface during storms or episodes of high tides;

2) an episode of exceptionally low marine planktonic (photosynthetic) productivity which

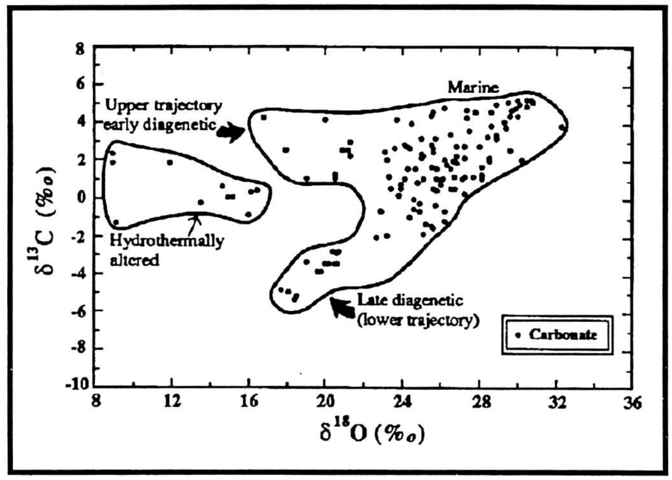


Figure 20: $\delta^{13}C/\delta^{18}O$ diagram of analyses of the Late Proterozoic Beck Spring Dolomite and correlative diagenetic trend interpretations. Upper trajectory is interpreted as hydrothermal and early diagenetic alteration of marine carbonate. Lower trajectory represents depleted ^{13}C and ^{18}O samples from exposure surface breccias and vug-fill carbonate and is interpreted as a late diagenetic alteration trend. The lower diagenetic alteration (paleokarst exposure surface) trend suggests ^{13}C & ^{18}O depletion in the presence of both plant-respired CO_2 and meteoric water which indicates the presence of a land-based photosynthetic (algal?) community during the Late Proterozoic.

could result in a ^{13}C depleted ocean or near-shore lagoonal reservoir;

3) dissolution and reprecipitation of carbonate in the presence of ^{13}C depleted CO_2 derived from plant (photosynthetic) communities and ^{18}O depleted meteoric water; or

4) decarbonization and reprecipitation from a hydrothermal alteration event.

Oxidation of organic matter heaped on to near-shore environments (possibility #1), by definition, requires proximity to the coeval basin. In this study, isotope analyses primarily focused on areas which arguably were associated with brecciated chert residuum and other paleokarst features. In addition, a significant amount of organic material would be required to achieve the carbonate depletions observed in the study area. Therefore, this is probably not the case for the study area.

Periods of exceptionally low productivity (possibility #2) may result in precipitation of ^{13}C depleted carbonates. ^{13}C depletions as much as -10‰ ($\delta^{13}C$pdb) have been suggested by Burns and Matter (1990). $\delta^{18}O$ values however, would not be similarly depleted. These carbonates would also lack the observed contrast between ^{13}C enriched (normal marine) carbonate values found in clasts and ^{13}C depleted values of the vug-fill carbonate matrix.

Decarbonization associated with penetrating hydrothermal fluids (possibility #4) could produce similarly depleted ^{13}C and ^{18}O carbonates. Analyzed values of hydrothermally altered carbonate in the study area are demonstrably different from the ^{13}C depleted carbonates below the exposure surface (Figure 19). Petrographic analyses of altered carbonates also reveal various distinguishing characteristics, including, mechanical brecciation, sparry calcite, and cross-cutting veins. Hydrothermal alteration was not the cause of the observed ^{18}O and ^{13}C depletions.

Dissolution and reprecipitation of carbonate in the presence of ^{18}O depleted meteoric water and ^{13}C depleted, plant-respired CO_2 (possibility #3), has been documented for Holocene and Pleistocene subaerial exposure surfaces for early carbonate stabilization events (supratidal and lowland karsts)(Gross, 1964; Allan and Matthews, 1982). This environment requires close proximity to the coeval basin and is characteristic of many modern and ancient platform-type carbonate environments. The Beck Spring and Mescal Formations however, were far from the coeval basin during the late diagenetic episode of continental karsting. Early diagenetic carbonate dissolution features (Figure 21)(characterized by isopachous rim cements, small scale vug-fill precipitates, and pendent structures) are depleted in ^{18}O but retain an enriched marine $\delta^{13}C$ signature. Continental paleokarst-related, vug-fill carbonate is consistently depleted in both ^{13}C and ^{18}O relative to marine values. Significantly depleted ^{13}C carbonate values below the Precambrian Beck Spring/Kingston Peak unconformity are therefore best interpreted as resulting from ^{13}C depleted organic CO_2 produced by photosynthetic organisms that colonized the ancient land surface (Kenny, *et. al.*, 1990).

Supporting evidence for this interpretation is found in isotopic analysis of the silicified chert

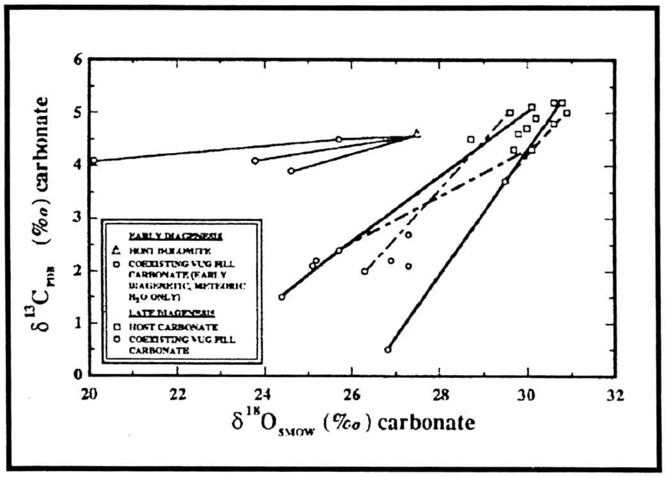


Figure 21. $\delta^{13}C$/ $\delta^{18}O$ diagram of marine (host) and vug-fill carbonate of the Beck Spring Dolomite. Early diagenetic features show invariant $\delta^{13}C$ and depleted ^{18}O values resulting from an influx of meteoric water only. Late diagenetic vug-fill carbonate is consistently depleted in both ^{13}C and ^{18}O suggesting carbonate dissolution and reprecipitation in the presence of meteoric water and depleted, plant-respired CO_2.

residuum which accumulated at the top of the formation during the paleokarst event. Several phases of silica precipitation can be identified in outcrop and in thin section. Analysis of the silica cement or matrix reveals a depletion in ^{18}O relative to the early diagenetic chert nodules suggesting precipitation from meteoric water.

The pervasively silicified upper units of the Mescal Formation (~1.2 Ga.) at Shell Mountain (Az.) contain significantly depleted $\delta^{18}O$ and δD cherts relative to early diagenetic, unweathered cherts lower in the section (Figure 22). The upper unit of the Mescal is an upland paleokarst as documented in previously published field studies (Shride, 1967). Petrographically, the pervasively silicified Mescal Formation contains "colloform" or laminated botryoidal silica fabrics (Figure 23). The small spheroids of the laminated botryoidal fabric range from 0.1 to 0.5 mm in diameter, have a brownish color banding due to the presence of microscopic inclusions (i.e., water), and strongly resemble organic structures or silica replaced travertine or sinter which form on blue-green and green algae. However, further studies are needed

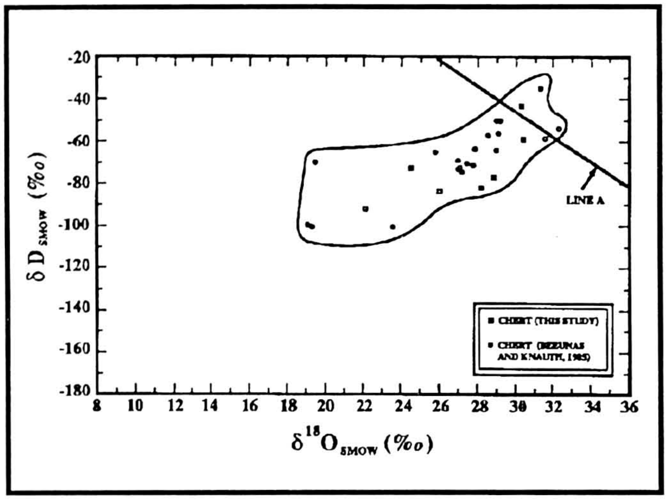


Figure 22: Isotopic composition of the Late Proterozoic Mescal cherts. The domain is elongated in a direction parallel to the meteoric water line (not shown). Line A is the assumed locus of isotopic compositions of cherts in equilibrium with ocean water at various temperatures (from Knauth & Epstein, 1976). Unweathered cherts (marine) low in the stratigraphic section plot near Line A; silica "cement" and late diagenetic "chert" associated with the paleokarst exposure surface have depleted δD and $\delta^{18}O$ values and plot below Line A.

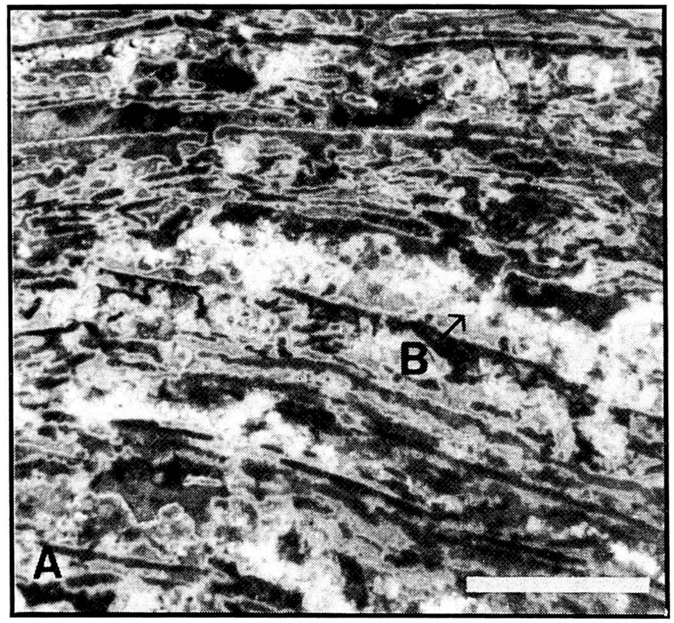


Figure 23: Photomicrograph of late diagenetic, laminated, botryoidal silica fabrics from the top of the Late Proterozoic Mescal Fm. (Az.). Depleted $\delta^{18}O$/δD values indicate silica precipitation/replacement from meteoric water. A) High original porosity, rhythmic laminae, and botryoids of silica. Scale bar is 1 cm. B) Small spheroids of laminated botryoidal fabric which range in size from 0.05 to .5 mm in diameter. Spheroids are chalcedony and show brown color banding due to the presence of microscopic inclusions.

to verify this preliminary interpretation. Isotopically, the botryoidal fabrics are depleted in $\delta^{18}O$ and δD relative to marine values, again suggesting precipitation of silica from meteoric waters.

Thin sections of chert from exposure surfaces at the top of the Beck Spring and Mescal Formations contain microstructures in vugs that were filled with fibrous quartz during the Precambrian weathering event (based on isotopic evidence). The microstructures in the chert are interpreted to be microfossils and include 2 µm wide x 100 µm filaments and 12-24 µm hollow, organic-walled spheroids from the Beck Spring and 2 µm wide filaments from the Mescal (Figure 24). The filaments have a size and morphology consistent with cyanobacteria and bacteria; spheroids may represent large cyanobacteria, envelopes of colonial coccoid cyanobacterium, or eucaryotic algal unicells. These microfossils represent the earliest documented occurrence of land-based photosynthetic organisms.

The combined isotopic, field, petrographic and micropaleontologic evidence at 2 separate localities are strong arguments that the late Precambrian land surface was colonized by photosynthetic communities.

References

Allan, J.R. and Matthews, R.K., 1982, Isotope signatures associated with early meteoric diagenesis: *Sed.*, v 29, p 797-817.

Beeunas, M. and Knauth, L.P., 1985, Preserved stable isotopic signature of subaerial diagenesis in the 1.2 BY Mescal Limestone, central Arizona: *GSA Bulletin*, v 96, p 737-745.

Burns, S.J. and Matter, A., 1990, Carbon and oxygen isotope stratigraphy of latest Precambrian to Cambrian (?) carbonates of central Oman: *GSA Abstracts with Programs, Dallas*, p A190.

Figure 24: Photomicrograph of chalcedonic botryoid from the top of the Mescal Fm. Microstructure in chert is interpreted to be a 2 µm wide filamentous microfossil. Size and morphology is consistent with cyanobacteria or algae; enveloping silica is depleted in ^{18}O and D suggesting precipitation/replacement from meteoric (fresh) water. These microfossils represent the earliest documented occurrence of terrestrial photosynthetic communities. Scale bar is 100 µm.

Gross, M.G., 1964, Variations in the $^{18}O/^{16}O$ and 13C/12C ratios of diagenetically altered limestones in the Bermuda Islands: *Jour. Geology*, v 72, p 170-194. Kenny, R., Knauth, L.P. and Horodyski, R.J., 1990, Isotopic, field, and micropaleontologic study of the Proterozoic Beck Spring (Ca.) and Mescal (Az.) Formations: evidence for Precambrian terrestrial photosynthetic communities: *GSA Abstracts with Programs*, Dallas, p A191.

Knauth, L.P. and Epstein, S., 1976, Hydrogen and oxygen isotope ratios in nodular and bedded cherts: *Geochimica et Cosmochimica Acta*, v 40, p 1095-1108.

Shride, A.F., 1967, Younger Precambrian geology in southern Arizona: *USGS Professional Paper 566*, 89 p.

Tucker, M.E., 1983, Diagenesis, geochemistry and origin of a Precambrian dolomite: the Beck Spring Dolomite of Eastern California: *Jour. Sed. Pet.*, v 53, n 4, p 1097-1119.

Zempolich, W.G., Wilkinson, B.H. and Lohmann, K.C., 1988, Diagenesis of late Proterozoic carbonates: the Beck Spring dolomite of eastern California: *Jour. Sed. Pet.*, v 58, n 4, p 656-672.

Baseline Biological Inventory of Caves Near the Hardrock Mineral Prospecting Area, Oregon and Shannon Counties, Missouri

by Mick Sutton

In August 1990, CRF signed a contract with the Missouri Department of Natural Resources to map and inventory caves in an area of the southern Missouri Ozarks which the US Forest Service is considering opening up for lead mining. This highly karstic area includes some of the largest springs in the nation, emptying into two National Scenic Rivers—the Current and the Eleven Point. Many people fear that mining activity has a high potential for causing widespread groundwater contamination, affecting not only the springs and rivers, but also the many stream caves which surround the proposed mineral lease area. The inventory is intended to give a general picture of the caves and their biota on private and public lands in the general area of the proposed mineral leases. If the mining proposal develops further, this information will be used to design more detailed ecological studies of those sites that are found to be biologically significant and vulnerable to contamination. Some of the caves within the area had been inventoried previously (Gardner, 1986).

Field work commenced in mid-October 1990, although many preliminary trips, mainly for the purpose of mapping, took place over the summer. The caves are most notable for their biological variation within a general pattern. Only a few taxonomic determinations have so far been returned from specimens submitted for identification. The percentage of field work completed is difficult to estimate, since the sites vary greatly, and some are unknown quantities, but it is not less than 20%. Two small caves were added to the work list and one – Johnson Cave – was deleted; the latter is apparently a synonym for Walters Spring.

Aquatic communities

All of the cave streams communities examined include troglobitic isopods as a prominent component. Usually, they are by far the most populous of macro-invertebrates, with amphipods present in much lower numbers, but at one site the two groups were present about equally. Vertebrate stream life invariably includes long-tailed salamanders (*Eurycea longicauda*) and smaller numbers of grotto salamanders (*Typhlotriton spelaeus*), but the population density of Eurycea varies greatly between sites. Three of the larger streams have fish (*Typhlichthys subterraneus*). The Falling Spring fish almost certainly constitute a small, isolated population, and the same may well be true of the Turner Spring and Posy Spring populations. One site, Posy Spring, contains cave crayfish (presumably, *Cambarus hubrichti*). Aquatic snails (not yet identified) were found in three of five streams examined. Aquatic fly larvae (at least two species) occur in two of the streams examined.

Rimstone pools and mud-bottomed drip pools usually contain small numbers of amphipods or isopods (but not both).

Terrestrial communities

The sites examined include one important bat cave: Turner Spring has a (previously documented) gray bat maternity colony. No other rare and endangered bats have been encountered, but Falling Spring contains an exceptionally high density of hibernating pipistrelles, while Pipe Spring shows strong evidence of past use by gray bats. All except the driest and smallest caves include both long-tailed and cave salamanders. (Long-tailed salamanders are seen more frequently on moist clay banks than in the water).

Invertebrate fauna at almost all sites includes small muscoid flies (*Spelobia tenebrarum*), hump-backed flies (Phoridae) and Heliomyzid flies (*Amaebolaria defessa* and *Heliomyza brachypterna*). *Spelobia* were invariably attracted to carrion bait. Leiodid beetles (probably *Ptomophagus cavernicola*) were found at all bait sites—normally, these very common beetles are widely dispersed, and rarely encountered. Wood debris invariably yielded Chordeumatid millipedes; all types of organic debris contained springtails and mites. Springtails collected from three caves may represent undescribed species of *Onchiurus* (Christiansen, pers. comm.). Small, troglobitic spiders were found in one cave; pseudoscorpions were collected from bat guano. Rove beetles (probably *Aleochara* sp.) are also common in dense organic debris, especially beaver dens, which form prominent food resources in Turner Spring and Pipe Spring.

The following section summarizes briefly what has been learned of the biology and hydrology of the caves examined so far. Mapping results are described elsewhere by Scott House.

Barrett Spring Cave

Barrett Spring is one of the longer known stream caves within the study area. Aquatic snails were collected from the spring outlet: the cave has not otherwise been inventoried.

A stream flows through the cave and exits as Barrett Spring on the east side of Hurricane Creek. Under dry conditions, the output was measured at 0.84 liters/sec. The water flows down a short spring branch and sinks where it intersects the dry gravel stream bed of Hurricane Creek. Within the cave, the stream is predominantly shallow and gravel-bedded, although the entrance section is ponded 20-30 cm deep with a sandy bed. The stream has a relatively high gradient, at one point cascading over a 3 m waterfall. The stream passage trends north-east. The catchment is probably local, in the uplands east of Hurricane Creek.

Cave salamanders (*Eurycea lucifuga*) occur, predominantly near the entrance. One pipistrelle (*Pipistrellus subflavis*) and several Keen's bats (*Myotis keenii*) were noted in July and August.

Cascade Spring

This 30 m long cave is an addition to the list of known sites . Cascade Spring is a small outflow emerging 10 m. above normal river level on the Eleven Point River, several hundred meters upstream from Posy Spring. The cave has not yet been inventoried.

The small (<1 liter/sec.) stream flows over a gravel riffle at the entrance but a short way inside, the water is ponded. A tributary enters from a small canyon which can followed for 15 m. Both streams are evidently close to saturation or slightly over-saturated in calcite, as flowstone is being actively deposited where turbulence occurs.

Falling Spring Cave

Falling Spring is one of the most significant sites within the study area. It is (marginally) the longest stream cave known within the area, it contains a rich aquatic fauna, and it is recharged from the uplands east of Hurricane Creek: at least part of the recharge zone may fall within the proposed mineral lease area. The mean flow rate was measured by Aley (1978) as 21 liters/sec. A successful dye trace originated from an intermittent stream in Section 36, west of Highway 19, several km east of the proposed lease boundary.

The stream can be followed for about 1 km, at which point, air-space becomes minimal, and the stream continues in a completely or almost completely flooded passage. It has a very low overall gradient; the substrate varies from chert bedrock to gravel and sand. There is a population of southern cave fish (*Typhlicthys subterraneus).* Long-tailed salamanders were noted in low numbers. The invertebrate stream fauna is dominated by an isopod (not yet identified) and a small aquatic snail. The snail is slightly pigmented, and may be an epigean species. Amphipods are present in much lower numbers than isopods. Crayfish traps were set, but no crayfish were found. (Pigmented crayfish have previously been noted a short way upstream from the entrance). The drip-pool habitat is of very limited extent; the pools are inhabited by amphipods.

The terrestrial habitat consists mainly of extensive clay banks and rough bedrock walls and ceiling. There is a thin scattering of bat guano throughout, and a few areas of larger (raccoon?) scats. The terrestrial fauna is dominated by a large number of hibernating pipistrelles: in November, over 120 were counted, distributed more or less evenly. Cave salamanders and long-tailed salamanders are present in relatively low numbers. Invertebrates include: Leiodid beetles (probably *Ptomophagus cavernicola),* rove beetles (probably *Aleochara* sp,.), hump-backed flies (*Phoridae),* and Sphaerocerid flies all attracted to carrion bait; two species of Heliomyzid fly; a springtail; a dipluran; several species of mite; a millipede; and small numbers of camel crickets (*Ceuthophilus* sp.)

Kelly Hollow Cave

This is the longest known cave within the study area, with a surveyed length of 1950 m. The cave has not yet been inventoried; Gardner collected from the entrance area but did not examine the extensive stream passage.

Hydrologically, Kelly Hollow does not appear to be of major significance. Although its two large, parallel trunk passages doubtless served as master drains for a large area, they long ago ceased to function in that capacity. A small misfit stream enters the lower trunk from a tiny hole in the ceiling of a small dome and flows along and under the breakdown-modified passage for several thousand feet. The upstream limit of the stream passage was discovered during the present project. The shallow stream flows over a narrow bed of gravel and over small chert ledges. There are occasional pools up to 30 cm deep. Where the trunk ends in breakdown collapse, the stream channel skirts the fracture zone, drops down a series of two 5 m pits into a large terminal room, and sinks in channels too small and rubble-choked to enter. The destination of the water is unknown. Grotto salamanders, *Typhlotriton spelaeus,* occur in the stream. The Upper (Main) trunk has no active stream channel, but at several points minor inputs briefly intersect it.

Mine Hollow Cave

The cave consists of 100 m. of irregular, spongework type passage with a normally dry stream bed. The passage continues downstream below the valley floor, but would require digging to continue. Mine Hollow drains part of the lease area, and the cave is close to the valley bottom; contaminants might be expected to enter the cave via the intermittent stream. The cave was previously inventoried by Gardner; it may be re-examined as time permits.

New Liberty Church Cave

This is a short, simple cave consisting of 17 m of dry crawlway The entrance is in a low bluff, about 6 m above the valley floor of Hurricane Creek. There is no flowing water, and the silty floor is dry. The cave lacks a dark, constant temperature zone; the presence of cave-adapted forms is therefore unlikely. The cave is a new addition to the list of known caves in the area.

Pipe Spring Cave

Pipe Spring Cave contains a small stream recharged from the uplands east of Hurricane Creek. The recharge area is probably small and local.

The cave features a dry walk-in entrance leading to a room where the stream cascades 2 m off a thin chert ledge and is lost in breakdown, emerging as a spring branch outside. The stream runs over bedrock and gravel. The twilight zone is long, Just inside the dark zone, the stream is artificially dammed and half of the flow is conducted by a long pipe to a stock tank. Under dry conditions, the diverted flow was 0.1 liters/sec; the stream below the diversion was also flowing at approximately 0.1 liters/sec. The dam pool extends back for 20 m to a point where the stream emerges from a large, impenetrable breakdown pile. Tributary to the main stream is a long, high-gradient series of shallow rimstone pools which were static during the two visits, but may carry a small stream in wet weather.

Since the stream is ponded within the dark zone, the free-flowing section was examined in the deepest part of the twilight zone. The water temperature was 14 C, so this section of stream is probably within the aquatic constant temperature zone. The stream fauna consisted of isopods and amphipods in roughly equal numbers, together with large, presumably Dipteran, larvae. The latter may be an entrance zone phenomenon—as noted above, if a free-flowing stream exists within the dark zone, it is not accessible. Grotto salamanders and long-tailed salamanders are found in the ponded section of stream. Isopods, amphipods, and grotto salamanders are found in the rimstone pools: they appear to be mutually exclusive: only one group was found in any individual pool.

Terrestrial fauna consists of the usual Sphaerocerid and Phorid flies, Leiodid beetles, millipedes, etc. A beaver den supplies food for rove beetles (*Aleochara* sp.?), mites, etc. But the most significant finding was a large mass of extremely compacted bat guano within the breakdown room. It appears that this room once housed a significant bat colony. Fresh guano occurs in only small quantities, and at present, only a few scattered pipistrelles use the cave.

Posy Spring

There was a short, preliminary reconnaissance to this site. It is one of the most significant stream caves within the study area. The average flow rate is 53 liters/sec. (Vineyard & Feder, 1974). It is approximately 800 m. long, and flows from the general direction of the lease area. During the reconnaissance trip, three fish (*Typhlicthys*) and two crayfish (*Cambarus* presumably *hubrichti*) were noted. A relatively crude map of the cave was recently completed by Missouri Speleological Survey surveyors. Time permitting, it will be desirable to enhance the map both for accuracy and for level of detail.

Possum Trot Hollow Cave

The cave has a large, conspicuous entrance and receives significant visitation. It has about 200 m of dry to moist passage. Aquatic habitat is limited to several small drip pools and one large one: the small pools contain amphipods. There is a rich terrestrial invertebrate fauna, fueled by scattered concentrations of decayed guano and by fairly large quantities of wood debris, probably introduced by human visitors. The taxa include free-running mites, springtails, millipedes, many webworms (Diptera: *Macrocera nobilis*) and small, presumably troglobitic, orb-weaver spiders.

Turner Spring Cave

Turner Spring was inventoried by Gardner, but for only a short distance. It was therefore re-inventoried during the present project.

Although Turner Spring is one of the longest and most significant caves—hydrologically and biologically—within the study area, it's recharge zone would *probably* insulate it from activity within the lease area. The spring's output was studied by Aley, who measured the mean flow (1969–1973) as 37 liters/sec. Aley conducted a dye-trace from Rough Hollow, 4 km east of the spring. He concludes that much of the sinkhole terrain in the vicinity of Wilderness, east of the spring, lies in the recharge area. Dye-tracing indicates that injection points to the west, in Kelly Hollow and Hurricane Creek, are not tributary to the spring. However, this does not preclude the possibility of Hurricane Creek drainage entering the cave from upstream of the dye-injection points (this sort of cross-over is not uncommon, especially in high flow situations). Moreover, the stream would probably be vulnerable to mining activity within the Irish Wilderness "excluded lands".

The stream flows through a series of relatively long pools up to 1.5 m. deep, separated by gentle riffles. The floors of the pools are either bedrock, or sand—deep in places—over bedrock, with occasional small gravel beds. The stream can be followed for approximately 1.2 km in a generally north-easterly direction; the explored section ends where the ceiling gradually drops to the water level. Other types of aquatic habitat—drip pools, etc., are very limited in extent.

The stream has a population of *Typhlicthys* in fairly large numbers, and including very large individuals—one that was captured and measured exceeded the published maximum size for Missouri specimens (Pflieger, 1975). There is a large population of long-tailed salamanders, and a smaller population of grotto salamanders, both of which tend to occur in sandy-bottomed pools. (Cave salamanders also occur, but were never observed in the water). Gardner reported isopods (*Caecidotea antricola*) and amphipods (*Crangonyx* new sp. or subsp.). We found isopods in large numbers, but no amphipods. On the other hand, we collected aquatic snails, which were present in fairly large numbers, though not reported by Gardner. Presumably, the amphipod population is small. The specific identity of the specimen(s) collected by Gardner has not been published (Hollsinger, pers. comm.). A crayfish trap yielded one epigean crayfish (*Cambarus hubbsi*).

The most significant terrestrial wildlife is a gray bat colony, which produces large quantities of guano. The colony does not roost directly over the stream, but guano gradually makes its way down a steep bank to the water's edge, and probably forms a significant food input—however, no significant difference was noted in the population density of snails, isopods, or fish upstream versus downstream of the bat colony. The guano yielded pseudoscorpions (*Hesperochernes occidentalis*), mites, and fly larvae in large numbers. Larvae were reared to adulthood, and yielded fungus gnats (*Sciaridae*). Numerous beaver dens form other concentrated food sources for terrestrial fauna—rove beetles, millipedes, mites, etc.

White Cat Cave

This is a short, simple cave consisting of about 50 m of crouchway and crawlway in a single passage with some short spurs. The entrance is in a low bluff, about 6 m above the valley floor of Hurricane Creek. There is no flowing water, but the silty floor is generally moist.

Small, scattered quantities of organic debris (guano, rotting wood) yielded millipedes, pseudoscorpions and springtails.

References:

Aley, T. , 1978. *Ozark Hydrology: A Predictive Model in Missouri Speleology*, Vol. 18.

Gardner, J.E., 1986. *Invertebrate Fauna from Missouri Caves and Springs.* Missouri Department of Conservation.

Pflieger, W.L., 1975. *The Fishes of Missouri.* Missouri Department of Conservation.

Vineyard, J.D. & Feder, G.L., 1974. *Springs of Missouri.* Missouri Geological Survey and Water Resources.

The Effects of Predation on Invertebrate Community Structure in the Cave Rat Fecal Latrine

by Paul Richards

The invertebrate community of the cave rat latrine was censused monthly from 4/22/89 to 5/26/90 in four caves in Mammoth Cave National Park to determine competitive relationships among prey and the effects of predation on community structure. Laboratory rat fecal piles were placed in each of the four caves to mimic cave rat fecal latrines. These laboratory rat fecal piles were renewed on a monthly basis in order to simulate the daily additions to piles in natural rat latrines. The census data were analyzed using correlation statistics to show relationships among organisms. The correlations show an important effect of predation, give no support to competition among prey, but do support an apparent competition hypothesis based on indirect effects of predation on the three main prey species.

Little Beauty Cave, White Cave, Great Onyx Cave, and Davis Hall in the Flint Ridge portion of Mammoth Cave were chosen as study sites. These sites were deemed appropriate because of available data and for the presence or past presence of the cave rat *Neotoma magister.* The cave rat fecal community is useful for investigating the effects of predation because it is relatively simple but also complex enough to allow generalization to much more complex non-cave communities. There are a number of trophic levels, several sizes of species within each trophic level, and potentials for indirect interactions.

The cave rat's fecal piles in latrines are the basis for the invertebrate community of interest. The major invertebrate predator, as calculated from Importance Value (size x frequency x density), in the rat fecal community is the staphylinid beetle *Quedius* sp. (Poulson and Lavoie 1978). Some of the major prey types, as calculated from Importance Values, are sciarid fly larvae of the genus *Bradysia* sp. and the catopid beetle *Ptomaphagus hirtus* (Poulson and Lavoie 1978). I have found one other potential major prey type, the larvae of a Psychodid fly, which may have been missed by others due to its cryptic nature. I include this species based only on the absolute numbers of individuals found (see Table 2), not on importance values as others have done, although I am certain it will be included when importance values are calculated.

Lavoie (1982) has studied succession in this community in detail. In the field she studied successional decomposition and in the laboratory she studied competitive interactions among two of the prey species and fungi. However, she did not study the effects of *Quedius* sp. predation even though she made some strong inferences concerning the importance of predation based on her field experiments in deep caves without *Quedius* sp. and a near entrance site with *Quedius* sp. She suggested that the presence of *Quedius* sp. in near

Table 2: Total numbers of organisms counted between 4/22/89 and 5/25/90. These data are to be used only for observing general trends since sample sizes are not equal between caves. DH = Davis Hall; GO = Great Onyx Cave; LB = Little Beauty Cave; WC = White Cave.

Species or major group		**Total number by cave**			**Total**
	DH	**GO**	**LB**	**WC**	
Coleoptera					
Staphylinidae					
Quedius					
Adults	28	21	21	0	70
Larvae	105	23	84	3	215
Sm. Black sp.	0	1	5	38	44
Leodidae					
Ptomaphagus hirtus					
Adults	14	2	0	214	230
Larvae	0	1	3	548	552
Diptera					
Sciaridae					
Bradysia sp.					
Adults	83	20	42	440	585
Pupae	55	11	17	152	235
Larvae	652	235	573	2415	3875
Psychodidae					
Pupae	0	88	16	358	462
Larvae	1	756	97	2975	3829
Leptocera sp.					
Adults	2	16	41	58	117
Pupae	82	82	58	193	415
Larvae	4	217	96	183	500
Other Diptera					
Pupae	1	9	14	21	45
Larvae	16	58	31	64	169
Collembola					
Hypogasturidae					
Hypogastura sp.	10	1251	147	2623	4031
Other Collembola	162	464	940	14	67
Acari (Mites)					
Detritivores	12	104	236	6	358
Predators	1	252	143	528	924
Others 16	324	403	555	1298	
Pseudoscorpionida					
Hesperochernes	0	0	1	44	45
Enchaetreid worms	0	737	784	2060	3581

entrance sites was responsible for the virtual absence of *P. hirtus* in her experimental fecal piles.

In order to begin a detailed investigation of predation in this system I conducted a preliminary field study. From the results of this study I inferred a strong effect of predation on community composition (Richards 1989) including apparent competition. In this report I extend my preliminary work to a complete one year study from which I can make stronger inferences.

Rat fecal pellets were acquired from cages of laboratory rats kept under sterile conditions at the University of Illinois at Chicago animal quarters. Rat pellets were separated from bedding by flotation. They were oven dried and stored until they were used at the field site. At the field site pellets were remoistened to 60% water by weight.

At intervals of one month, 13 trips to the field site were made. During the first trip I established fecal piles of 60 pellets, 120 pellets and 240 pellets. There were a minimum of two replicates of each pile size in each cave. The total number of fecal piles placed in each field site were 7 in Little Beauty Cave, 9 in White Cave, 7 in Great Onyx Cave and 6 in Davis Hall of the Flint Ridge portion of Mammoth Cave. A total of 29 fecal piles were sampled each month for a total of 348 samples gathered in the twelve month period. During the 12 subsequent months I removed one half of each pile, to be returned to the laboratory, replacing it with an equal portion of new fecal pellets. Upon returning the to the laboratory I removed a 10 pellet sample from each field collection. I counted all Psychodid larvae, *Bradysia* larvae, *P. hirtus* and *Quedius* sp. in each sample. I also counted all other invertebrates when possible (see Table 2 for totals). Densities of organisms were calculated by dividing the census data by the number of pellets in the sample.

I have totaled the various organisms that were observed over all piles and dates within each cave (see Table 2). Table 2 is to be used only to observe general trends and patterns since sample size is not equal between caves. One pattern to note is the apparent response of *P. hirtus* to the presence of the predator *Quedius* sp. Where there are many *Quedius* sp., as in Davis Hall, Little Beauty Cave, and Great Onyx, there are very few *P. hirtus*. White Cave, on the other hand, had only three *Quedius* sp. but had hundreds of *P. hirtus*.

Spearman's Correlation coefficients between all pair-wise combinations of *Quedius* sp., *P. hirtus*, Psychodid larvae, and *Bradysia* larvae were calculated and are presented in Table 2. All double-zero matches between *Quedius* sp. and *P. hirtus* were eliminated to reduce the chance of spurious correlations. A significant negative correlation was found between *Quedius* sp. and *P. hirtus* and between *Quedius* sp. and Psychodid larvae. There were significant positive correlations between all pair-wise combinations of *P. hirtus* and *Bradysia* sp. larvae, Psychodid larvae and all fly larvae.

The data suggest that *Quedius* sp. dramatically depresses *P. hirtus* populations in laboratory rat fecal piles (see Table 2). This result is consistent for all twelve months when analyzed separately (data not included). Significant negative associations between *Quedius* sp. and both *P. hirtus* and Psychodid larvae show that predation depresses these species. It should be noted that *P. hirtus* appears to be affected to a much greater extent than Psychodid larvae. In the three caves with many *Quedius* sp. (see Table 2), *P. hirtus* density is always depressed to very low numbers whereas Psychodid larvae are variably depressed. The positive correlation of *Quedius* sp. and *Bradysia* sp. larvae is interesting and at the present time unexplained.

There does not appear to be direct competition among *P. hirtus* and the two species of fly larvae. If competition between *P. hirtus* and fly larvae were important in the field then one would expect a negative association to exist between them. The data do not support this because a significant positive association was found between *P. hirtus* and each of the fly larvae (see Table 3).

My data, as well as Lavoie's (1982), show that *P. hirtus* coexists with *Bradysia* larvae in fecal piles in which predators are absent, thus suggesting that competition is not important in the field. My data also extends this conclusion to Psychodid larvae and all fly larvae collectively. If competition is

Table 3: Spearman Rank Correlation Coefficients for all pair-wise comparisons of *Quedius* sp. and all potential prey species. Q = *Quedius* ; Pt = *P. hirtus* ; B = *Bradysia* sp. ; Psy = Psychodids ; F = Total Fly larvae (*Bradysia* sp. + Psychodids + other fly larvae). N=348, except for Q and Pt pair N=193. (* p<.0005, ** p<.0001).

	Q	**Pt**	**B**	**Psy**	**F**
Q	-	-0.80319**	+0.18632*	-0.21755**	+0.05760
Pt		-	+0.26971**	+0.57146**	+0.46098**
B			-	+0.19630*	-

important in the cave rat fecal community a negative correlation between *P. hirtus* and fiy larvae would exist independent of predator densities but the data clearly show this is not the case.

These results suggest to me an apparent competition hypothesis. If the large populations of *Bradysia* larvae and Psychodid larvae are causing a numerical increase in predator populations which causes the elimination of *P. hirtus* from the community, then fly larvae have an indirect negative impact via predation on populations of *P. hirtus.* The data presented do not reject this pattern, which is termed apparent competition. Negative correlations would be expected with an apparent competition model in the presence of predators and a positive or non-significant correlation in the absence of predators. This type of analysis remains to be done. Further analysis is required to separate apparent competition from a simple direct predation effect do to differential prey vulnerabilities.

References

Lavoie, K. H. 1982. The Influence of Biotic and Abiotic Factors on the Successional Decomposition of Cave Rat Dung. Ph.D. Dissertation. University of Illinois at Chicago.

Poulson, T. L. and K. H. Lavoie. 1982. Cave Rat Feces: A Model for the Study of Communities. *Cave Research Foundation Annual Report.* pp.41-45.

Richards, P. 1989. Predation in The Cave Rat Latrine. *Cave Research Foundation Annual Report.* pp. 45-47.

Acknowledgements

I would like to thank Dr. Tom Poulson, David Griffith, Jeannette Griffith, Laurie Graham, Keshab Bhattacharya, Michael Sutton, Jonathan Higgins, Bill Richards, Alan Parman, Jessica Parman, and Mary Geraghty for providing field assistance. This work would not have been possible without the cooperation of the National Park Service at Mammoth Cave National Park, the assistance of the Cave Research Foundation and the University of Illinois at Chicago. This work was supported by a research fellowship from the Cave Research Foundation and a grant from the National Speleological Society.

CRF FELLOWSHIP AND GRANT SUPPORT DURING 1990

Supported by an endowment fund, each year the Cave Research Foundation may award up to $7500 as Fellowships or as one or more grants for graduate research in karst-related fields. The truly exceptional proposal may receive a Karst Research Fellowship (limit $3500.00), meritorious proposals may receive one or more Karst Research Grants, in amounts less than $2000.00, awarded to qualified students in the natural or social sciences. Proposals are screened by a committee of scientists who may or may not be affiliated with the Cave Research Foundation. These judges seek promising or innovative topics, supported by evidence that the student has command of the literature and of the methodology.

The Fellowship competition is cyclic and is in phase with the academic year. An announcement of the competition is mailed in early Autumn and states the requirements for applications; the deadline for receipt of the proposal, supporting documents, and letters of reference is January 31. Awards are made in mid-April.

The Cave Research Foundation received 4 proposals in 1990. Of these, two proposals were awarded a Fellowship; one proposal received a grant. The awardee, graduate school, title of the proposal and synopsis of the research are given below for each funded proposal.

1. For his proposed research entitled **Karst hydrology of the Obey River Gorge, Tennessee: Development of an absolute timescale for drainage basin evolution through cave sediment paleomagnetism**, Mr. Ira D. Sasowsky, Department of Geology, The Pennsylvania State University, Materials Science Laboratory, University Park, Pennsylvania 16802 was awarded a 1990 CRF Karst Research Fellowship in the amount of $2200.00.

Mr. Sasowski's study of a deeply incised gorge on the Cumberland Plateau is designed to develop a model of drainage basin evolution, including a timescale applicable to the Appalachian Highlands on the basis of paleomagnetic, geochemical, hydrologic, and speleogenetic techniques. The basin is distinguished by large catchment, high hydrologic gradients, and a history of rapid downcutting in a relatively simple structural geologic setting. In addition to the basic questions such as how does groundwater evolve as it moves through this system, and what are the effects of mixing and dilution in the karst aquifer, the research offers an opportunity to determine a minimum age for the Highland Rim (Harrisburg) surface, on the basis of paleomagnetic dating of cave sediments.

2. For his proposed research entitled **The effects of predation on the cave rat fecal community of Mammoth Cave National Park**, Paul Richards, Department of Biological Sciences, University of Illinois at Chicago ,Box 4348, Chicago, IL 60680 was awarded a CRF Karst Research Fellowship in the amount of $2500.00.

Mr. Richards' research examines the role of predation (among the more important of several interactions such as competition, mutualism, and indirect effects) in determining community structure, using field and laboratory approaches. The relatively simple cave rat fecal community offers advantages and challenges – advantages owing to slight fluctuations in environment and low species diversity in most communities; challenges stemming from the reality that the rat fecal community is complex enough to allow generalizations to much more complex non-cave communities, as there are a number of trophic levels, sizes of specimens within each trophic level, and potentials for indirect interactions as well as abiotic effects on a micro scale and seasonally. The research is the first to address the subject of predation in the cave rat fecal community.

3. For his proposed research entitled **Early development of karst systems,** Christopher G. Groves, Department of Environmental Sciences, University of Virginia, Charlottesville, Virginia 22093 was awarded a CRF Karst Research Fellowship in the amount of $1000.00.

Mr. Groves proposes to build upon recent theoretical advances concerning the dissolution kinetics within the CO_2-H_2O-$CaCO_3$ system and to examine fundamental questions including 1) what is the role and importance of the threshold between laminar and turbulent flow within conduits and 2) by what mechanism do conduits overcome what seem to be initially short penetration lengths.

Research summaries and progress reports submitted by these and by other CRF investigators are published elsewhere in this volume. Please refer to those summaries and feel free to contact the respective authors (see addresses of contributors, elsewhere, this volume) for additional details concerning the research.

INTERPRETATION AND EDUCATION PROGRAMS

Figure 25: CRF's main research and expedition headquarters were housed in these buildings located on Flint Ridge in Mammoth Cave National Park for more than 25 years. CRF and other researchers are currently occupying other facilities in a different area of the Park. (*Photo by Scott House*).

INTERPRETATION

Ice Level Monitoring, Lava Beds National Monument

by Mike Sims

The objective of this project is to monitor the level and condition of the ice in six caves that have permanent ice floors. Continuous long-term data on ice levels will help Park Service management understand the dynamics of ice formation in the caves and facilitate decisions which will help perpetuate these resources.

During 1990, ice level monitoring stations were established in eight caves. Ice level and temperature measurements were taken in late winter and again in the autumn. Thus, the base level measurements have been established. The winter measurements found all ice floors solidly frozen, and the average temperature was about -3° C. Autumn measurements found 0.5 to 3 inches of water over the ice, except for Big Painted Cave where the water was 2.8 feet deep, and average temperatures of +1 °C in all eight caves.

Changes in ice level from winter to autumn 1990 ranged from -0.06 to +0.09 feet. We noted that at Captain Jack's Ice Cave a large ice mound, present in when the cave was mapped in 1982, was totally gone in 1990.

Photo-Monitoring at Lava Beds National Monument

by Bill Frantz

The purpose of the photo-monitoring project at Lava Beds National Monument is to develop a set of photos of cave features with enough documentation of how and where each photograph was made to allow it to be easily rephotographed. Comparing two photographs will allow researchers and Park Service personnel to monitor changes in the caves. In addition, where old photographs exist and can be relocated and rephotographed, new photographs will be made to monitor changes that have already occurred.

With the aid of other CRF investigators and Charisse Sydoriak, then Resources Manager at Lava Beds, we have selected thirteen caves for initial monitoring efforts. These include examples from all the monument's management classes. During the 1990 season we were able to complete the initial photography of thirteen sites in six caves, bringing the project to a total of twenty sites in eleven caves.

During the year Barney Stoffel of the National Park Service has provided cave locations, help, and guidance. Marc and Soren Sorenson, and Ethan Frantz from CRF have provided invaluable help in the field.

During 1990 we plan to rephotograph the existing sites, and establish new sites in the two remaining caves from the original list.

Reconnaissance Inventory of Lava Beds National Monument

by Mike Sims and Dan Weinberg

The objectives of this project are to: 1) Develop a reconnaissance inventory card and procedure to provide basic documentation on caves, and 2) locate, explore and prepare reconnaissance inventory cards on as many caves as possible. At a minimum, the Merrill-Skull trench and the Cave Loop-Post Office trench are to be documented.

The first objective has been completed. A reconnaissance card was designed and approved by the Park Service. Procedures for preparing the card were written (Figure 26).

During 1990, reconnaissance cards were prepared for seventy-four caves. This included 39 caves in the Merrill-Skull trench, and all seven caves in the Fleener Trench from the monument road north to the end of the trench. Miscellaneous cards were done on caves of the Cave Loop-Post Office trench and other caves as they were located.

The reconnaissance inventory card serves to briefly record features of the caves and alert Lava Beds staff and cave researchers to any items of note for each cave. Cavers should carry Reconnaissance Cave Inventory cards when they are exploring the monument and should complete the cards on any caves they find.

Completion of the cards is mostly self-explanatory. In recording the "cave features", Y means that the feature was observed; N means that the feature was not seen on that particular trip to the cave. Bearings to the cave entrance are taken with a compass to the highest point of the major buttes used for triangulation, for example, the lookout on Schonchin Butte, and the "hippo head" on Hippo Butte.

Cave numbers, beginning with NPS-CA-LABE-001, have been assigned to all the named caves of the monument. Other caves will have numbers assigned to them as they are discovered or named.

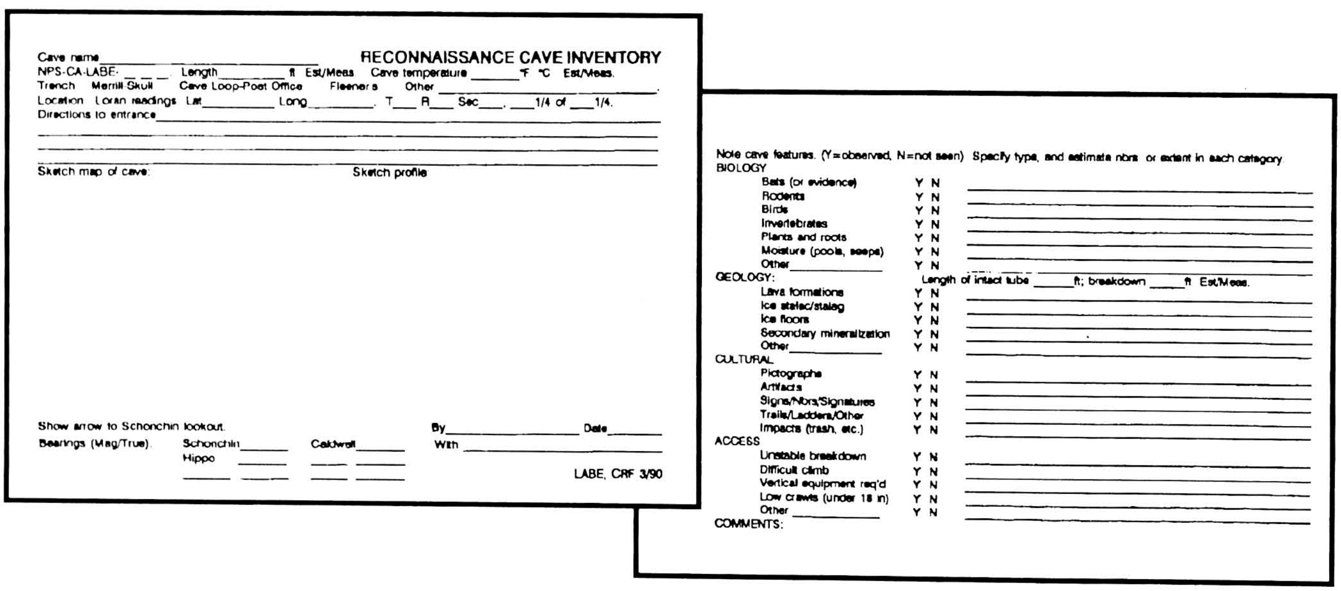


Figure 26: Reconnaissance cards used to record information on caves at Lava Beds National Monument.

EDUCATION

Names and Places in Mammoth Cave

by Mick Sutton and Sue Hagan

Gazetteer

1990 was a year of consolidation for the Mammoth Cave gazetteer. The exponential increase in data entries that we've seen over the past few years is starting to tail off – the database increased from 1,475 to 1,640 entries over the year. Some of the new entries are brand new names, e.g. Ghengis River (near the Khan Entrance) or Diamond Dome (in a newly discovered area off Woodbury Pass). Others are fairly well known traditional names such as the Ten Commandments – a line of damaged stalactites in the Frozen Niagara area (why the Ten Commandments? – because they are all broken!). Still others are obscurities ranging from the ominous – the Devil's Pulpit, the Dentist's Chamber – to the romantic – Romeo and Juliette's Window, Nanny Ramsey's Flower Garden – to the bizarre – The Brain of the Cave, Oscar Wilde's Sunflower.

There was a lot of work on improving the quantity and quality of information for existing entries, on cross-referencing, and on standardizing the format. We produced a preliminary electronic text version and made it available to a few reviewers. A printout is planned for sometime in 1991, and will be more widely distributed for comment.

We have also started to pay more attention to the bibliographic database being assembled in parallel with the gazetteer. This currently contains 220 written sources – modest by Mammoth Cave bibliography standards, but including most of the major sources and a smattering of rarities. Entries range from the classics on everyone's bookshelf – *The Longest Cave, Rambles in the Mammoth Cave* – to such obscurities as the text from a 1940's radio broadcast or the handwritten notes that an 1851 tourist pencilled into an 1840 guidebook.

The research continues to unearth obscure scraps of Mammoth Cave lore and history. An interesting variant of the well-known discovery legend has a black man chasing the bear into the cave; he could get no-one to believe the tale of the giant cave he discovered. The radio broadcast tells the story of Crystal Lake's discovery. Earl Lee was lowered down the pit. Dizzy from the spinning rope, he thought he saw a floor, dropped from the rope and discovered the lake: "we heard him snorting and yellin' down there, and we ran to the edge and hung our lights over into the pit. He wasn't paying much attention to us, though, because he was pretty busy swimming and blowin' away like a porpoise." Fortunately, he soon thereafter discovered Plymouth Rock, and was rescued.

Passage Description

Descriptions of passages along the Half-day tour and of major Kentucky Avenue side passage series – Morrison Avenue and Woodbury Pass – were completed, and delivered to the NPS. Descriptions of many of the smaller side passages off Kentucky Avenue was also completed. The emphasis at present remains on the Kentucky Avenue area; descriptions are being written or brought up to date as each section is added to the inked version of the 1:600 map sheet. We are hopeful that, with the assistance of all area cartographers, this systematic approach can be put into effect as each of the 1:600 maps reaches the production stage.

We greatly appreciate the interest and assistance of the Mammoth Cave staff.

PUBLICATIONS AND PRESENTATIONS

MEETING PRESENTATIONS AND ABSTRACTS

Geosciences

Davis, D. G., and Luiszer, F., 1990, A new speleothem: preliminary report on linear concretions in sand deposits in Colorado caves. Rocky Mtn. Speleo-Seminar, University of Colorado, Colorado Springs, Colorado, October 6.

Groves, C.G., "Initiation of Karst Processes: Concepts and Simulation Model Structure". Paper presented at the Environmental Science Research Forum, University of Virginia, March.

_____, "Kinetics of Calcite dissolution in Karst Aquifers: Field Measurement and Theoretical Prediction". Poster presented at the spring meeting of the American Geophysical Union, Baltimore, MD, May.

_____, "Kinetics of Calcite Dissolution in Karst Aquifers: Field Measurement and Theoretical Prediction". Paper presented at the annual meeting of the National Speleological Society, Yreka, CA, July.

_____, "Exploring in the World's Largest Cave System". Seminar presented to the Environmental Science Organization Speaker Series, University of Virginia, September.

_____, "Modern Methods for the Investigation of Karst Landscape Development". Seminar presented to the Department of Environmental Sciences Seminar Series, University of Virginia, November.

Hess, J.W., NM. Spiess, J.C. Tinsley, G. Mele, and B. F. Lyles, 1990, Flow Behavior of Big Spring, Redwood Canyon Karst Area, kings Canyon National Park, California, Presented at National Speleological Society Convention, Caifornia.

Ingraham, N.L., J.B. Chapman, and J.W. Hess, 1990, Stable Isotopes in Cave Pool Systems: Carlsbad Caverns, New Mexico, Chemical Geology, Isotope Geosciences Sec-tion, 12:1, p. 65-74.

_____, N.L., J.B. Chapman, and J.W. Hess, 1990, Hydrologic System of Carlsbad Cavern, New Mexico: Stable Isotopic Analysis, Presented at International Symposium and Field Seminar on Hydrogeologic Processes in Karst Terranes, 7 - 17 October 1990, Antalya, Turkey.

Rogers, B. W., 1990, Mineralogy of Lava Tube Caves in Medicine Lake Volcano, California (abs.), Natl. Speleo. Soc. Convention, Yreka, California, July.

_____, 1990, General Geology and Development of Lava Tubes in New Mexico's El Malpais National Monument: Confirming Epsomite in the Field by Taste Testing (abs.), Natl. Speleo. Soc. Convention, Yreka, California, July.

_____, 1990, The Quintessential Cave Geology Talk; Never Too Many Rubber Pigs (abs.), Natl. Speleo. Soc. Convention, Yreka, California, July.

_____, 1990, The Pacific Basin Speleological Survey: A Five Year Retrospective (abs.), Natl. Speleo. Soc. Convention, Yreka, California, July.

Tinsley, John C. and Heazlit, C.K., 1990, Tephrochronology and sedimentology of sinkhole deposits in the Redwood Canyon Karst, Kings Canyon National Park, California [Abstract]: Program of the 1990 National Speleological Society Convention, Yreka, California, p. 32.

TALKS

Rogers, B. W., 1990, Prehistory of Micronesia, A Speleologists View, talk given to the Santa Clara County Archaeological Society, Santa Clara, California, June.

_____, 1990, An Elfin Ramble Through The Yucatan Including Caves, Cenotes,and Entirely Too Many Ruins, Friends of Golden Gate Grotto, Menlo Park, California, September.

Sowers, Janet M., 1990, Lava Beds National Monument – A cave management plan: Talk presented to the Cave Management Seminar co-sponsored by the National Park Service and the American Cave Conservation Association, Albuquerque, New Mexico, March 14, 1990.

Tinsley, John C., 1990, Origin of caves: Talk presented to Lyceum, Los Gatos Public Schools, 4th Grade, October.

_____, John C. and Heazlit, C.K., 1990, Tephrochronology and sedimentology of sinkhole deposits in the Redwood Canyon Karst, Kings Canyon National Park, California, June.

ARTICLES

Rogers, B. W., 1990, The Earth Shook, The Sky Burned, And All The Bunny Rabbits Ran Away, Part 13: New Mexico's Four Windows Cave, El Malpais National Monument, *Cave Research Organization of South Africa Bulletin*, No. 1, pp. 3-12.

_____, 1990, Four Windows Cave, (map) Jan., 1990, *Third Source*, p. 5.

_____, 1990, Four Windows Cave, El Malpais National Monument, New Mexico, Brochure, 2 p.

_____, 1990, The Earth Shook, The Sky Burned, And All The Bunny Rabbits Ran Away, Part 14: Shovel (Arch Sink), Mike's Sink, and Catwalk Caves, The Core of the Gaping Holes System, *S. A. G. Rag*, 9:1, pp. 2a-6.

Sowers, Janet M., 1990, Caving in Lava Beds National Monument: in Johnson, V., ed., *National Speleological Society 1990 Convention Guidebook*, p. 119-120.

_____, 1990, Lava Beds National Monument – Working together to take care of caves: in Johnson, V., ed., *National Speleological Society 1990 Convention Guidebook*, p. 176-179, also published in California Caver, v. 40, no. 1., p. 6-10.

Sutton, Mick, 1990, Surveys and Secrets – Early Maps of Mammoth Cave: in *Mammoth Cave Inside Out*, National Park Service, Spring.

_____, and Sue Hagan, 1990, To map the longest cave: in *Mammoth Cave Inside Out*, National Park Service, Summer.

_____, and Sue Hagan, 1990, To map the longest cave: in *Mammoth Cave Inside Out*, National Park Service, Fall/Winter.

Waters, A. C., J. M. Donnelly-Nolan, and B. W. Rogers, 1990, Selected Caves and Lava Tube Systems in and near Lava Beds National Monument, California, *U. S. Geol. Survey Bulletin 1673*, 102 p.

MISCELLANEOUS

Tinsley, J. C., Donnelly-Nolan, J., Sowers, J. M., and Rogers, B. W., 1990, co-leaders of the National Speleological Society Convention Geology Field Trip, entitled Geologic features of Mount Shasta and Medicine Lake Volcanoes.

CAVE BOOKS

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

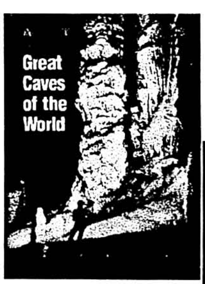
The sales and distribution of Cave Books' publications materials, wholesale and retail, is being managed by:

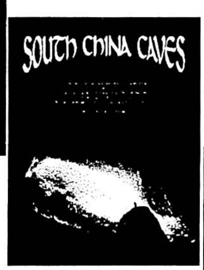
Roger E. McClure .... Business Manager
Thomas A. Brucker .... Sales Manager
Rich Wolfert .... Retail Sales (for western areas)
Richard A. Watson .... Used and Small Lot Remainders.

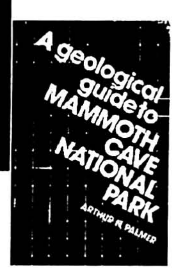
Cave Books created a publishing initiative in 1983 with the goal of publishing one new cave book each year. Funding and management of this publishing effort will be handled independently of other internal publication efforts. The personnel managing publishing include:

Roger E. McClure .... Publisher
Richard A. Watson .... Editor
Karen Lindsley .... Production 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.







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 primarysupportfor many Foundation programs, including the Annual Report. Books published by Cave Books (Intl. Standard Book Number ISBN prefix 0-93978-) 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

Cave Books
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.

Listing of Cave Books Publications to Date

Atlas of the Great Caves of the World - by P. Courbon, C. Chabert, P. Bosted and K. Lindsley, 1989, (Illus.) 369 p.

Carlsbad, Caves & a Camera - by Robert Nymeyer, 1978, (Illus.) 318 p.

Cave Research Foundation: Origins & the First Twelve Years, 1957-1968 - Richard A. Watson (ed.), (Illus.), 495 p.

Cave Research Foundation: 1969-1973 - Richard A. Watson (ed.), (Illus.), 265 p.

Cave Research Foundation: 1974-1978 - Richard A. Watson (ed.), (Illus.), 341 p.

Cave Research Foundation Annual Report:

1979 Annual Report - Thomas L. Poulson & Bethany J. Wells (eds.), 1981, (Illus.) 74 p.
1980 Annual Report - Margaret V. Palmer (ed.), 1981, (Illus.) 51 p.
1981 Annual aeport - Karen B. Lindsley (ed.), 1984, (Illus.) 55 p.
1982 Annual Report - Margaret V. Palmer (ed.), 1984, (Illus.) 45 p.
1983 Annual Report - Kathleen H. Lavoie (ed.), 1984, (Illus.) 42 p.
1984 Annual Report - Karen B. Lindsley (ed.), 1985, (Illus.) 60 p.
1985 Annual Report - Karen B. Lindsley (ed.), 1986, (Illus.) 48 p.
1986 Annual Report - Karen B. Lindsley (ed.), 1987, (Illus.) 51 p.
1987 Annual Report - Karen B. Lindsley (ed.), 1987, (Illus.) 74 p.
1988 Annual Report - Karen B. Lindsley (ed.), 1989, (Illus.) 91 p.
1989 Annual Report - Karen B. Lindsley (ed.), 1990, (Illus.) 74 p.
1990 Annual Report - Karen B. Lindsley (ed.), 1991, (Illus.) 80 p.

Cave Research Foundation Personnel Manual (3rd ed.) - Diana 0. Daunt-Mergens (ed.), (Illus.), 176 p.

Caves Beyond: The Story of the Floyd Collins' Crystal Cave Exploration - by Joe Lawrence, Jr. and Roger W. Brucker, 1975, (Illus.), 320 p.

Geological Guide to Mammoth Cave National Park - by Arthur N. Palmer, 1981, (Illus.), 210 p.

Grand Kentucky Junction: Memoirs - by P. P. Crowther, C. F. Pinnix, R. B. Zopf, T. A. Brucker, P. G. Eller, S. G. Wells, J. P. Wilcox, 1984, (Illus.), 96 p.

Introduction to Speleology - by Arthur N. Palmer, 1981, (Illus.), 176 p.

Jewel Cave Adventure - by Herb Conn and Jan Conn, 1981, (Illus.) 240 p.

MAWS - by Erd Noswat (pseud.), 1976, (Illus.), 36 p.

Memoirs of a Speleologist: The Adventurous Life of a Famous French Cave Explorer - by Robert De Joly (trans. by Peter Kurz, 1975, (Illus.), 1 85 p.

Rambles in the Mammoth Cave Duning the Year 1844 by a Visiter - by Alexander C. Bullitt, 1985 (Illus.), 134 p.

South China Caves: Information on the Caves and Karst of South China and A Report on the 1988 Joint Expedition BetweenThe Institute of Karst Geology, The Speleological Society of South China Normal University and the Cave Research Foundation, by Rondal R. Bridgemon and Karen B. Lindsley (eds.), 1991, (Illus.), 62 p.

Speleology: The Study of Caves - by George W. Moore and G. Nicholas Sullivan, 1981, (Illus.), 163 p.

Subterranean Climbers: Twelve Years in the World's Deepest Chasm - by Pierre Chevelier (trans.by E. M. Hatt), 1975, (Illus.), 223 p.

Ten Years Under the Earth - by Norbert Casteret (trans. by Burrows Massey), 1975, (Illus.), 255 p.

Under Plowman's Floor: A Novel- by Richard Watson, 1978, 244p.

Yochib: The River Cave - by C. William Steele, 1985, (Illus.), 176 p.

CRF MANAGEMENT STRUCTURE 1990

DIRECTORS

Ron R. Bridgemon, President

Richard B. Zopf, *Secretary*
Sarah G. Bishop
James Borden
Tom Brucker

Roger E. McClure, *Treasurer*
R. Scott House
R. Pete Lindsley
Melburn R. Park

John C. Tinsley

General

Chief Scientist .... Thomas L. Poulson
Science Committee Chair .... John Tinsley
Conservation Committee Chairman .... Sarah G. Bishop
Publications Committee Chair .... Roger McClure
Cave Books
    Publisher/Manager .... Roger McClure
    Editor .... Richard Watson
    Production Manager .... Karen Lindsley
    Sales Manager .... Tom Brucker
    Retail Sales .... Dave Hanson
    Western Sales .... Rich Wolfert
Newsletter Editors .... Sue Hagan
    Mick Sutton
Annual Report Editor .... Karen Lindsley

Guadalupe Escarpment Area Management

Operations Manager .... Dick Venters
Personnel Officer .... Joli Eaton
Chief Cartographer. .... Dave Dell
Finance and Supply Coordinator .... Bill Ziegler
Field Station Maintenance .... Ron Kerbo
Science Officer .... Dave Jagnow
Lechuguilla Precision Survey
    Manager .... Robert G. Babb
    James Hardy
Hooter editor .... Bill Ziegler

Missouri Project Management

Project Manager .... Scott House
Log Keeper .... Mick Sutton
Trip Coordinator .... Doug Baker
Treasurer .... Leonard Butts

Central Kentucky Area Management

Operations Manager .... Mel Park
Personnel Officer .... Phil DiBlasi
Chief Cartographer .... R. Scott House
Medical Officer .... Stanley D. Sides
Safety Officer .... Bob Osborne
Supply Officer .... Jan Hemberger
Vertical Supplies Officer .... Dick Market
Log Keeper .... Mel Park
Field Station Maintenance .... Lee Snead
    Kevin Downs

Sequoia & Kings Canyon National Parks (SEKI)

Operations Manager .... John Tinsley
Personnel Officers .... Dave Cowan
    Sandra Cowan
Chief Cartographer .... Peter Bosted
Safety Officer .... Howard A. Hurtt
Science Officer .... John W. Hess
Field Station Maintenance .... Mike Spiess

Lava Beds National Monument (LABE) Project

Project Director, LABE .... Janet M. Sowers
Personnel Officer .... David Cowan, Sandra Cowan
Cartographers .... Mike Sims, Bruce W. Roger

Arkansas Project Managemen

Project Manager .... Pete Lindsley
Operations Manager .... Jack Regal
Project Cartographers .... Gary R. Schaecher
    Robert L. Taylor, John P. Brooks
    Jack Regal

OPERATING COMMITTEES

The Foundation has established 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*	E. Calvin Alexander	William P. Bishop
Nicholas Crawford	David J. DesMarais	John W. Hess
Carol A. Hill	Francis Howarth	Thomas Kane
Kathleen H. Lavoie	Arthur N. Palmer	Margaret V. Palmer
Thomas L. Poulson	Patty Jo Watson	Ronald C. Wilson

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

Publications: provides policy guidance and direction on all Foundation matters, proposes publications initiatives, assists individuals/groups in accomplishing their publication goals, review/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; second, to produce revenue to fund Foundation activities.

Roger E. McClure, *Chairman*	Thomas A. Brucker	Karen Lindsley
Richard Watson	Dave Hanson	Rich Wolfert
Mick Sutton	Sue Hagan	Dave Hanson

Contributors to this Report

Arroyo-Cabrales, Joaquin
Texas Tech Univ. Museum
Fourth and Indiana Ave.
P. O. Box 4499
Lubbock, TX 79409-3191

Baker, Doug
Apt. 201 Shepherd Hills Manor
RR7
Jefferson City, MO 65101

Bosted, Peter
S.L.A.C, Box 4349 Bin 44
Stanford
CA 94061

Bridgemon, Rondal R.
4074 W. Redwing St.
Tucson, AZ 85741

Buecher, Bob
7050 E. Katchina Ct.
Tucson, AZ 85715-3322

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

Devereaux, Bill
5107 Vale Court SE
Salem, OR 97306

Frantz, Bill
16345 Englewood Ave.
Los Gatos, CA 95030

Groves, Chris
Dept. of Geography & Geology
Western KY University
Bowling Green, KY 42101

Hagan, Sue
Route 1, Box 110A
Annapolis, MO 63620

Hess, Jack
Water Resources Center
2505 Chandler Ave., Suite 1
Las Vegas, NV 89120

House, Scott
2159 Lonedell
Arnold, MO 63010

Johnson, Bob
1917 Sogol Ct.
San Jose, CA 95122

Kenny, Ray
Arizona State Univ.
Geol. Dept., Tempe, AZ
75287-1404

Lindsley, Karen
12 Orchard Road
Lucas, TX 75002-8061

Lindsley, Pete
12 Orchard Road
Lucas, TX 75002-8061

Miller, Ken
c/o John Tinsley
1040 Oakland Ave.
Menlo Park, CA 94025

Palmer, Arthur N.
Dept. of Earth Sciences
State University of New York
Oneonta, NY 13820-4015

Palmer, Margaret V.
Dept. of Earth Sciences
State University of New York
Oneonta, NY 13820-4015

Perkins, J. Mark
5130 SW Idaho
Portland, OR 97221

Richards, Paul
Dept. of Bio. (m/c 066)
Univ. of Illinois at Chicago,
Box 4348
Chicago, IL 60680

Rogers, Bruce
U.S.G.S.
Branch of West. Regional Geol.
345 Middlefield Rd. MS 975
Menlo Park, CA 94025

Sasowsky, Ira D.
Dept. of Geosciences
Pennsylvania State University
University Park, PA 16802

Sims, Mike
505 Roosevelt St.
Oregon City, OR 97045

Smith, Jim
Dept. of Geology
Western Kentucky Univ.
Bowling Green, KY 42101

Sowers, Janet M.
5844 San Jose Ave.
Richmond, CA 94804

Sutton, Mick
Route 1, Box 110A
Annapolis, MO 63620

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

Weinberg, Dan
1320 Buena Vista
Reno, NV 89503

fini