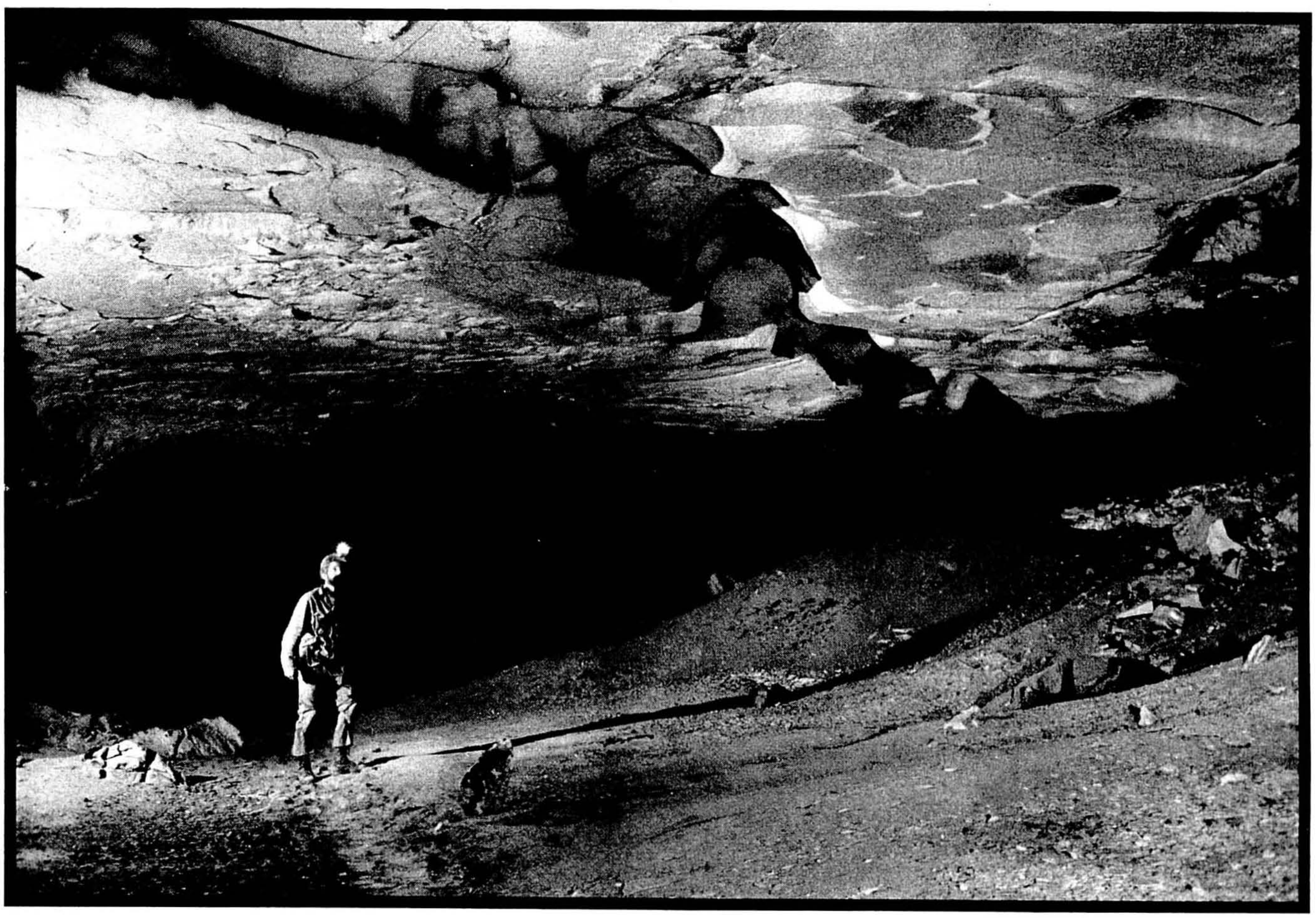
Cave Research Foundation

1992 ANNUAL REPORT



Cave Research Foundation

Annual Report 1992

Cave Research Foundation
1541 Peabody Avenue
Memphis, TN 38104-3831

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.

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Cover photo (Figure 1): Kaemper avenue, in the former upstream direction from its access crawl. *(Photo by Arthur N. Palmer).*

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CAVE CONSERVATION

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

Caves are fragile in many ways. We take considerable care that we do not destroy that which we study because many of the cave features take hundreds of thousands of years to form. Also, many of the processes that formed the cave passages we travel are no longer active in these areas.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 3581O, USA, for excellent advice and guidance for novice and experienced alike.

Highlights of 1992

The Hamilton Valley Project

In 1992, the Foundation completed purchase of land encompassing almost an entire karst valley that lies the east of Mammoth Cave National Park. By the end of the year, there were indications that the size of the CRF Hamilton Valley Preserve would grow beyond its original 185 acres. A year or more will be necessary before we see the field research facility and headquarters that we envision erected there, but that path is not nearly so long as the one we have traversed to get this far.

When it became apparent that we would lose the operations base on Flint Ridge where we were founded and where we had prospered since 1957, there were several important issues to grapple with. Should we buy or lease property and move our operations outside park boundaries? Being off the park could mean that we would be out of sight and out of mind to the park staff. Even leaving Flint Ridge, where we had a special use permit for our historic facilities, implied a degree of that. Indeed, we have since found that the transfer to Maple Springs has diminished our stature. We have lost a measure of independent planning and much of what we had previously had to offer to university scientists seeking to work at Mammoth Cave.

In 1991 and the beginning of 1992, three paths were open to us: (1) We could do nothing, that is, be content with the shift of our operations to the park's Maple Springs site and the changes that that implied. (2) We could move off the park in the way that a caving club might—into a modest structure on leased or possibly purchased property. There, we would have limited means of supporting scientific programs and only our traditional skills and ongoing program to keep the park interested in us. (3) We could establish ourselves as a mature organization and involved partner on the eastern flank of the park.

In evaluating the three options, I tried to envision a CRF-East twenty years in the future. At Maple Springs, with the cave completely mapped, no means of doing or attracting outside scientific workers, I think that we would have faded from the scene entirely. I then asked myself whether a simple wooden clubhouse structure would more resemble the run-down Austin House or the run-down Collins House in twenty years time. Who would want to work out of it? The hardy few perhaps, maybe even a graduate student or two, but what faculty member would take this kind of ramshackle field support seriously? Having moved off the park in this manner, what would the difference be, in twenty years, between us and the group exploring some Cave X in the area? What benefit would we be to a park with fixed boundaries and competing interests?

Concerning the final option, I asked myself what would we have to offer—what could we offer—to the Park Service and to the caving world with a real base of operations and a sizable land preserve as well. Computers on site, a library with data readily accessible, these assets have already intrigued the Park Service research staff. The first building erected will be enough to provide residence, work, and study area for visiting scientists, but dedicated buildings for this will follow so that investigators and expedition personnel can productively coexist in ways that have never before been possible. The dollar cost for this option seemed daunting at first but the more we learned of funding sources and of the commitment of our JVs, the more possible this option became. Clearly, this was the right way to go.

The Hamilton Valley Project is not the effort of a caving club. It is also more than bricks and mortar. It is a large commitment to the work of studying the Central Kentucky Karst. It, as well, makes us important members of the local community and it makes us part-custodians of the water shed and even some of the passages of what is presently the worlds longest cave. I congratulate the Cave Research Foundation and its Board of Directors for having had the vision, and the courage, to undertake this project.

See related article on page 56.

Melburn R. Park, Ph.D.
President, Cave Research Foundation

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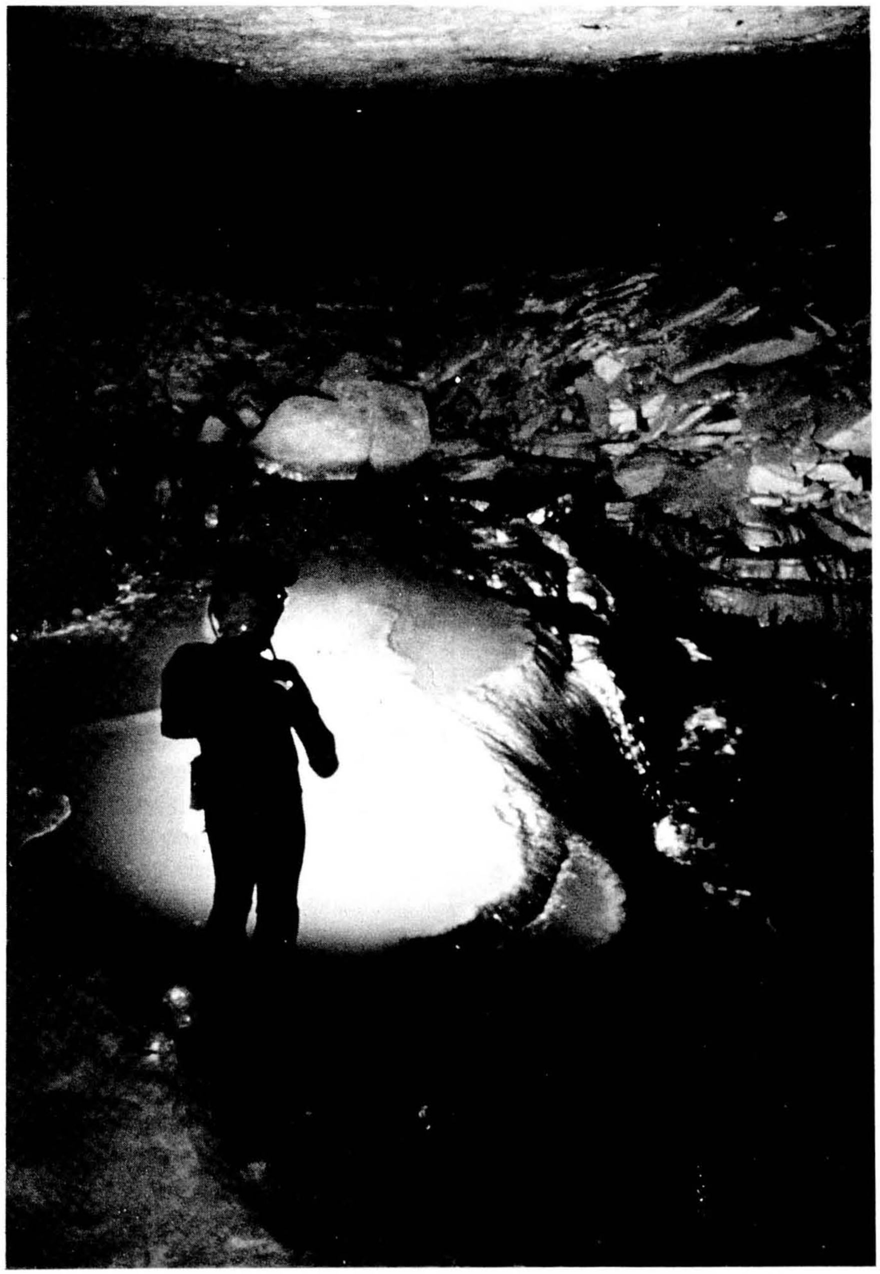

Figure 2: Jim Smith in State Trooper Cave, Warren Co., Kentucky. (*Photo by Chris Groves*).

Cartography at Lilburn Cave, California, 1992

by Peter Bosted

Perhaps because of the availability of quadrangles for several areas of the cave, 1992 turned out to be quite a productive year for cartography at Lilburn Cave, with almost twice as many feet surveyed as in 1991. There were five expeditions during which surveying took place, in May, June, July, September, and October. Each expedition had between four and seven survey trips, making for a total of twenty-nine trips. Survey totals ranged from 100 to 400 ft., with 200 ft. being typical. This reflects the increasingly small size of passages being surveyed. A total of 460 stations were set, and 5245 ft. were surveyed, of which 4300 ft. were new passage, and 945 ft. were resurveys to improve sketches or fix loop closure errors. Two of the surveys were underwater, from diving trips in the South Seas. These surveys increased the measured depth of the cave to 508 ft.. The total length now stands at 13.52 miles (21.77 km). The sketchers for 1992 were C. Festerson (1 trip), B. Farr (2 trips, diving), S. Koehler (3 trips), J. DeSpain (5 trips), C. Vesely (6 trips), and P. Bosted (12 trips).

Many of the survey trips were to the relatively dry and pleasant North end of the cave, for which quadrangles were generally available. A new route was found from the entrance to the Crystal Crawl area, and from there a new route was found to the Badminton Room. The lower East Stream was surveyed yet again, with a lot of survey shots permitting a more accurate portrayal of this complicated area. Nearby, a new pit complex was found which leads down to the Rise area. Meanwhile, probably the deepest unbroken pit in the cave (at 120 ft. deep) was descended. It connected from the CF survey down to the main passage beyond the White Rapids. Over in the West Stream area, an upper level consisting of several small rooms was found above the Black Stalactites, and the stream itself was pushed upstream to a near connection with the portion that is accessed going downstream from the Kleinbottle Complex. The very dry conditions of the past six years made this a much more pleasant trip than it would be normally.

Only three trips surveyed in the middle part of the cave, with two trips to the Schreiber Complex mopping up side leads, and one trip mapping accidentally unsurveyed passage close to the Main Entrance. Due to the dry conditions, many trips were taken to the South End. One trip to River Pit found a fairly long extension (for Lilburn), while a team in November climbed a dome to find an interesting new area that was not surveyed due to some of the party getting too cold. Pits in Hog Heaven were descended and found to be blind. Four trips were made to the Thanksgiving Hall Passage, through which the main stream runs. The main passage was resketched, and over 400 ft. of side passages were found. A good climbing lead still remains in one of these. Finally, the two diving trips in the South Seas (where the main stream sumps at the South end of the cave) found the lake to be much deeper than expected (over 130 ft.), and more diving will be needed to fully explore the passages leading away from the lake.

Four trips were made to nearby Cedar Cave. The first two were aborted when one or more party members could not fit around a tight corner near the entrance. The last two trips continued mapping in small, but continuing passage, adding 155 ft. to the length. This is definitely a "small person's cave".

Substantial progress was made in working on the 11" by 17" quadrangles. The fifteen quadrangles that depict the northern portion of the cave (everything north of the Hex Room) were all completed by P. Bosted and have been updated to include the 1992 surveys. Most areas only require two or three levels, but the area that includes the Alto Stream in so complex that it requires four levels to portray. J. Tinsley has begun work on four quadrangles for the Pandora/Enchanted River area, while B. Frantz has begun work on four quadrangles around the River Pit area. A new computer program was written by P. Bosted so that line plots for each quadrangle could be generated directly on the Macintosh (rather than importing them from a Vax). The program also draws and labels the borders for each quadrangle. The plots are then imported into the drawing program Canvas as one of the layers that can be turned on or off. Another layer is then used to draw the passage walls, either by tracing scanned images, or, in most cases, by drawing straight from the survey notes. A copy of this layer is filled in with the color appropriate to the level of the cave, and can be combined with other drawings to show the interrelationships of the various levels. The final layer in the drawing program contains all of the passage detail and cross sections. Normally, two versions of each quadrangle are printed out: one containing the passage walls and line plot only (useful for surveying leads), and one containing all the details but no line plots. Examples of each are shown reduced by a factor of two in Figures 3 and 4. The quadrangles have already proved useful in finding new leads, and also in being able to find the way around in this complex, three-dimensional cave.

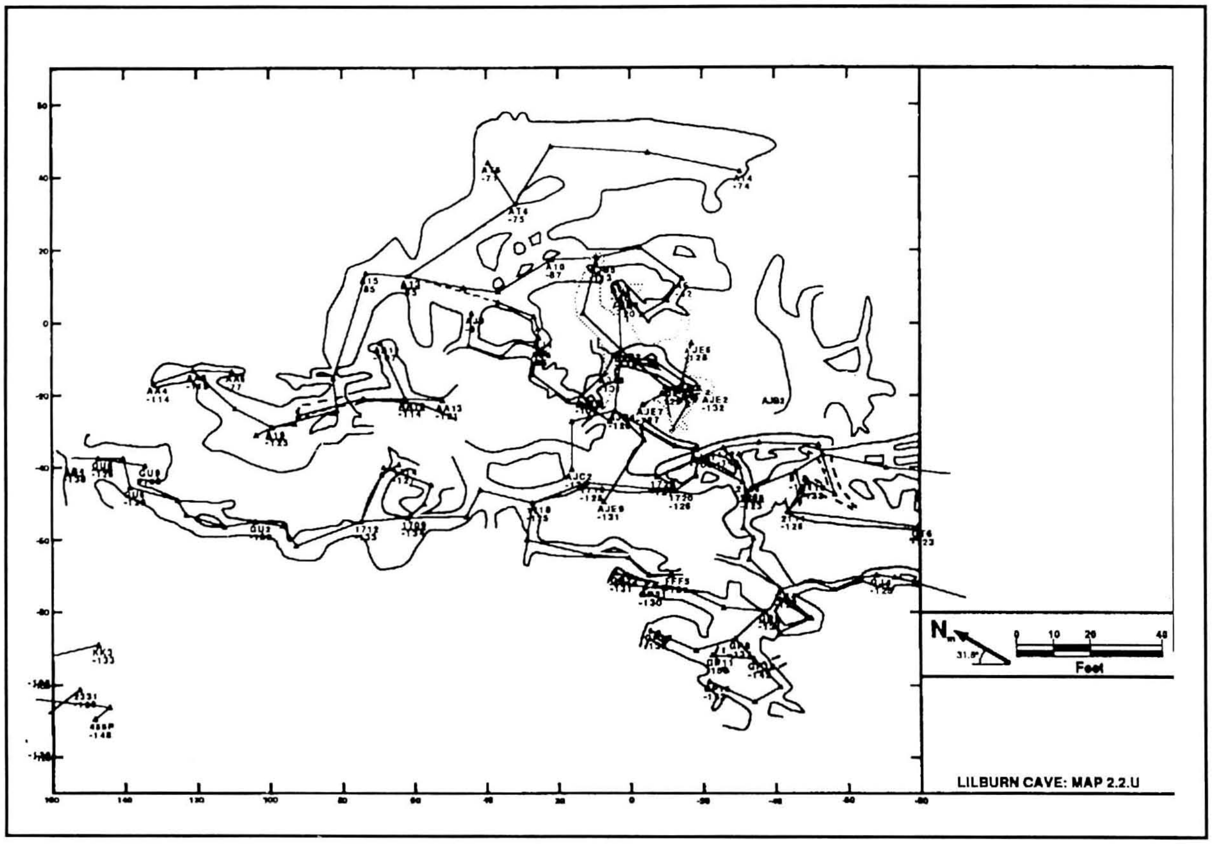

Figure 3: Quadrangle for the Meyer Entrance area of Lilburn Cave showing passage walls and line plot only. This map has been reduced from its original 11 x 17" size.

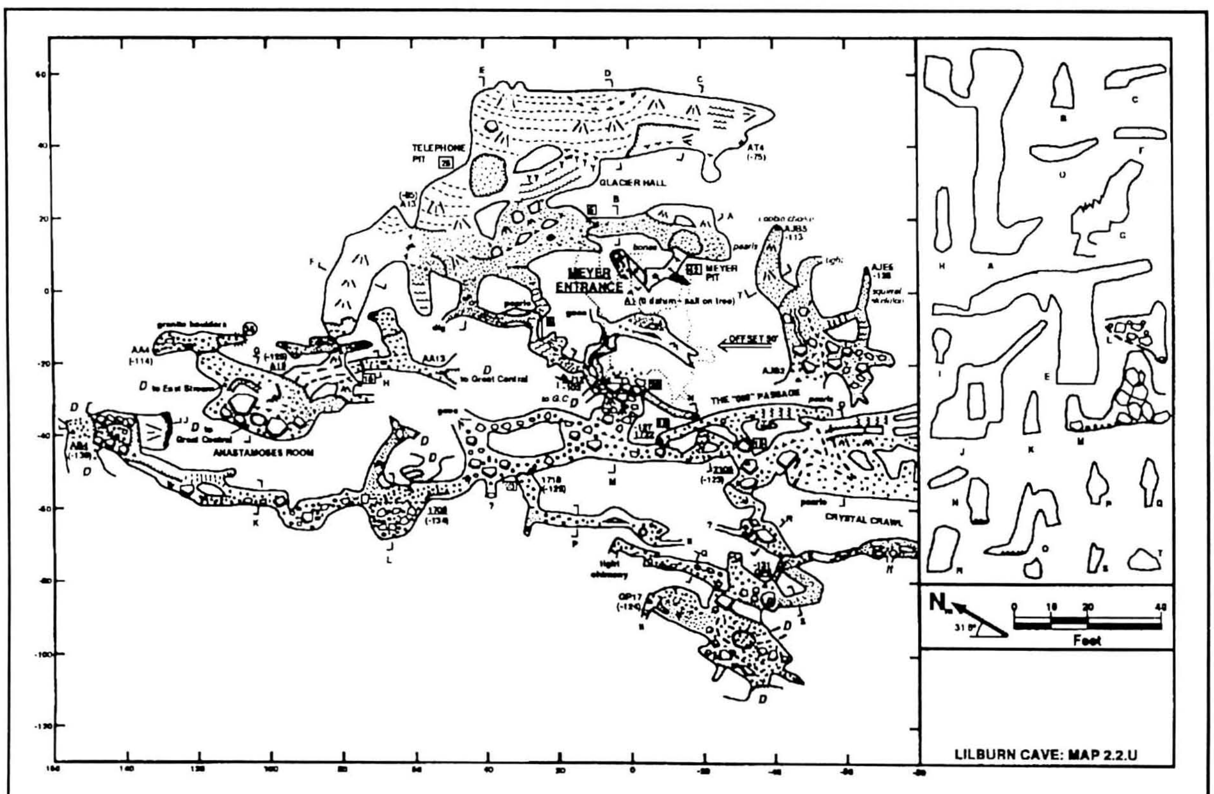

Figure 4: This is the same map as shown in Figure 3, but the line plot has been turn -ed off and the passage detail turned on.

Prospects for finding another mile or two in Lilburn Cave remain reasonable as there are several good climbing leads as well as many crawlways that need pushing. Completion of more quadrangles should help in this effort. In addition, it will be interesting to see if this year's heavy winter storms will remove substantial amounts of sand from the three dive sites: the Rise, South Seas, and Big Springs.

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Missouri Cave Inventory and Mapping

by Scott House and Doug Baker

Continuing a pattern of recent years, most of the CRF work in Missouri focused on the 1.7 million acre Mark Twain National Forest. Work trips outside of the Forest were either on private lands or were associated with one major project on land owned by the Missouri Department of Conservation but lying within the boundaries of the Ozark National Scenic Riverways.

Mark Twain National Forest

A number of caves were mapped and inventoried as part of a project to do assessments and baseline data in a lead prospecting area. The area, in southern Shannon and northern Oregon Counties, lies in the heart of the southern Ozark karst region where several of the nation's largest springs have their recharge areas. (See article elsewhere.)

Most of the caves within the region are relatively small. Virtually all of them have active streams of one sort or another with flows varying from trickle size to river dimension. The caves typically exhibit ph.eatic development with extensive vadose modifications; large rooms or trunks re-excavated by small streams are not uncommon. Most of the caves surveyed and/or inventoried lie within the Hurricane or Spring Creek basins; both are tributaries to the Eleven Point River, a National Wild and Scenic River. Some of the caves surveyed and inventoried are on private land; the intent of the effort is to create baseline data on the area's cave without regards to ownership. Private landowners graciously provided access to survey crews (Figure 5).

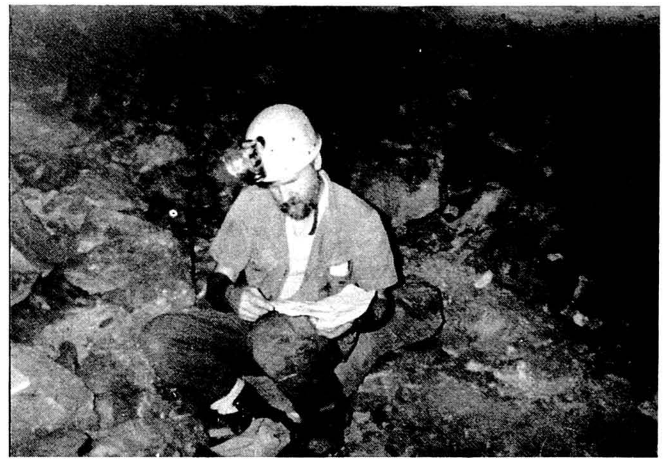

Figure 5: Mick Sutton checks his notes during cave inventory in Mark Twain National Forest. (*Photo by Scott House*).

Several trips were required to finish 1000 foot-long Brawley Cave and its satellite caves Upper Brawley Cave and Rimstone Cave. The survey of Cat Cave was completed as well as nearby Vulture Cave (yes, it has one nesting in it.) Several survey crews were required to map New Liberty Cave (Figure 6) about which virtually nothing was previously known. The cave turned out to be over a half-mile in length with a large main passage, extensive crawlways, climbs, and maze areas. 100 foot-long Dobbs Spring Cave was mapped after some negotiations; it serves as a water supply for a farmhouse. The survey of Adams #2 was completed by a very small survey crew.

Two large and wet caves directly on the Eleven Point River were surveyed. Posy Spring Cave was completed with just over 2700 ft. of passage and Blowing Spring Cave (3500 ft.) was also finished. The six survey trips required wetsuits and cavers with little fear of low air spaces; Blowing Spring lies just barely above the level of the river and represents a considerable hazard since one must enter through a barely passable spring entrance. 600 foot-long Greer Spring Cave represented a hazard of a different sort; tremendous currents exist in this cave which is one of two outlets to Greer Spring which, at an average daily flow of 187 million gallons, is Missouri's second largest spring. Most of the flow comes out of the lower boil outside of the cave but the cave flow

Figure 6: Jerry Wagner surveys in New Liberty Cave, Oregon County, Missouri. (*Photo by Scott House*).

Figure 7: Doug Baker helps survey in Statue Cave, Oregon County, Missouri. (*Photo by Scott House*).

Figure 8: Entrance to Cropper Cave, Oregon County, Missouri. (*Photo by Scott House*).

still represented about 50 cfs of the total at the time of the survey.

Lastly within the study area two very similar caves along Spring Creek were surveyed. Both Statue Cave (720 ft. long) (Figure 7) and Cropper Cave (600 ft.) (Figure 8) run beneath small ridges and pirate stream drainages from the hollows over the ridges. These maps give a good idea of what goes on throughout much of this region. While this initial survey was completed indications are that a new agreement will be initiated for further work in the area.

Elsewhere, Mark Twain National Forest's longest cave, Douglas County's Still Spring Cave, nears completion. Six trips accumulated about 2000 feet of tough survey. Long stream crawls, requiring a wet suit, lead to extensive canyons and rooms far upstream. Dry crawls bypass most of the stream crawls but only provide moderate relief since wetsuits are required for the survey objectives. Work continues trying to reach the upstream end of the cave but additional discoveries keep popping up putting the survey length at almost 17000 feet. Lastly the survey of Brazil Pit was finished and an overland survey was run to nearby Sinkhole Cave.

Powder Mill Creek Cave

This large and intriguing cave is located within the Ozark National Scenic Riverways (National Park Service) on land actually owned and managed by the Missouri Department of Conservation. Access to the cave, a state natural area, is controlled by the Department while facilities support is provided by the ONSR.

The cave now totals over 29000 feet in length and will probably pass the Devils Icebox next year to become the state's sixth longest cave.

Most of the survey work in 1992 involved the lengthy side passage section called Hellhole. The name originated from the entrance crawl which is so obscure that, despite 25 years of previous exploration and mapping, it had never been entered. Much work was put in to this area to resolve sheet boundaries divisions for the final maps. The years work failed to resolve these problems but progress was made in reducing the number of unsurveyed leads in Hellhole. Most of the mapping activity in Hellhole involved a canyon maze that underlies the northern portion of a large upper-level passage named Grand Gallery. Four survey crews mapped 1000 feet of frustrating survey which primarily consists of a narrow 12 foot high canyon overlying a breakdown strewn passage two to six feet high by 10 feet wide. The lower level connects to the canyon from time to time; the canyon intersects Grand Gallery a few times via slump pits. Gand Gallery itself was extended for several hundred feet of moderately large passage. The passage is heavily decorated with columns 6 to 10 feet high and stalactites over 3 feet in length not uncommon. One noteworthy formation is a white compound flowstone mound 14 feet high with a 12 x 6 foot base.

One lead off of a Hellhole route led to a meandering canyon that dropped into another passage of walking size (8 feet high by 10 feet wide) which was mapped for several hundred feet. This eventually intersected yet another upper level canyon, not yet surveyed, 20 feet high by 8 feet wide.

Elsewhere in the cave, one survey trip was taken to continue the survey of Bear Avenue which is accessed via the Windy Crawl, an extremely tight crawlway which effectively limits this area to those with small builds. Nearly 800 feet of pleasant passage was surveyed; it was hoped that this area might connect with some of the canyons in Hellhole but that hope was dashed by the trend of the mapped passage. Much more work is planned for 1993, centering again on the Hellhole series.

Personnel

Most of the above work was coordinated by Mick Sutton, Doug Baker, or Scott House. Other JV's who have helped with the drafting, or administrative duties include Bob Osburn, Sue Hagan, Jerry Wagner, and Tim O'Dell. Numerous others participated in the field work.

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

by Scott House

Work on completing area maps, a new start on the Historic Mammoth section, continued work on smaller caves, and a cartographic salon winner highlighted the 1992 effort.

FIELD WORK

Morrison and Proctor Cave (Hawkins River Area)

Field work in the river areas concentrated on completing certain areas. Several trips were taken to Lee Avenue to fix old survey inconsistencies and finish off leads along it. Several other trips concentrated on the Coons Trail and X-15 Pit areas on the route to Kaemper Avenue. The large areas of the river downstream from the Doyel Valley entrance also received work in an attempt to get this area finished. Large areas of the river are now essentially finished and drafting work can go ahead.

Mammoth Cave Ridge

Mammoth Cave Ridge was once again the scene of the heaviest activity as several area maps move toward completion while more maps have been started. Much of the work was on the Historic end where new maps are now underway. Two and a half miles of Historic Mammoth was resurveyed and a small amount of new passage was done as a by-product. Passages resurveyed comprised a network of interconnections involving Gothic Avenue, Gratz Avenue, Aboriginal Avenue (off Jessup Avenue), Briggs Avenue, Sylvan Avenue, Wilsons Way, Harveys Avenue, and Lost Avenue. Also on the Historic end of the cave several trips were taken to Cutliff Way to finish off leads that yielded 600 feet of new passage and trips to the Minnas Way area yielded a few hundred difficult feet of passage. In the central area of the cave over a quarter mile of new passage was discovered and mapped within five minutes of the elevator entrance; a thousand feet of hard-earned passage turned up off of northern Marion Avenue, and a number of trips to the Belfry/Blackstone area resurveyed some areas and found hundreds of feet of new passage. Work continued on Mystic River with more than a half mile resurveyed. On the southeast end of the ridge trips on the Cathedral

Domes map area surveyed another 800 ft. of passage while several hundred more feet were mapped in various leads in the Frozen Niagara area. Resurvey in Mammoth Cave totalled over three miles this year while leads yielded over a mile of new passage.

Flint Ridge

The bulk of the work done this year was to finish the network of passages that connect Salts and Colossal and to replace the trunk survey in Salts. Over 3000 ft. of replacement survey was completed in Colossal while work in Salts amounted to over 9000 ft. of resurvey. Over 1500 ft. of new survey was also done in the two caves. Trips to Unknown Cave concentrated on finishing pit areas around the Union Shafts and the Unknown Entrance; these yielded 500 ft. of new survey while nearly 1000 ft. was resurveyed.

LENGTH OF THE SYSTEM

The Mammoth Cave System is now 340 miles long. New mileage comes mostly from the Proctor/Morrison area.

Cave	*Miles*	*Kilometers*
Colossal Cave	29.36	47.26
Crystal Cave	14.15	22.77
Salts Cave	19.63	31.59
Unknown Cave	44.49	71.60
Flint Ridge Total	*107.63*	*173.22*
Mammoth Cave	133.92	215.52
Proctor/ Morrison	38.03	61.21
Roppel Cave	60.81	97.87
System Total	*340.39*	*547.81*

This represents an increase of 4.6 miles over last years total. More new survey than that was recorded but we "lost" some considerable footage in Unknown due to earlier recording errors.

SURFACE SURVEYS

Progress was made toward completing the entrance-to-entrance surface survey grid. Trips concentrated on extending the survey line to entrances of Roppel Cave outside of the park and completing one internal loop within the park. Efforts are being made to obtain new equipment to hasten this effort.

OTHER CAVES IN THE PARK

Much work was done on the smaller (less than 300 miles!) caves in the park. On the north side of the Green River 4000 ft. was surveyed in Buffalo Creek Cave and more remains to be done. Another 400 feet of new and resurvey was done in Running Branch Cave which is now nearly done. A new cave at the mouth of Cow Ford Hollow was surveyed and completed at 400 ft. 900 ft. was resurveyed in Wilson Cave in an effort to produce a new map. Temple Hill Cave was surveyed and found to end after 230 ft. Johnson Spring Cave was also surveyed to approximately 220 ft. Other, very small, caves on the North Side that were surveyed included Jawbone Cave, Stillhouse Sink Cave, Pinnix Pocket, Bear Den Cave, and Cade Cave.

On the south side of the park one trip was taken into Smith Valley Cave and a couple of trips extended the length of White Lightning Cave by several hundred feet. Another 200 ft. was surveyed in Johnson Cave (not to be confused with Johnson Spring Cave), and a resketch trip was taken to Rigdon Pit. Outside of the park surveys were completed of Adwell Cave and Indian Cave.

DATA REDUCTION

Most of the survey data accumulated by this project is entered into the commercial SMAPS program (version 4.3) and then "dumped" into CRF's Cave Map Language (CML) for archiving. Some of the data is reduced using SMAPS while other material is compiled by CML. CML, written for MS-DOS or Macintosh computers in C, has advanced features that allow it to perform more error-tracking procedures. A new "front end" for CML has been written for Macintosh users that promises to be a very usable product for instant manipulation and data retrieval. Our goal is to achieve seamless transfer of data back and forth from CML to SMAPS.

The database of CRF survey books now has nearly 3000 entries and continues to be a very useful product. It is through manipulation of this database that the length of the cave is determined. CRF, the National Park Service and the Central Kentucky Karst Coalition continue to work on a merger of survey book databases which will also include work done over the years by NPS teams. The eventual goal is to integrate all these available survey networks into one.

CARTOGRAPHY

Work continues on finishing some of our 1:600 base maps. Our first final product, the Kentucky Avenue sheet drawn by Mick Sutton, was finished in 1992 and won a first place ribbon in the NSS Cartographic Salon. The pencil draft of the Cathedral Domes sheet is nearly done and only awaits finishing of a few difficult leads. The Bishops Dome and Frozen Niagara sheets are both nearly finished and may be done this year. The Cleaveland Avenue, Blue Springs Branch, and Marion Avenue sheets are all dependent on the underlying Mystic River section being finished before they are inked. Similarly, the Main Cave sheet is mostly done but awaits the finishing of Roaring River before it is completed. Both the Main Cave and Cleaveland Avenue sheets have been split into two sheets in the interest of maintaining a manageable size. Much of the survey work on the Alberts Domes sheet is finished and drafting is now underway. The following list names various sheets in pencil on mylar format and the cartographer in charge

Sheet	Cartographer
Main Cave	Scott House
Blue Springs Branch	Roberta Burnes and Mick Sutton
Marion Avenue	Bob Osburn
Cleaveland Avenue	Doug Baker
Snowball Dining Room	Bob Osburn
Bishops Domes	Kevin Downs
Cathedral Domes	Scott House
Frozen Niagara	Scott House
Alberts Domes	Bill Putnam
Historic	Doug Baker
Cocklebur	Kevin Downs

Work on the river sheets is progressing well but with much new cave being found and detailed maps providing new information on possible leads it is difficult to approach being finished. All of the sheets are currently being drawn by Bob Osburn.

In Flint Ridge the Pohl Avenue sheet (drawn by Paul Hauck), in all its complexity, continues to near completion as pencil on mylar. Work is now beginning on several sheets in the Colossal/Salts area as surface surveys are closed. Most of these will be drawn by Jim Borden while Upper Salts will be drawn by Mick Sutton.

Excellent progress has been made on other caves within the park. We still have a backlog of old surveys that were never turned into final maps but we are rapidly catching up by training new cartographers and fixing old survey data. Sixteen maps were completed and inked this year: Temple Hill Cave, Jawbone Cave, Curd Cave, Little Lower Proctor Cave, Little Proctor Cave, Davis Waterfall Cave, A. L. Morrison Cave, Cade Cave, Cow Ford Cave, Bent Tree Sink, Johnson Spring Cave, Pinnix Pocket, Bear Den Cave, Stillhouse Sink Cave, Indian Cave, and Adwell Cave. Several more caves are currently finished (or nearly finished) and are being drafted by the indicated cartographers:

Sheet	Cartographer
Mouse Cave	Bob Osburn
Rigdon Pit	Phil Bodanza
Dickey Pit	Phil Bodanza
Johnson Cave	Gerry Estes
Cripple Creek Cave	Gerry Estes

The following are still being surveyed:

Running Branch Cave	Scott House
Crow/Hackett Caves	Scott House
Buffalo Creek Cave	Stan Sides
Long Cave	Tim Schafstall
Smith Valley Cave	Tim Schafstall
Wilson Cave	Jim Greer
White Lightning Cave	Rick Olson

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Fitton Cave Survey Project

by Pete Lindsley

Six successful expeditions were fielded in 1992 and we were able to survey the stream passage all the way from the Bat Cave entrance to a point past the Round Room. We essentially completed the survey in Fitton Spring and also completed the majority of the downstream passage in the Grand Central area. Early in 1992 an interesting cave radio location was made at the Out Room; this time the transmitter was located on the surface and the direction-finding receiver was used in the cave. The location essentially matched the previous, more conventional transmitter-in-the-cave location. Danny Vann is taking over the Area Manager job from Jack Regal starting in spring, 1993.

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THE SCIENCES

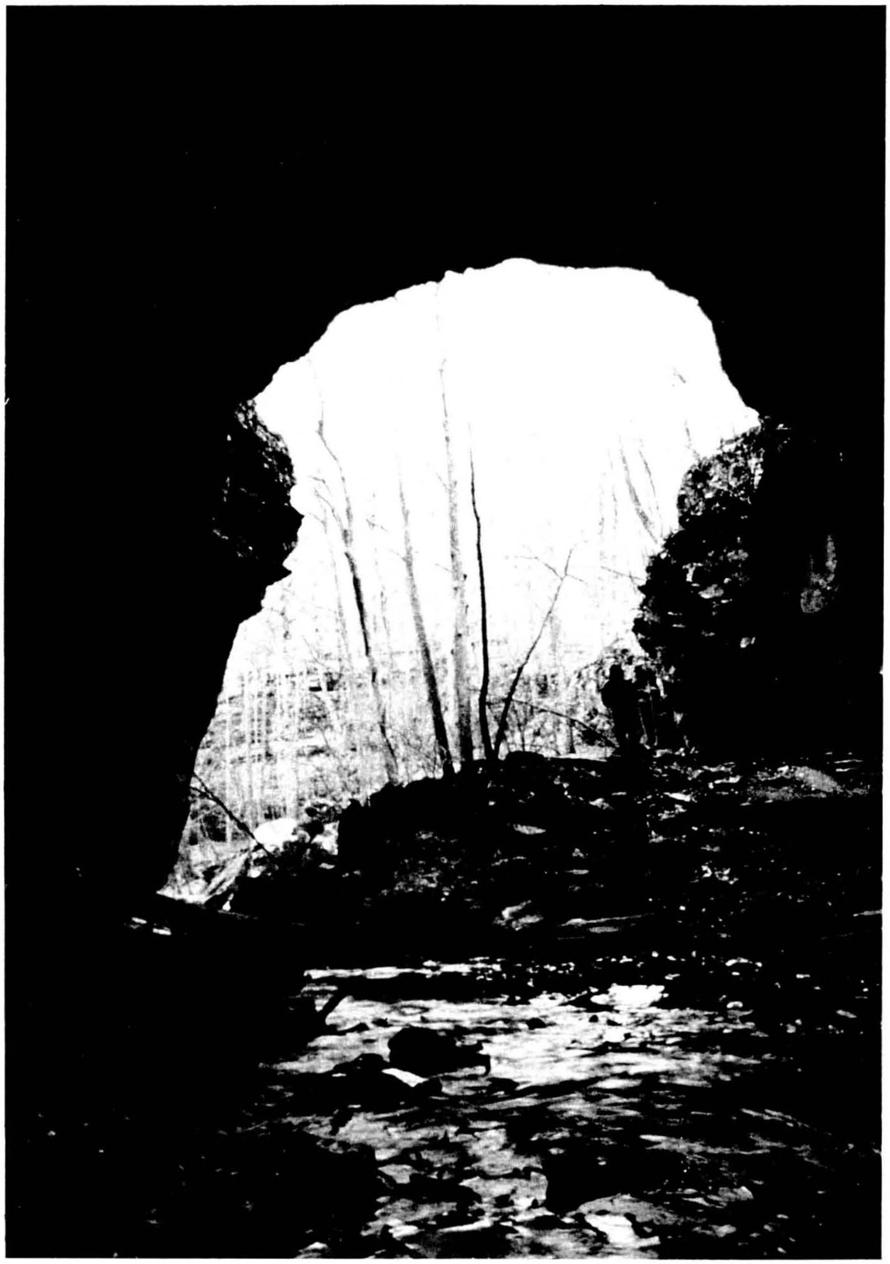

Figure 9: Large cave entrance located in Carter Caves State Park, Kentucky. (*Photo by Chris Groves*).

GEOSCIENCES

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

by John Tinsley, Kenneth Miller, and Robert A. Johnson

Introduction

Deposits of fine sediment resulting from foot traffic occur in heavily-visited lava caves at Lava Beds National Monument, northern California, USA. The accumulations range in thickness from fractions of a millimeter to centimeters and the deposits mantle many of the natural rock surfaces within the cave to be discolored by the dust particles. These accumulations of particulates are unsightly, obscure the features of the lava rock of the cave, and thereby detract from the visitors' experiences. Although several aspects of these deposits were studied, we report on only one aspect here, our study of upper Skull Cave. The entire report (Tinsley and others, 1992) deals with findings in Valentine Cave and elsewhere in Skull Cave and can be obtained from the National Park Service, Lava Beds National Monument, at Tulelake, California. The project has been concluded and sampling gear removed from the Monument.

From November, 1989, to January, 1992, sedimentary deposits in the upper level of Skull Cave were sampled and studied in order to characterize sedimentation problems in terms of deposition rate, depositional process, and provenance (source of sediment). In addition, aerosolic dust was collected at an above-ground site near the cave to enable comparison of atmospheric aerosolic dust with in-cave sediment. Using the petrographic microscope, comparisons show that the in-cave deposits are characterized by a high proportion of coarse glassy volcanic ash (vitric tephra) and a low content of organic matter compared to above-ground samples. The latter tend to be finer grained and relatively rich in pollen and fine organic particles. Although our study was not specifically designed to test the idea, wind currents arising in response to atmospheric considerations outside the cave do not seem to be important in moving this sediment inside the upper levels of Skull Cave. Sedimentation rates inferred from in-cave dust collectors indicates that the rate of deposition of dust decreases as the distance from the trail tread increases, a finding that implicates visitor traffic and the trail tread as co-contributors to the problem.

The trail tread in upper Skull Cave is composed largely of a vitric tephra or volcanic ash, a material which is light, easy to handle, easily obtained from many localities in and around the Monument, and was thus easy to transport into the caves for use in constructing trails decades ago. Yielding to this tempting expediency turns out to be the root cause of the problem.

The sets of data we collected are small, however, the conclusions are informative and compelling. We conclude that the trail tread is the source of the in-cave sediment. The vitric tuff tends to shatter, and become ground to a fine powder owing to visitors' foot traffic. Initial aggregates of particles range from 1 cm to 2 cm in diameter; upon become ground and/or shattered, particles commonly are less than one micron in diameter. We suggest that a two-step program, consisting of (1) replacing the trail tread with a crushed non-glassy basalt aggregate which will not shatter under impact of footfalls, followed by (2) a cleaning of the dusty in-cave rock surfaces by vacuuming and flushing with water, the clean natural appearance of the lava surfaces will be restored. The rock will tend to remain dust-free because the abundant near-by source of the fine particulates at the trail tread will have been removed.

Sampling Techniques and Methodology

Figure 10 from Tinsley and others (1992) shows plan and profile views of the deployment of flat plates of non-vesicular basaltic lava which served as pas-

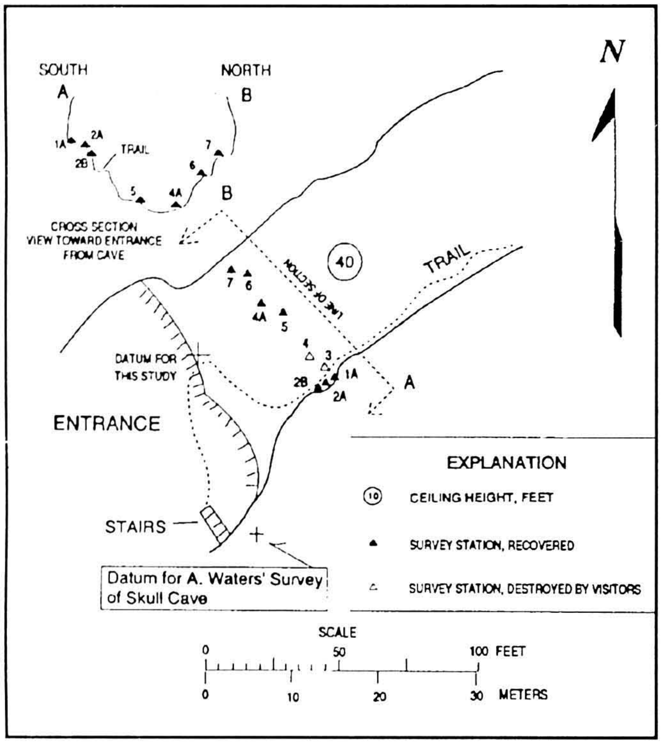

Figure 10: Map showing entrance area of Skull Cave, including plan and vertical profiles illustrating deployment of dust traps.

sive sediment collectors in upper Skull Cave. The outline of each lava plate used as a collector was traced onto a sheet of paper and the area determined using a planimeter. Periodically, the dust that settled on the lava "dust traps" was washed with distilled water from the collector into sealable plastic bags for the trip to the laboratory. The sample was eluted into a weighed beaker, dried, and re-weighed to determine total mass of the sample. From the sampling interval, gross mass of the sample, and the area of the collector, the dust flux was calculated using the familiar units of grams/sq. meter/day. Sample masses were tabulated by station and grouped by month and year.

Figure 11 from Tinsley and others (1992) shows dust flux data for four sampling intervals from the upper Skull Cave array. This summary of the data illustrates several important, fundamental trends. In August, 1990, we recovered only traps 5, 6, and 7. The others were toppled or seized by visitors and hurled from the trail, landing where we subsequently found them. We successfully became more clever at concealing the traps from idle hands during our subsequent deployments, and our collectors' survival rate (the proportion of traps successfully recovered) improved markedly.

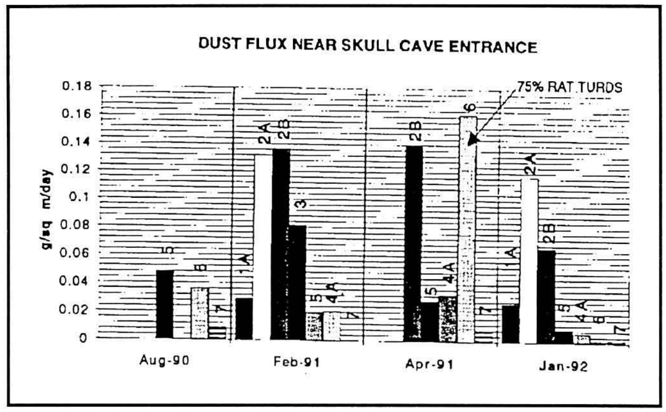

Figure 11: Histogram showing gross dust flux at Skull Cave expressed in units of grams/sq. m/day, tabulated by collector, and grouped by month and year that the collectors were serviced. Collector's number is given above its bar graph in the histogram.

The trends we measured are reasonably clear when the geography of the trail and the deployment of the collectors are considered. Collector 1A is located above the trail; collectors 2A and 2B are close to trail level and adjacent to the trail. Collectors 5, 4A, 6, and 7 were deployed at increasing distances from the trail. In general, the farther from the trail, the less the dust flux as measured by our techniques. There were anomalies from time to time. As samples were small, any ancillary contributions stood out prominently. For example, a wood rat had the unmitigated temerity to defecate on one of our collectors, and the residua constituted 75-80% of the sample. [It may have been an editorial comment on our study, but the rat wouldn't sit for an interview, so we can only speculate.] In any case, the average particle size decreased from 25 microns for collector 2A to 6 microns for collector 6. The volcanic glass (refractive index of 1.525) in the trail tread materials was virtually identical to that of the particulates trapped at distant collectors in the cave. The glass component is distinguishable from other components because the groundmass is isotropic (extinguished under crossed polarizers) and contains small crystallites and minute grains of plagioclase feldspar, biotite, and hypersthene. Trail tread samples also contained some pollen (juniper, sage, grasses, pine), and lint from various textiles.

Figure 12 from Tinsley and others (1992) shows how the average content of oxidizable materials as a percentage of total sample mass distinguishes particulates trapped outside the cave from particulates trapped inside Skull Cave. Samples were treated with a 30% solution of hydrogen peroxide to oxidize the susceptible components, and the measured reduc-

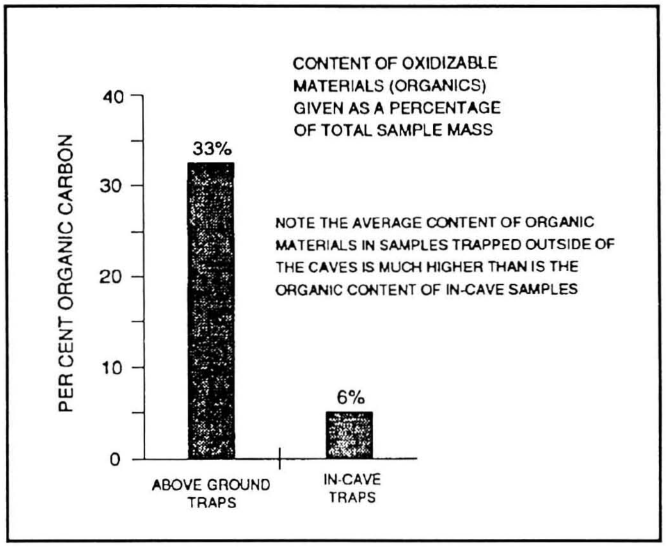

Figure 12: Average content of oxidizable particulates retained in three above-ground dust traps compared to that retained on in-cave dust traps. Analysis conducted using 30% H_2O_2. solution.

tion in total sample mass was attributed to elimination of the organic fraction. The technique is admittedly crude, because components other than organic carbon may be oxidized, but it offers the advantage of being rapid and for these samples is definitive.

Figure 13 from Tinsley and other (1992) shows measured dust flux plotted as a function of distance from the trail tread. Absent the rat feces, collectors near the trail tread collected dust at a greater rate than collectors located 6 meters or more away from the trail.

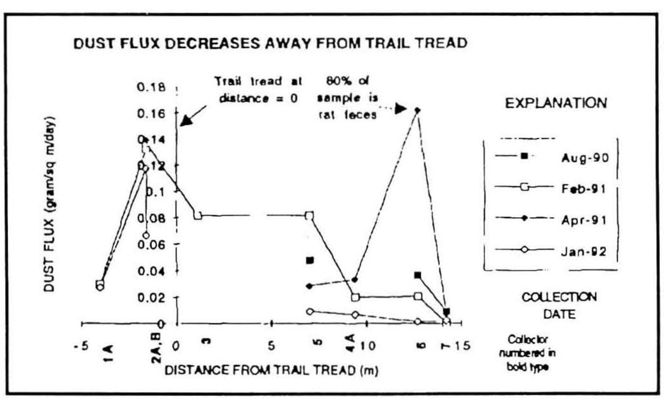

Figure 13. Scatter plot showing highest levels of dust flux were recorded adjacent to the trail tread in Skull Cave; flux decreased as distance from the trail tread increased for 4 collection periods. Rat feces produced an anomalous value at collector 6 in April, 1991.

Results

The similar compositions of the trail tread materials and the silt-sized materials recovered from the collectors, the measurable decrease in dust flux with increasing distance from the trail, and the decrease in mean particle size with increasing distance from the trail indicate that the trail tread is the source of the silt-sized detritus that is raining down upon and coating the rock surfaces in upper Skull Cave. The vitric tuffaceous material is apparently quite brittle and tends to shatter into very small, angular fragments, evidently under the impact of visitors' footgear on the trail. Wind currents generated by passing visitors apparently are sufficient to disperse the suspended fine particulates across the entire breadth of Skull Cave at the site of the collector array near the entrance.

Remediation

If the brittle, glassy material of the existing trail tread could be removed and replaced with a basalt that is crushed to about 1/2-inch diameter and washed to remove fines, the source of the buff-colored fine sediment would be eliminated from the cave. The new trail tread would be darker in color, more nearly matching the native cave rock in terms of composition and appearance. In addition, if the fine silt could be vacuumed or washed off the rock surfaces along the trail, the appearance of the lower walls and breakdown blocks in the cave would be restored to a relatively dust-free condition which existed after the lava cooled. We anticipate that if the trail tread could be replaced, the result would be a visual experience that would minimize this visitor-derived impact.

It is unwise to consider paving the trail with cement or asphalt. These substances, although relatively inexpensive, durable, and available, are also foreign and likely to be toxic to the cave environment. Neither concrete nor asphalt would enhance the visitors' experience. Using a dense, non-vitric crushed basalt as the material for the trail is the most attractive option; a basalt would be chemically similar to the rock of the cave, compatible with the population of cave-dwelling organisms, and it would not comminute significantly under foot to produce an aerosolic dust.

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Sedimentology of the Redwood Canyon Karst

by John C. Tinsley

The winter and spring of 1992 were reasonably tame for the sediment chasers of Redwood Canyon, owing to the drought which has plagued California among other places for the past 7 years. There are few changes in sediment distribution to report, although there were some surprises within the cave, as we shall see.

Big Spring is thought to remain plugged by sediment, a condition that was observed by Bill Farr during dives in 1991. Runoff was insufficient to inundate a series of low alluvial terraces located below the confluence of Big Spring with Redwood Creek. This area is a sensitive natural recorder and indicator both of sediment movement and relative water stage attained by runoff events. Inspection of this reach enables us to quickly appraise the impact of spring runoff events without waiting for the more detailed digital hydrological records maintained by the data logger at Big Spring to be analyzed and computed. The large sinkhole in Pebble Pile Creek continued to fill, without continuing to drop large volumes of sand and gravel into the cave. No new sinkholes were observed to have formed during 1992, although some minor modifications which included raveling of the perimeter were logged at several new sinks formed during 1990-1991.

Inside Lilburn Cave, proceeding downstream or from north to south, sediment did not move appreciably in the Upstream Rise and White Rapids areas; the Ant Lion passage was only minimally active, and the floor of the Hexadendron Room was not inundated during the runoff season.

Although there were few changes over winter at the Z-Room near the southernmost sump, the most remarkable changes were observed following an unseasonable rainfall in normally dry July. A section of sediment 6- to 8-foot thick washed out of the Z-Room area and accumulated downstream where it buried a SCUBA tank cache placed in late June under 3 to 4 feet of sand. Curiously enough, the storm that provoked the problem occurred during early July, which is usually a dry month in the Mediterranean climate of California. Although the sedimentologists were maintaining polite smirks and most of their composure as they measured up the changes in the sediment profiles , the dive teams were not amused, for they had arrived expecting to dive without incident and concluded by digging for lost gear. The divers procured digging implements by dismantling the static sediment sampler, but initial attempts to locate the missing gear were not successful. On the succeeding expedition, equipped with shovels and a metal detector, part of the missing gear was located and employed on subsequent dives. However, at least one SCUBA tank remains at large. Perhaps we should string a net across the resurgence at Big Spring? A new opportunity to obtain throughput times may be at hand. The incident underscores the dynamic nature of Lilburn Cave's hydrologic system, including its ability to move appreciable volumes of sediment on short notice. Even seemingly minor events can produce remarkable local changes in sediment storage and movement within the Lilburn Cave system.

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Spectral Analysis and Interpretation of the Lilburn Cave-Big Spring Hydrologic System, Kings Canyon National Park

by Linda Urzendowski, Igor Jankovic, John Hess and Mike Spiess

Introduction

Spectral analysis for a karst time series can provide information regarding the cave-spring flow dynamics and help define the internal geometry of the system. A representative section of the 1992 stage-height time series of Lilburn Cave and Big Spring (Figure 14), a karst cave-spring system that experiences cyclic ebb and flow behavior, was analyzed using spectral methods to better interpret the hydrologic and physical properties of the system.

Discussion

The time series in Figure 14 shows that an instantaneous increase in spring stage height corresponds

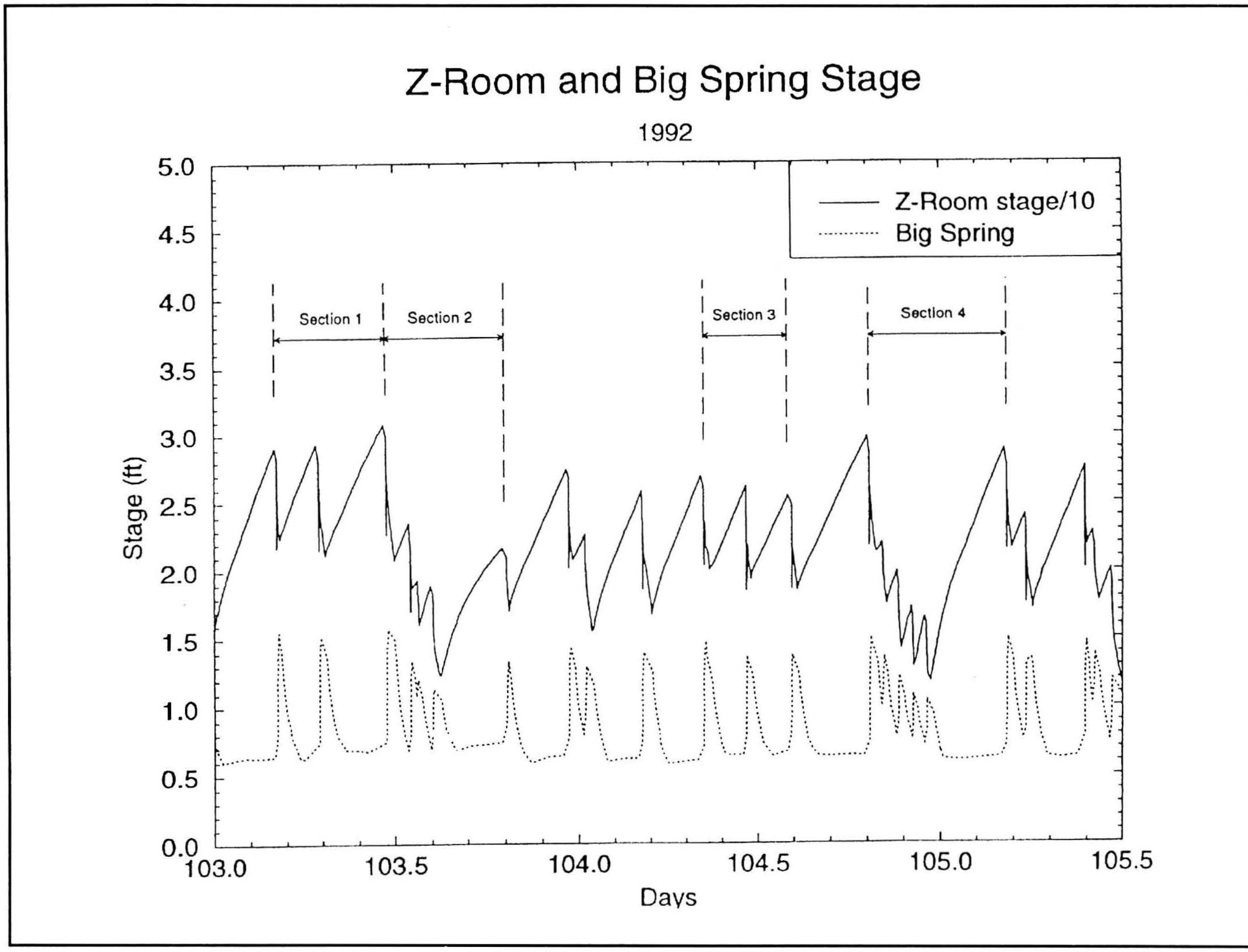

Figure 14: Time series data set representing the stage level fluctuation of Lilburn Cave (Z-Room) and Big Spring for days 103 to 105.5 in 1992. Quasi-linear behavior occurs in sections 1 and 3, while nonlinear behavior is present in sections 2 and 4.

with a drop in cave (Z-Room) levels. The ebb and flow behavior suggests the presence of a siphon (Meinzer, 1942). The instantaneous response may indicate that the system is completely filled with water and the rise at the spring is a pressure response when the cave achieves a significant amount of hydraulic head to activate the siphon.

Both quasi-linear and nonlinear flow behavior have been observed within this cave-spring system, with the nonlinear behavior initiating at approximately 30 feet (9.15 m) of stage in the Z-Room and quasi-linear behavior occurring below this level. The nonlinear behavior could be a result of a large quantity of water quickly entering the system and backing up at the Z-Room. At approximately 30 feet (9.15 m), more water may be present at the Z-Room than can be handled linearly, resulting in multiple flushes of decreasing magnitude occurring at the input in order to relieve this instability. The Z-Room reaches a minimum and begins rising when much of the water has drained and the system has become stable again. During this time of nonlinear behavior at the input, the output continues to respond linearly with each flush at the Z-Room.

Spectral analysis was performed on each of the four data sections of Figure 14 to determine the nature of the power spectra. The power spectra for the Z-Room and spring for the two quasi-linear sections (1 and 3) are shown in Figure 15. These similar spectra are all relatively smooth, decreasing curves which

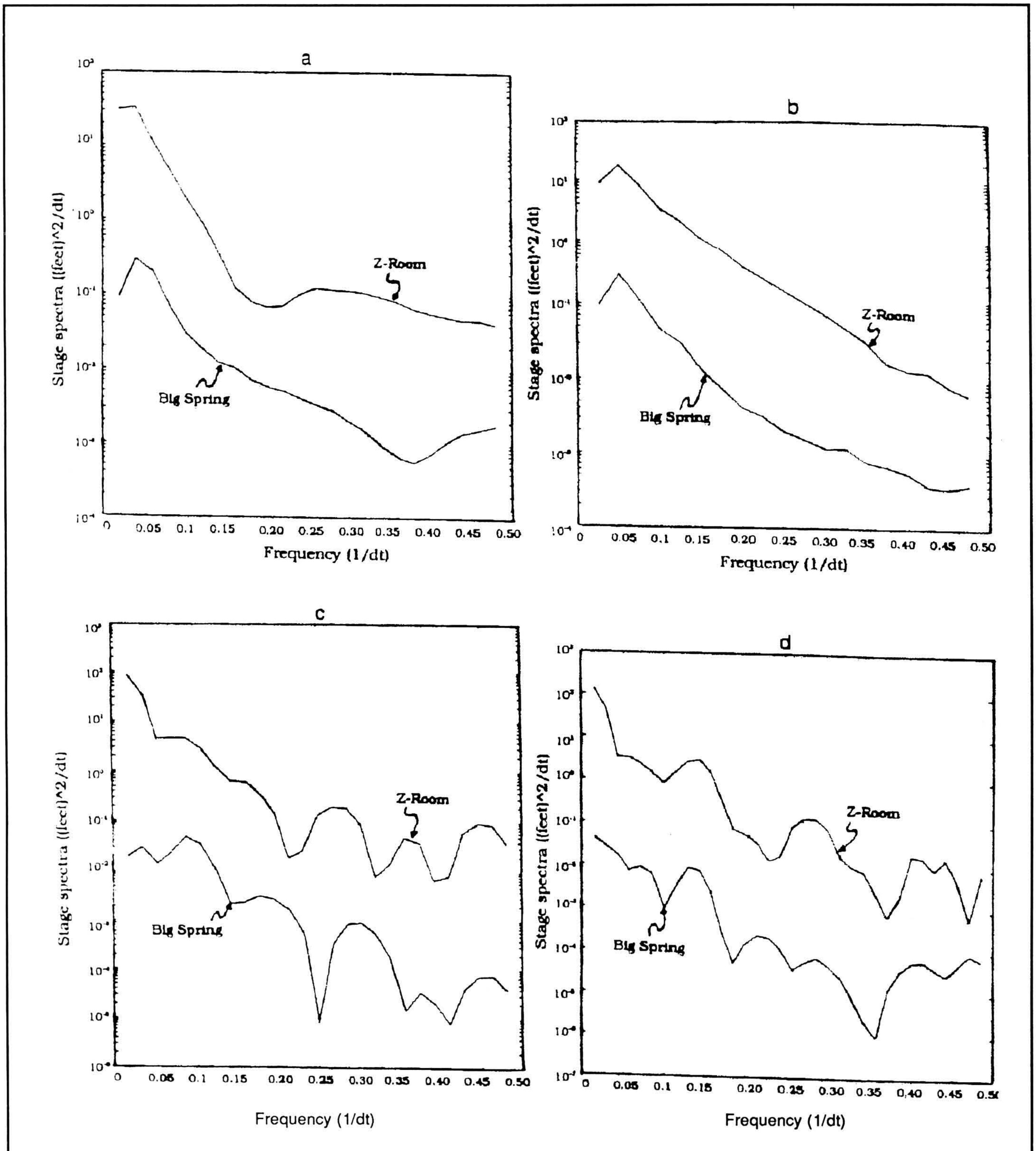

Figure 15: Power spectra of the four time series data sections in Figure 14. The smooth nature of graphs a and b (data sections 1 and 3, respectively) indicates linear or quasi-linear behavior, while the variable pattern of graphs c and d (data sections 2 and 4, respectively) is a nonlinear response. Notice the linear relationship between the Z-Room and Big Spring in all four data sections.

strongly suggest a linear to quasi-linear system. Both sets of power spectra display slight irregularities regarding the smoothness of the curves, which are attributed to noise within the data. The power spectra for the two nonlinear sections (2 and 4) are also shown in Figure 15. Both power spectra fluctuate similarly with an apparent decreasing trend. The variations show an average exaggeration of the power spectra of about 10 times, with one spike at the spring in section 2 deviating by almost 100 times. This is characteristic of nonlinear behavior.

The power spectra shown in Figure 15 show the spring always occurring at a lower spectra than the cave. This is due to attenuation of the input noise occurring within the system, and is common in karst systems because of the complexity of flow paths that can smooth out initial noise (Andrecevic, pers. comm., 1992).

The input and output spectra for a true linear system would always level off at approximately the same value, respectively, and appear nearly identical in shape. For the Lilburn Cave-Big Spring system, the cave always levels off at a different spectrum, as does the spring (Figure 15), with both spectra behaving similarly. This indicates that there is a variable acting externally on the system causing the input to behave stochastically, although the system responds linearly between input and output. This stochastic behavior is thought to be the result of flow path blockage due to a variable sediment load present within the system during the ebb and flow season. Sediment is thought to have entered the cave system after a large sinkhole collapse in 1988, with great quantities observed at the spring indicating sediment transport through the system. When sufficient hydraulic head is reached, the system is breached and the flow cycle resumes.

Acknowledgements

I wish to thank Brad Lyles, Todd Mihevic, David Gillespie, Lora Gillespie, Mike Slattery, Lorrie Linnert and John Tinsley for their field assistance and technical support for this project.

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Network Flow Modeling of Developing Karst Aquifers: Selective Enlargement of Competing Flowpaths

by Christopher G. Groves and Alan D. Howard

Introduction

In order to investigate the conditions leading to preferential flowpath and competition for flow among a number of potential initial flowpaths within incipient karst aquifers, a new FORTRAN program has been developed by solving a general flow problem for pipe networks and combining this with laboratory based information on calcite dissolution kinetics. The study networks were composed of between 146 and 156 individual conduits, but can designed into a wide variety of configurations of conduit, input, and output geometries, limited only by computer memory requirements. Although the study networks are aligned horizontally, there is no inherent limitation of the flow solution to a two dimensional space. Solutions are limited, however, to laminar flow conditions; the program generally ceases operation at the time that turbulent flow begins to occur at some location in the network. All conduits remain water filled, closed with

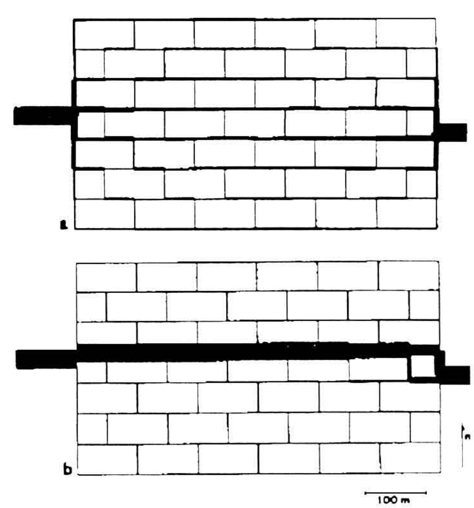

Figure 16: Map view of simulated network A showing (a) initial and (b) final discharges after 4,100 years. Maximum discharges are (a) $4.6x10^{-8}$ and (b) $2.7x10^{-6}$ m^3/s.

respect to the addition of additional CO_2 gas as dissolution proceeds. In addition, complete and instantaneous mixing of fluids is assumed to take place at passage intersections (nodes). Complete program documentation and discussion of model development are given by Groves (1993).

Modeling Results

Although the flow model is at present limited to laminar flow conditions, important patterns of selective enlargement have been found to occur even during the very early stages of passage development simulated by the model. In the absence of initial variations in passage size, the major flowpaths to develop are those along the most direct path between entrance and exit. Those passages that are most closely aligned with the hydraulic gradient will also be enlarged more rapidly than those oriented in a more oblique or perpendicular fashion (Figure 16).

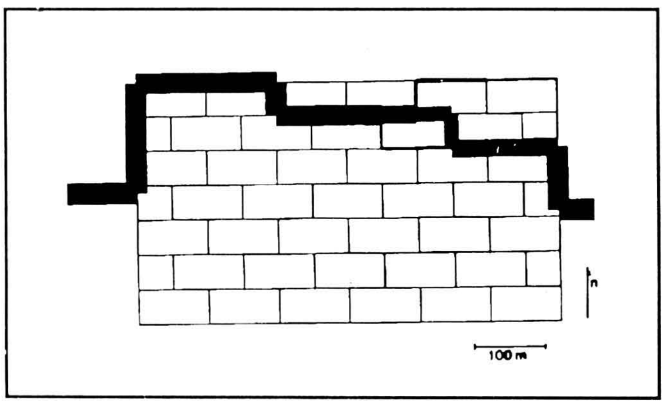

Figure 17: Final discharges for network D after 22,000 years. Maximum discharge is 4.6×10^{-6} m^3/s.

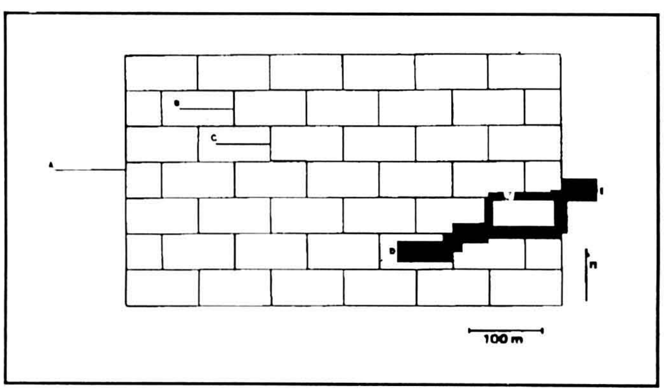

Figure 18: Final discharges for multiple input network L after 1,900 years. Maximum discharge is 1.6×10^{-6} m^3/s

A series of runs done with a randomly generated initial fracture widths showed that with a small range of widths (ratio of largest to smallest of three), passage development is little affected by the width variation, such that enlargement occurs primarily along the most direct path between entrance and exit. With a greater variation (50x ratio), the fracture sizes had a large effect on the selection of paths of preferred solutional enlargement (Figure 17). The major passages to develop (those carrying the highest discharges) were generally along circuitous routes formed from chance connections of relatively large fractures, rather than along the shortest path. When a wide variation in fracture widths is present in an incipient karst aquifer, the initial distribution of these widths can be expected to be a major influence on the pattern of flow routes that ultimately develops. It is the presence of small passages (constrictions) along a potential flowpath, rather than the presence of particularly large passages, that controls these patterns of development.

A number of hypotheses have been suggested in the literature to explain development of maze (nonselective) *vs.* branchwork (selective) pattern development of cave passages. Results from multiple input simulations support the observation of Palmer (1975), based on field evidence, that a number of alternate flowpaths can form where flows are forced to seek alternate routes around constrictions causing the fluids to dissolve a number of fractures simultaneously. In contrast, the suggestion that mazes form simply due to phreatic, artesian flows where all passages are constantly in contact with throughflowing waters (Bretz, 1942; Howard, 1963) is not supported. Phreatic conditions were simulated in each of the runs, and in each case preferred flowpaths were developed at the expense of other passages in the network. Similarly, earlier analytical solutions of Curl (1974) suggested that all passages should be competitive when the entire network is under laminar flow conditions. He suggested that the first passages reaching turbulent flow in a network will experience increased dissolution rates, and these passage will gather increased flow. Results from this effort, in contrast, show well developed flowpaths under totally laminar flow conditions within the developing flow systems. This discrepancy may be explained by Curl's (1974) assumption of linear kinetics.

Other simulations were configured with multiple input flow conditions, to study development of branchwork patterns resulting from a conduits developing at a number of discrete inputs. In most cases, the flowpath from the input closest to the exit developed to the point that turbulent conditions were reached at that location (and thus the program ceased operation) before very much development from the other tributaries in the system could take place (Figure 18).

Continuing Work

Development and refinement of the network model is an ongoing process. In addition to examining competitive passage development within early stages of karst aquifer development, a variety of other phenomena can be investigated by modifications or additions to the model. An effort has been made to design a generalized code that can be relatively easily extended. Further topics for study include the importance of *Mischungs–corrosion* in karst aquifer development, by using multiple inputs with different initial PCO_2's, and testing of other hypotheses relating to the development of branchwork *vs.* maze patterns. For example, water inputs could be located at a large number of locations throughout the network to simulate Palmer's (1975) observation of maze cave development in limestones situated beneath permeable, but insoluble, clastic rocks. Potential extensions to the model include development of mixed laminar/turbulent and fully turbulent solutions to the network flow problem, non-steady head conditions at network exits to study effects of lowering baselevels through time, simulation of conduits that are only partially filled with water in limited discharge cases, and vertical cross section modeling of cave network development.

Acknowledgements

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Origin of Disconformity Dedolomite in the Martin Formation (Late Devonian, Northern Arizona)

by Ray Kenny

Abstract

Calcitized dolomite (dedolomite) occurs along a prominent disconformity in the Upper Martin Dolomite of north-central Arizona (Figure 19). Petrography, stable isotopes and field associations were used in an effort to constrain the origin and timing of the dedolomite. $^{18}O/^{16}O$ and $^{13}C/^{12}C$ ratios of the dedolomite show significant depletions relative to unaltered dolomite above and below the disconformity. This depletion trend and dedolomitization are interpreted to have resulted from (a) subaerial exposure and an influx ^{18}O-depleted meteoric water or, (b) descending groundwater from paleoaquifers in the Low Pennsylvanian. Sedimentary features consistent with a subaerial exposure include detrital-filled desiccation cracks and an accumulation of iron-rich residual clays. Features suggestive of dedolomitization by paleogroundwater include calcite-replaced evaporite nodules and the great volume of water inferred to have been associated with extensive continental, Low Pennsylvanian karstification of overlying (younger) carbonate units.

Acknowledgements

The author wishes to thank L. Paul Knauth and Kerrie E. Neet who read earlier versions of the manu-

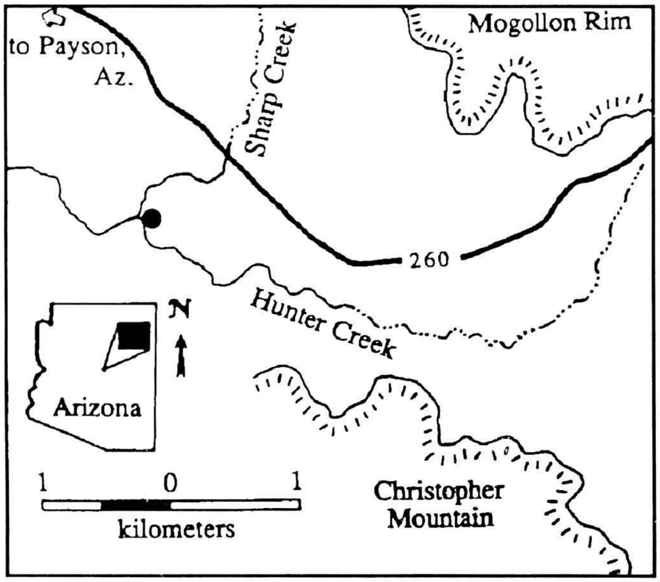

Figure 19: Index map of study area in north-central Arizona (USA). Dot indicates sample location along Hunter Creek at junction with Sharp Creek; NW1/4, S32, R13E, T11N on Woods Canyon Quadrangle, Arizona.

script. The manuscript was also improved by helpful comments from D.H. Krinsley, N.P. James and B.W. Sellwood. Partial support for this study was received from the Geology Department at Arizona State University and grant from the Cave Research Foundation.

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Silicified Mississippian Paleosol Microstructures: Evidence for Ancient Microbial-Soil Associations

by Ray Kenny and David H. Krinsley

Abstract

Silica-replaced microfeatures in a well-developed, Upper Mississippian paleosol from north-central Arizona, were examined by canning electron microscopy using back-scattered electron imagery. Preserved microfeatures include hollow and solid tubiform filaments and mycelium-like stringers which radiate from problematic (biogenic?) soil structures. Preservation of these features suggest that microstructures in the soil zone are not uniformly destroyed during post-diagenetic silica replacement and that biological soil symbionts may have occurred as early as the Upper Mississippian (-280 Mya) (Figure 20).

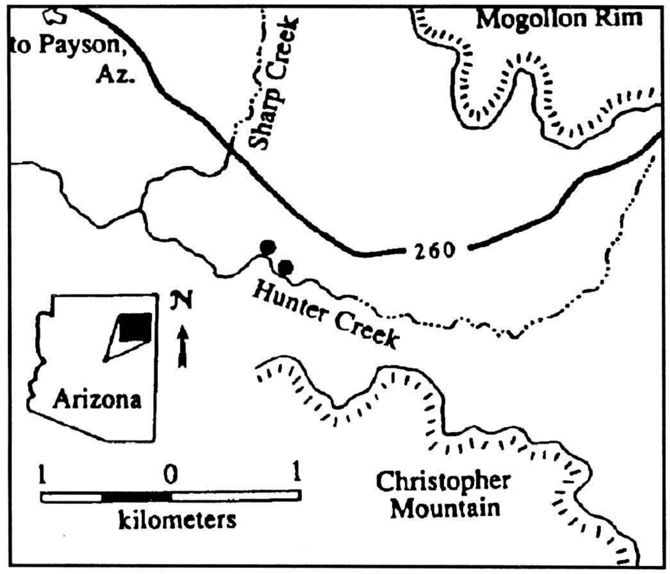

Figure 20: Index map of main sample sites (solid dots) along Hunter Creek (north-central Arizona, USA).

Acknowledgements

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Evolution of the Appalachian Highlands: Magnetostratigraphy, and Historical Geomorphology of the East Fork Obey River, Fentress County, TN

by Ira D. Sasowski

Abstract

An investigation of the East Fork of the Obey River was made to evaluate the rates of basin evolution in the Appalachian Highlands. This site is deeply incised into the Western Cumberland Plateau Escarpment in central Tennessee and possesses an extensive karst developed in the valley walls and bottom.

The hydrology of the site was investigated by field study including water balance, water chemistry, and morphologic inspection of the limestone conduit systems. Flow records, published reports, cave maps, and dye-trace results were also used. Character of the flow system within the karsted portion of the basin is that of a linked system of conduits, both parallel with and perpendicular to the main valley axis. Abandoned valley-parallel conduits exist well above the present day flood level. Active conduits exist up to 30 meters below the present day surface channel of the East Fork. Both the tributary and master surface drainages are pirated to the sub-surface upon breaching the Harstelle Formation. In the case of the East Fork itself, this situation results in a 10-km reach of stream which is dry except during flood stage. This piracy involves all of the flow from a 248 km^2 basin area upstream from this sinkpoint. This is the largest such piracy known in the United States.

The groundwater geochemistry of the site is almost completely dominated by acid mine drainage (AMD). This contamination originates in 3 coal mining areas within the basin. Although primarily abandoned, these sites are still discharging acidic waters from spoil piles and deep mines. The neutralization of AMD waters by contact with the underlying limestones does not occur at a sharp boundary; the acidic character persists far into the karsted portions of the basin. This character is exemplified by Enchanted River Spring, which is the partial resurgence point for the pirated waters of the upper basin of the East Fork. This limestone conduit discharges waters with pH range of 4 to 6, more acidic than ever before documented at a large karst spring. The spring waters frequently have a deep turquoise-blue color, which apparently is due to the flocculation and precipitation of aluminum hydroxides as the pH of the waters increases. The present-day chemistry of the waters is not useful for extrapolation of chemical removal rates to the past because of the effects of mining so dominate the system.

The abandoned and active conduits (caves) in the valley walls contain clastic sedimentary fills which were deposited by underground streams. These sediments preserve a depositional remanent magnetization (DRM) which they acquired when they were deposited. One pervasive paleomagnetic reversal zone was delineated. A paleomagnetic polarity column for the caves was constructed, revealing that the minimum age of the oldest passages in the basin is 0.91 Ma. Calculation of downcutting rates from this minimum age, and the elevation of the passages above the surface streambed yields a rate of 0.06 meters / ka. This rate compares favorably with rates from another study in the region.

A new style of cave is recognized and assigned the designation "Cumberland Style." These caves are many of the longest known in Tennessee and occur on the Cumberland Plateau Escarpment. Diagnostic features include valley parallel trunk segments, exceptional concordance of trunk passage orientation with minor surface topographic variation, development on the down-dip side of valleys, and development on distinct "levels".

Previous theories of cave origin have implicitly assumed that the fractures, faults, or open bedding-planes along which caves develop are basically an inherent part of the rock mass, caused by tectonic forces associated with previous orogenic events (in the Appalachians, Mesozoic or older in age). It is here postulated that valley stress-release fracturing is the major factor influencing cave development in the Cumberland Plateau Escarpment, and that these controlling fractures are probably no older than Miocene in age. Support for the hypothesis is given by data on cave passage orientation, cave occurrence, and borehole, deep mine, and dam excavations, all of which show that young joints increase in frequency towards an escarpment and align closely with topography. It is probably that valley stress-release fractures are important in the formation of caves from many other settings as well.

Abstract from:

Sasowski, Ira D., 1992, *Evolution of the Appalachian Highlands: Geochemistry, hydrogeology, cave-sediment Magnetostratigraphy, and Historical Geomorphology of the East Fork Obey River, Fentress County, Tennessee*: Unpublished Ph.D. Dissertation, The Pennsylvania State University, Department of Geosciences, 141 p. plus appendices.

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Origin and Development of Upper Cenozoic Ground-Water Sustained Lakes, Southern Great Plains—Preliminary Findings

by S. Christopher Caran

Abstract

From the Late Miocene to the present, discharge from unconfined (water-table) and artesian regional aquifers has sustained lakes and other aquatic environments at sites across the southern Great Plains. Perennial lakes persist locally despite an unfavorable arid to semi-arid climate with high evaporation. Ground-water contributions have dominated the hydrologic budgets of these and other lakes in this region throughout the Late Cenozoic. This is the central hypothesis of the present research program concerning: (1) the structural (karstic) origin, infilling chronology, and paleohydrology of selected lacustrine basins; and (2) paleoenvironmental records preserved in the lacustrine deposits.

Introduction

Lacustrine deposits make up most of the stratigraphic units composing the Upper Cenozoic section of the southern Great Plains (Caran, 1991) (Figure 21). These deposits fill karstic subsidence basins developed in or above regional aquifers. The Bottomless Lakes of Chaves County, New Mexico, are modern lakes of this type and serve as a model for the environment of deposition represented by the Miocene through Quaternary lacustrine lithofacies. Investigation of this modern analog supports a detailed stratigraphic study of 10,000,000 yr of deposition in lacustrine basins across the region, producing one of the longest paleoenvironmental records in continental North America.

Origin and Development of Lacustrine Basins

The southern Great Plains is an area of extensive dissolution subsidence (Gustavson and others, 1980). Ground water dissolves Permian evaporites and carbonates at depth, causing collapse of the overburden and gradual or even catastrophic subsidence (Baumgardner and others, 1982). Lakes and other aquatic environments are created when the floors of the surficial depressions drop below the potentiometric surface. In those basins inset into unconfined aquifers, this process simply "exposes" the water table; whereas other lakes are maintained by artesian discharge through a leaky aquitard overlying the source aquifer. Lacustrine deposits filling these basins are faulted and folded, indicating continual subsidence before, during, and after basin infilling (Caran and Baumgardner, 1990).

The Bottomless Lakes Model

Dissolution subsidence is particularly pronounced in the Pecos River valley of New Mexico, site of the Bottomless Lakes. These small lakes are cenotes: steep-walled dolines partly filled with ground water. Aquifers discharge into these lakes through collapse chimneys and breccia zones extending to a depth of 100 m. Ground-water contributions greatly exceed surface-water inflow (runin) and incident precipitation. Potential lake evaporation is approximately seven times annual precipitation in this semi-arid region. Runin is also limited by the size of the contributing watersheds, which are only 1.9 to 6.6 times the lake-surface areas. Deposits exposed at the margins of the Bottomless Lakes are fine grained and primarily consist of clayey algal carbonates with invasive gypsum cement.

The Lingos Formation—Ancient Analog?

Sedimentary fill and basin geometry of the Bottomless Lakes is similar in many respects to those of the Late(?) Pleistocene middle Lingos Formation and other formations of the Paducah Group of the western Rolling Plains of Texas (Caran and Baumgardner, 1990). The middle Lingos Formation consists of lacustrine deposits filling karstic subsidence basins produced by intrastratal dissolution of Permian evaporites. Contributing drainage areas of Lingos lake basins were small and the volume of surface-water inflow was low. As a result, these basins received little coarse clastic sediment from the surrounding, low-relief terrain. Eolian influx was also minor. Lingos basin fill consists of autochthonous biogenic sediment and calcareous clays, comparable to deposits within the Bottomless Lakes.

Cenozoic Lacustrine Deposits

Lacustrine deposits like those of the Lingos Formation and Bottomless Lakes occupy discrete subsidence basins across the southern Great Plains and range in age from Late Miocene through Quaternary. These deposits preserve an extensive paleobiota, including fossil vertebrates, ostracods, insects, mollusks, diatoms, pollen, plant fragments, and trace fossils (tracks). The type Clarendonian, Hemphillian,

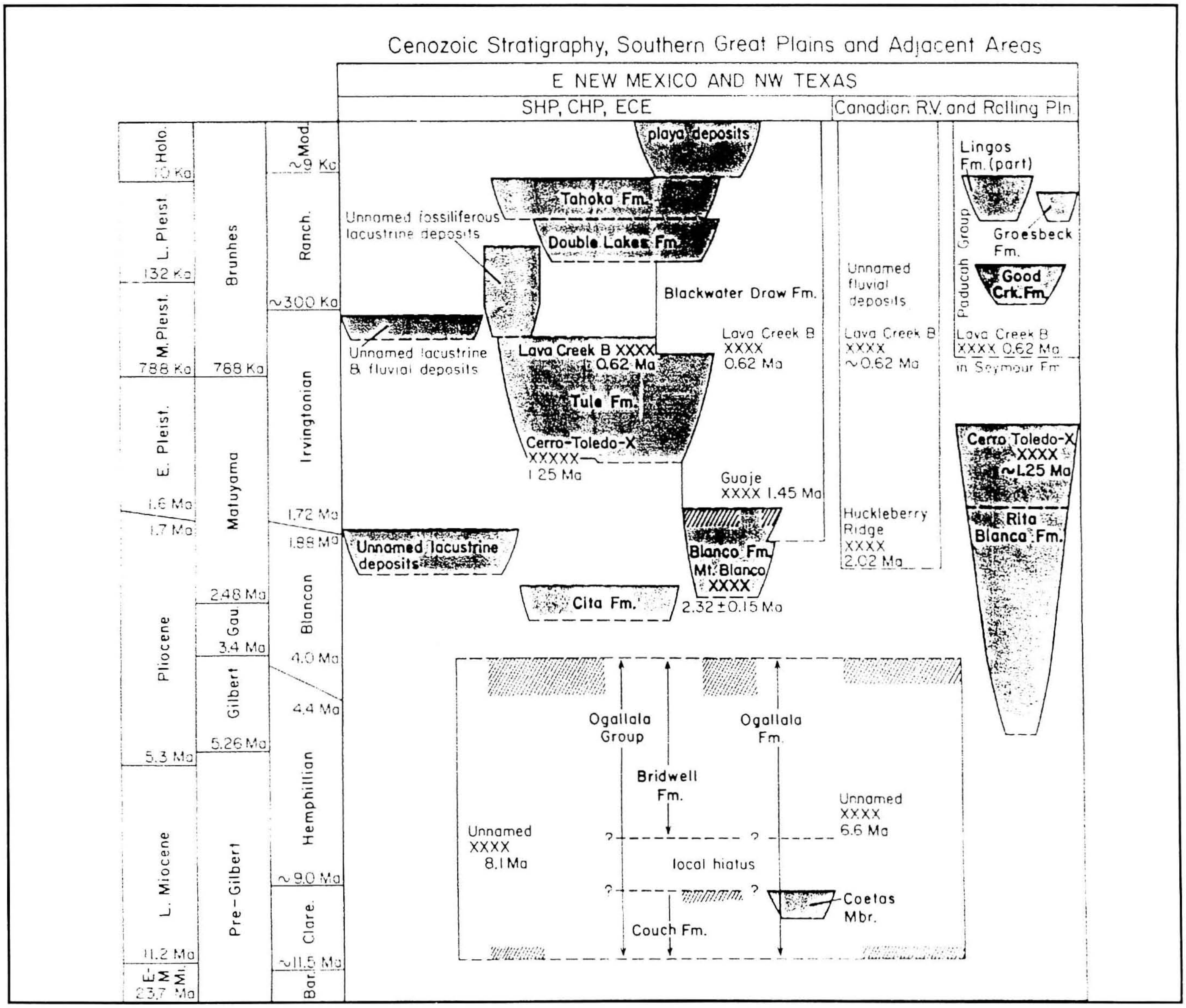

Figure 21. Upper Cenozoic stratigraphy of the southern Great Plains. Shaded symbols denote lacustrine deposits. Unshaded blocks represent fluvial and/or eolian deposits. Volcanic ash deposits are indicated by rows of Xs. Geographic abbreviations: SHP=Southern High Plains; CHP=Central High Plains; ECE=Eastern Caprock Escarpment; R.V.=River Valley; Pln.=Plains. Cenozoic stratigraphy of this region is treated in greater detail by Caran (1991).

and Blancan North American Land-Mammal Faunas were recovered from these lacustrine lithofacies and associated strata. Some of the lacustrine deposits also provide evidence of early man in North America. These faunas and cultural remains are important paleoclimatic and biochronologic indicators. Additional chronologic control is afforded by tephrochronology (seven dated volcanic ash deposits) and magnetostratigraphy. Excellent chronologic control, continuous deposition, and a 10,000,000 yr composite stratigraphic record provide a premier paleoenvironmental data base.

Research Applications

The current research program explores the origin and development of ground-water sustained lakes, which constitute a newly recognized class among nonmarine depositional environments. Investigations at exposures of Upper Cenozoic lacustrine deposits in the Texas Panhandle and at selected lakes in Texas and New Mexico provide much of the data for this study. Potential benefits of this research include improved understanding of: regional stratigraphy; karstic subsidence, a significant natural hazard; compartmentalization of regional aquifers as a result of karstic subsidence; ground-water contributions to lake hydrology; and Late Cenozoic paleoenvironment of the southern Great Plains.

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Geologic Leveling Survey in Logsdon River, Mammoth Cave

by Arthur N. Palmer and Margaret V. Palmer

In June, 1992, the geologic mapping of Mammoth Cave was extended to Logsdon River from the Doyel Valley entrance. Approximately 1 km of passage was surveyed with a tripod-mounted surveyor's level (Lietz C-2) and metric rod. The instrument had been carefully calibrated at the surface in closed loops, to allow each vertical reading to be adjusted by a correction factor dependent on the length of the shot. The homemade segmented rod had a swivel base to prevent embedding into floor sediment while being rotated, and a triangular spiked base that ensured a solid stance. Vertical readings were made to the nearest 0.5 mm. SUUNTO compass bearings and lengths obtained from stadia readings allowed the horizontal coordinates to be calculated. Although there are no closed loops in the survey as yet, loop errors with this system in other caves average about 3 mm/km in the vertical coordinate and about 1-2 m/km in the horizontal. At each station, vertical measurements were made from the station to the floor, ceiling, geologic features, and water levels (if any). Many thanks to Richard Zopf for running the level instrument and to Rick Olson for operating the compass and rod. The survey to date extends upstream to Strange Falls and downstream to the large Amos Hawkins Formation.

The Doyel Valley drill hole is located in the Fredonia Member of the Ste. Genevieve Limestone. The Lost River Chert Bed is visible only as a 3-meter-thick zone of scattered nodules in the walls of the route that descends from the borehole to the river. The ceiling of the mapped section of the river passage lies at or just below a thin but persistent chert bed about 3 m below the Lost River Chert (see Palmer, 1981, p. 62). The floor extends varied distances into a thick sequence of lenticular chert alternating with limestone and dolomite (Corydon Chert). This chert lies 5.2-6.7 m below the base of the Lost River Chert and comprises at least part of the floor in most of the surveyed areas. The passage shows considerable discordance to all cherts, and although local perching is evident, the overall importance of the chert in determining the passage level is questionable. The chief control on the passage seems to be a major bedding-plane parting, which coincides with the uppermost extent of the Corydon Chert. The stream has entrenched several meters below this horizon in the downstream parts of the survey. Still farther downstream, in the pits that connect with Procter Cave, the passage floor lies several tens of meters lower in the section. The surveyed passages occupy the same beds as Bransford East and Mystic River, and many of the lowest stream passages of Roppel and Fisher Ridge Caves. The Hawkins River sump, below Procter Cave, is stratigraphically lower than any other point yet observed in the Mammoth Cave System.

As with the geologic surveys elsewhere in the cave, one of the major goals was to determine the relationship of the river passage to the geologic structure. One technique is to contour the elevation of the dominant controlling beds or bedding planes and compare the resulting structural map to the trend of the passage. Precise measurements to the dominant parting were difficult because it was deeply recessed into the wall in many places and somewhat irregular in others. Therefore, to prepare the structural map, all stratigraphic measurements were adjusted upward or downward to the top of the thin chert bed between the Lost River and Corydon cherts. This horizon has no particular speleogenetic significance, but it is easily mapped in many parts of the cave.

The problem with contouring structural data from cave surveys is that so few nearby passages occupy the same strata. The small-scale irregularities of structure that may control passage trends are difficult to determine, since the distribution of data points is so nearly linear. The geologic structure would be far clearer if it were possible to crawl off into the solid limestone to examine the beds around the passages, not just within them.

The best way to contour structural data is by hand, because one's knowledge of geologic processes can help guide the contours where data points are absent. The easiest and most objective method is to feed all the coordinates into a contouring software package. Figure 22 shows the structural map of the surveyed part of the river passage drawn by the program SURFER (copyright Golden Software Inc., Golden, CO). Grid calculations were made with the inverse-distance method, one of several statistical routines for contouring. Other choices (e.g., kriging and minimum curvature) give crudely similar results, but the inverse-distance results most resembled the structural features we have mapped in more detail in other parts of the system.

The contour map shows a northwesterly dip of 5.25 m/km, which is about average for the Mammoth Cave Quadrangle. However, the dip is interrupted by a broad, gentle structural basin in the vicinity of the Doyel Valley entrance. This structure is rather common in our mapping data. Small basins of this sort appear to be depositional or compactional irregularities; the larger ones are caused by tectonic deformation. There is not enough information here to distinguish between the two. Note that the magnitude of the structure is overemphasized by the tiny 20-cm contour interval.

The structural influence on the passage is clear. The original cave-forming water was strongly dip oriented, as shown by the trend down the steepest available component of the dip in the upstream and downstream segments. Where it flowed into the basin (confined to the guiding bedding-plane parting), ponding occurred, and the down-dip orientation was lost. The main flow path wandered along the axis of the basin for several hundred meters, escaped over the northwestern threshold, and then continued on down the dip. Gravity was the main force controlling the flow. The passage was therefore strongly vadose in origin, despite its rather tubular shape. Local ponding in structural traps caused deflections from the down-dip direction. But as the passage began to grow, the threshold of the basin (presumably the lowest available outlet for the water) was probably breached very quickly by the stream; but by that time the passage had acquired its basic form and was able to enlarge with only minor concern for geologic structure. The structure imposed its control mainly over the initial flow, and that influence has been inherited by the large passage we see today. It will be instructive to see what happens to the structural interpretation as more of the passage and its tributaries are surveyed.

Although this interpretation is probably valid, it is important not to take details of the contour map too seriously. The computer draws contour lines on the

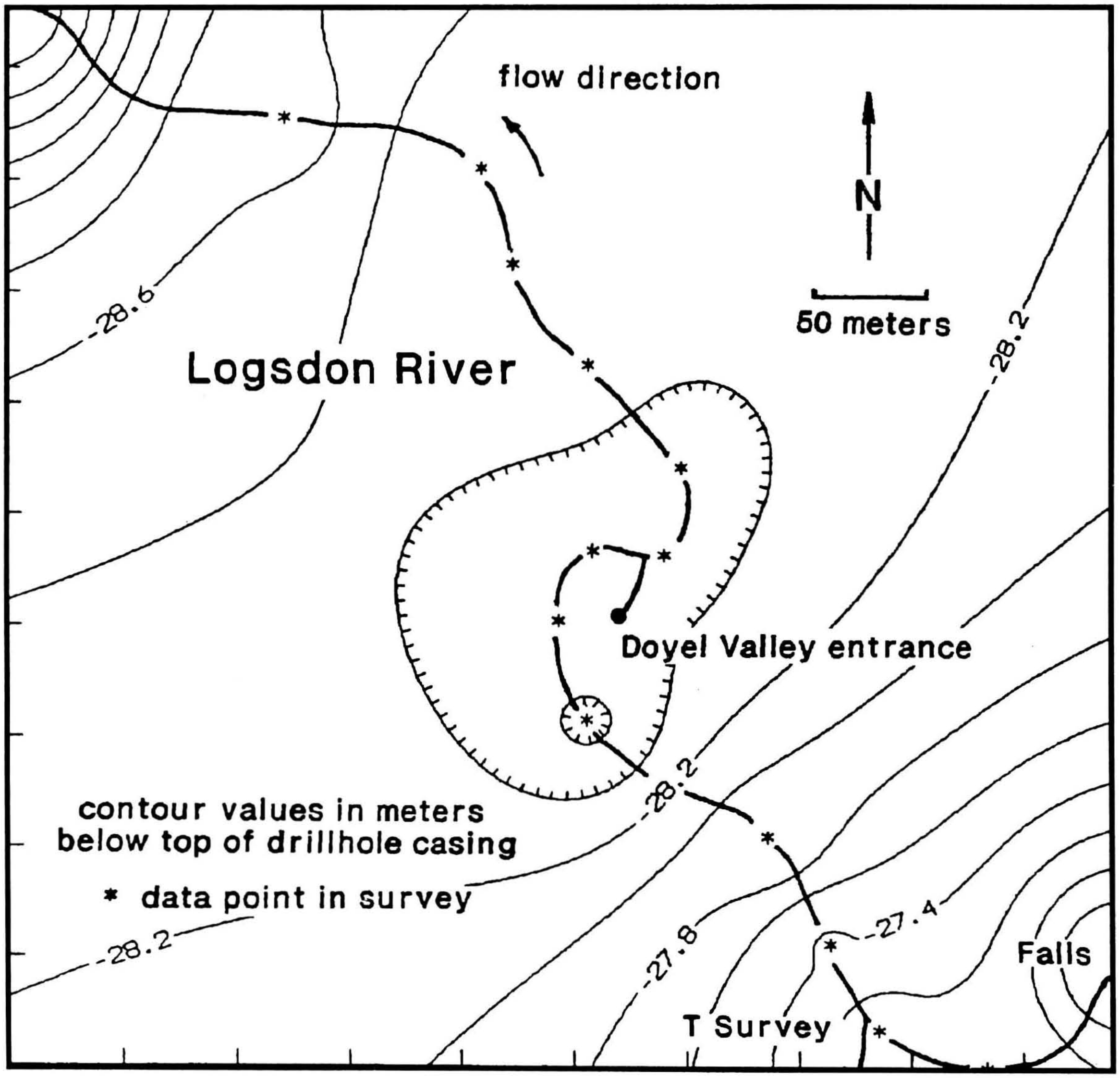

Figure 22: Structural contour map of part of Logsdon River, Mammoth Cave, showing relationship of passage orientation to local dip. Structural datum is the top of the thin chert bed below Lost River Chert Bed. Contours were computed with inverse-distance method from leveling survey data. See text for explanation and cautionary notes.

basis of average trends within the data. Lines are able to wander boldly into regions with no data because they are determined by a statistical examination of trends in all the known points on the map. Real geologic structures do not behave like that. They are controlled by such things as water currents in the original sea, and by relative strengths and weaknesses in the rocks during deformation. That is why a hand-drawn contour map, guided by intuition, is usually superior to computer-generated ones.

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ECOLOGY

Survey of the Ferns of Selected Lava Tube Entrances in Lava Beds National Monument

by Christopher M. Richard, Alan R. Smith, and C. Don MacNeill

STATEMENT OF PROBLEM

The cave-entrance and sink microhabitats in the Lava Beds National Monument (LABE) harbor a remarkable fern flora within the Modoc Plateau. Fern occurrences are routinely recorded in the CRF General Cave Resources Inventory, but these data do not record the diversity of fern populations. Most inventory work occurs in winter, when the dominant fern species is dormant and very easily overlooked by persons not specifically trained in fern recognition. Also, many fern specimens at the LABE herbarium, and consequently in the Plants of the Lava Beds National Monument Field Checklist (Hathaway, 1985), were misidentified.

The goals of this study are to produce an accurate survey of the ferns of selected caves in LABE, and to provide instructional materials for fern recognition. Concomitantly, research specimens have been placed in herbaria at LABE, U.C. Berkeley, and the Oakland Museum.

METHODS

Survey sites were all caves reported to have ferns by prior collections, or reports by staff of LABE or CRF. However, Jack William Cave, the site of an earlier *Dryopteris arguta* collection, remains unreexamined because at the time of our survey no one knew the cave's location.

A qualitative survey of each site was made in June 1992. Fern species were photographed *in situ*, and collections of each fern species made. The Staff of the University Herbarium and the Oakland Museum prepared the collections per standard herbarium practice. Specimens were distributed to the participating institutions. Multiple sets of photocopies were made from the collected specimens.

ANALYSIS OF FERN SPECIES

Adiantum capillus-veneris (Southern maidenhair fern)

We found a plant on the north wall of Fossil Cave, about 4 meters above the floor of the cave. This is the first collection of this species in LABE or Siskiyou County. This locality is about 240 km north of the nearest known population, which is in Butte County (Smith *et al.*, 1993). The basalt substrate is remarkable as typically this fern grows on limestone.

Cheilanthes gracillima (Lace fern)

We found a single clump on the lip of Blue Grotto Cave. It is the first record from LABE; however, it is known locally from near Medicine Lake and in the Big Valley Mountains in Modoc County (Smith *et al.*, 1993)

Cystopteris fragilis (Fragile fern)

It is the most frequently occurring fern in LABE, found on the lips of many caves, along the walls of collapse trenches, and in one case (Lava Channel Cave) in sandy soil. However, three specimens from the LABE museum labeled *C. fragilis* were determined to be misidentified. In fact, they are two *Woodsia* species.

Dryopteris arguta (Coastal wood fern)

The only record of this fern from LABE is a specimen in the LABE museum, by an unknown collector, in July 1940, from Jack William Cave. The nearest known localities are in Humboldt Co., more than 200 km distant (Smith *et al.*, 1993). We were unable to relocate Jack William Cave.

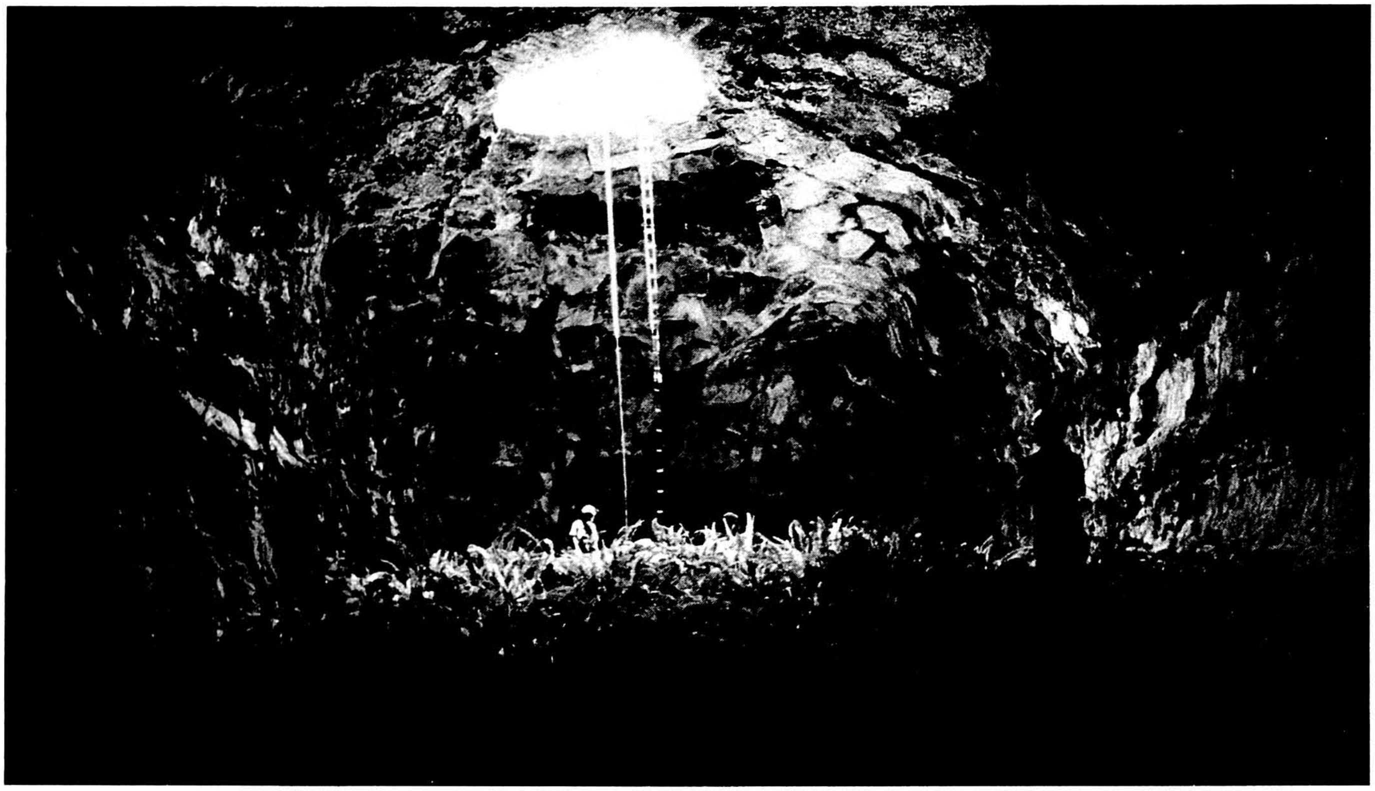

Figure 23: *Polystichum munitum* and *Dryopteris expansa* growing in the entrance breakdown area of Fossil Cave in LABE. (*Photo by Christopher Richard*).

Dryopteris expansa (Spreading wood fern)

This species was in the collection at LABE under the obsolete name *D. austriaca*, given by Erhard. Presumably the *D. expansa* entry in "Plants of the Lava Beds National Monument Field Checklist" (Hathaway, 1985) represents this specimen. This species has not been reported from LABE in the botanical literature (Smith *et al.*, 1993). We collected it at Fossil Cave and Fern Cave. LABE represents a range extension of ca. 200 km from the nearest known localities in coastal Humboldt and Del Norte Counties (Smith *et al.*, 1993).

Pentagramma triangularis (Goldback fern)

Reported by various surveys from Fern, Valentine, and The Fool Katcher Caves. Nearest known localities are over 100 km to the west (Smith *et al.*, 1993). We found it on the lips of The Fool Katcher and Fern Caves, but did not search at Valentine Cave.

Polystichum munitum (Western sword fern)

We collected *P. munitum* in Chest Cave, where it was the only fern seen, and in Fossil Cave (Figure 23) where it is the most abundant fern, growing lushly to 1.5 m. It was collected at Fern Cave by Erhard (1979), however, we did not find this large species there in 1992. Nearest known site is 120 km to the west (Smith *et al.*, 1993)

Woodsia oregana (Western Cliff Fern)

Applegate (1936) collected this species at Fern Cave, misidentifying the specimen deposited at LABE as *Cystopteris fragilis*. This study found *W. oregana* at Garden Bridge and Hercules' Leg Caves, and a surface tube near Thunderbolt. We did not find this species growing at Fern Cave, as Applegate had.

Woodsia scopulina (Mountain Cliff Fern)

Numerous plants were found, still verdant, growing in the sink and entrance area of Kirk White Cave, where Erhard (1978) reported it. A search of surrounding caves and breakdown trenches yielded no other specimens. Applegate (1936) collected this species from Lava Cliffs at the south boundary of LABE, misidentifying the specimen deposited at LABE as *Cystopteris fragilis*.

Summary

While our original intent was limited to resolving species identification ambiguities, and providing educational materials to CRF and LABE, this study made a significant contribution to the knowledge of fern distributions in California. Three species have been added to LABE's known flora, two by collection, one by redetermination. Two more species have updated synonymy. Five species are being newly reported in the primary literature as occurring in LABE; three are range extensions of over 200 km.

Since our field survey, two new caves have been discovered to have fern populations. Plants have been tentatively identified as *Polystichum* and *Dryopteris*. Jack William Cave, the only known site for *D. arguta* in LABE, has been relocated. We hope to explore these locations in 1993.

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Arthropod Communities Associated with Indiana Woodrat Caves

by Julian J. Lewis

The complexity of terrestrial cave communities relies on a number of circumstances including availability of food, water, suitable habitat, a source of the fauna itself and interactions between the members of the community. In Indiana, the absence of large summer bat colonies or the cave cricket *Hadenoecus* denies caves rich sources of guano that are present in some caves of adjacent states. However, Indiana lies within the northern part of the range of the Eastern Woodrat *Neotoma floridana*. This docile mammal, also known (perhaps more appropriately) as the Cave Rat or Pack Rat, imports large quantities of material into caves for its nests including items of aesthetic interest to the rat such as gum wrappers, cigarette packages, flash bulbs or bones. The woodrat's latrine areas also provide rich oases of nutrients in what would otherwise be barren, food-poor habitats.

In 1992 Dr. Kenneth Christiansen requested that I attempt to obtain more specimens of an undescribed, troglobitic species of the collembolan *Pseudosinella* that I had found at Big Mouth Cave (Harrison County) in the 1970's. The cave's large entrance provides a superb view of both the Ohio River, as well as the entire cave, which is essentially a single breakdown-filled room only 117 feet long. Little Mouth Cave, directly above Big Mouth Cave in the river bluffs, is highly decorated for its 325 feet of surveyed passage. Unknown to me during my visit 20 years prior, Big Mouth and Little Mouth caves are two of only three sites where the woodrat is known to occur in Indiana caves (Black, 1992).

With this knowledge in hand, Big Mouth and Little Mouth caves were revisited, along with the third woodrat site, Potato Run Cave. All three of these caves have entrances opening onto forest covered, limestone bluffs. None of the caves contain an active stream, although pools of water are present in Little Mouth and Potato Run caves.

The assemblage of terrestrial arthropods present in these caves was remarkable by Indiana standards. In Potato Run Cave, there is a nearly continuous belt of leaves, sticks, droppings, etc. from the entrance to the end of the 127 foot long cave. About midway through the cave occurs a flowstone bridge on which was a mixture of leaves and rat droppings that had been moistened by seepage. In this area were found numerous of the *Pseudosinella* along with other collembola. Several individuals of the troglobitic millipede *Pseudotremia indianae* were browsing in the leaf litter. What was striking about the assemblage, however, was the simultaneous presence of three arachnids: the harvestman *Erebomaster*, spider *Phanetta subterranea* and an unidentified pseudoscorpion, possibly *Hesperochernes*. At Big Mouth cave the fauna also included the troglophilic millipede *Cambala minor*, psocids, and unidentified staphylinid beetles and flies.

The presence of these relatively complex terrestrial arthropod communities in association with woodrat nest sites is an interesting discovery. Further work will be conducted to delineate the structure of the communities in these caves.

Acknowledgements

This work was funded by a grant from the Indiana Department of Natural Resources. The following individuals have provided field assistance: Gary Tongate, Adam Tongate, James Lewis, Victor Lewis and Ashley Tilford.

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

by Mick Sutton

By the end of 1992, the first phase of this southern Missouri mapping and inventory project was complete (for background, see Annual Reports for 1990 and 1991). The study area covered 90 square miles north of the Eleven Point River in Oregon and Shannon Counties. Forty-two caves were known within this area and sixteen additional caves were located during the course of the study. Twenty caves had been inventoried for cave fauna previously (Gardner, 1986); nine of these were revisited and thirty additional caves were inventoried. Maps existed for 17 caves; two of these were remapped and 29 others were mapped, ranging in length from 4.5 m to 2.0 km, and totalling 7.2 km of passage. A small but significant portion of the total was previously unentered passage. Thirty-five JVs took part in the study.

The study area consists mainly of uplands and upland valleys covered with well-drained oak-hickory forests. The geology and hydrology have been discussed in detail by Aley (1975). The terrain is a subsoil fluviokarst consisting of spring-fed rivers separated by uplands mantled with deep residuum and dissected by steep-sided valleys. The surface relief is about 120 m, but trunk conduits extend below baselevel for at least 100 m. The surface is underlain by gently dipping dolomites, sandstones, and cherts of Lower Ordovician age. The dolomites crop out as bluffs along the Eleven Point River and its tributaries. The upland valleys carry surface flow only for short periods following rain; most water is transported through the residuum to discrete subsurface channels. Groundwater flow does not generally follow surface drainage patterns; some of the groundwater from the study area enters the Eleven Point River via a series of alluviated and gravity springs, but groundwater also flows to Big Spring on the Current River.

The groundwater channels feed deep trunk conduits which enter the rivers via rise tubes. These enormous vauclusian springs are famous for their size and beauty. Big Spring is one of the largest springs in North America. Greer Spring, the third largest in the Ozarks, is south of the Eleven Point River, but its basin extends north of the river, possibly into the study area. The land surface occasionally intersects groundwater streams in the vadose regime, giving rise to gravity springs which provide entry points into stream caves. The spring branches flow for short distances before the water sinks again into the alluvium, which bars access into the downstream conduits. Other vadose channels have been intersected by the Eleven Point, giving access to stream caves feeding short spring branches which flow directly into the river. Other caves are hydrological relicts, left high and dry by diversion of the waters which once flowed through them. Some of these have been re-invaded by secondary streams.

The caves are generally simple dendritic stream networks, with only modest vertical development—the largest vertical range is 43 m in Kelly Hollow Cave. (Kelly Hollow Cave is a special case, where a typical upland cave stream is entered not through a spring, but partway along its course—the downstream end is blocked with gravel). Three-dimensional complexity is generally lacking, and overlapping passage levels are rare. An exception is Barrett Spring Cave (Figure 24), which is structurally complex, with two or three superimposed levels. Chert beds interspersed with the massive dolomites control passage elevations. Falling Spring, which cascades from 6 m up a bluff, is a good example—the entire cave is held up on a 1 m thick bed of chert. Most chert beds are thinner, and generally form the lips of small cascades within the caves. Structural control of passage orientation is common, as indicated by linear passage segments with abrupt bends; many passages are developed along joints or possibly faults. But the majority of passages are developed along bedding plane partings; Falling Spring, with many high-amplitude meander loops, is a striking example.

Some of the dry caves lack a dark zone. Many of these are small shelters, probably formed along bedding planes by high-water from creeks or rivers; others are fragments of small abandoned channels. Many of them are high on the hillsides. The caves house twilight zone fauna but can also include cave adapted taxa—Tusher Hill Cave, for example, is the only known site for a new troglobitic pseudoscorpion. The dry caves may house complex decomposer communities, sometimes including rare cave-adapted taxa such as the two species of troglophilic spider found in Many Springs Cave. There may also be drip pools containing amphipods. A few caves have intermittent streams; these do not have usually have aquatic communities, but the intermittent streams could be an effective conduit for introducing pollutants. The terrestrial communities may be highly significant, as in the case of a gray bat maternity colony in Thrasher Ford Cave.

Most of the cave streams probably originate in cryptic sinkholes buried in the residuum. The sinks receive diffuse input water from the overlying residuum and are not open enough to allow the input of coarse material. As a result, almost all of the streams are low in nutrients, and aquatic communities are sparse and highly cave adapted. A small but interesting class of stream caves are sub-valley drains, entered through intermittent rise tubes, with passages in transition from phreatic to vadose flow regimes. They are subject to frequent flooding, and fine sediments predominate. At least two caves south of the river, Dead Man and Greer Spring, may represent outputs from deep, permanently flooded channels. Another interesting class are stream piracy caves, which provide shortcuts through drainage divides. Clear examples are Cropper, Statue, and Blowing Spring Caves. In each case, the farthest humanly penetrable point is directly below the bed of a dry valley tributary to the stream into which the spring debouches.

Figure 24: Entrance to Barrett spring. (*Photo by Mick Sutton*).

Habitats and Communities

The cave communities are based on the decomposition of introduced materials. The bases of the food chains are microbial, but the identification of fungal and bacterial material were beyond the scope of this study. The presence of filamentous (bacterial?) mats was occasionally observed in streams, where their presence indicates an aquatic environment more nutrient enriched than normal. Fungal mycelia and fruiting bodies were commonly observed on all sufficiently moist organic materials, especially wood and dung.

Twilight Zone—Although these communities usually consist of species not especially adapted to cave life, there are important exceptions. The federally listed Indiana bat is critically dependent on twilight zones with cold-trap configurations. No such caves are known within the study area, but two candidate sites need to be examined in winter. Big brown bats also hibernate in cool twilight zones. Mosquitos shelter in the twilight zone of every cave examined, and *Ceuthophilus sp.* cave crickets are common. Less frequently encountered are terrestrial isopods (which include somewhat cave adapted species), terrestrial snails, heleomyzid flies, noctuid moths, and pipistrelles. The eastern wood rat, a species on the Missouri watch list, is dependent on the twilight zone. A great deal of wood and leaf litter is introduced by these animals, supporting a decomposer community featuring non cave-adapted springtails. Input of dung is provided by wood rats, raccoons, and other mammalian visitors.

The guano decomposer communities resemble those of the deep cave but have fewer troglobites (e.g. *Oxidus gracilis* millipedes rather than *Tingupa pallida*), and have a richer diversity of predato.s, including accidental or trogloxenic species such as histerid beetles and agelenid spiders. The most prominent vertebrate predator, feeding primarily on flies, is the cave salamander—although this species is found in deep cave sites, the twilight zone appears to be its primary habitat. Free-flowing streams within the twilight zone typically have troglophilic amphipods, usually *Crangonyx forbesi*, a species which extends some way into the dark zone. Salamanders and their larvae are often seen, and epigean isopods (*Lirceus sp.*) are occasionally found.

Dark zone—*Terrestrial:* This is by far the most extensive habitat, consisting of bedrock walls and ceilings, and floors which are generally covered with fine sediments. The humidity is uniformly high. The habitat is extremely patchy. Free-ranging cavernicoles occur at very low densities throughout, with decomposer communities localized around discrete food sources. Species using the dark zone primarily for shelter include pipistrelles, widely distributed but much more common in some caves than in others, cave crickets, and heleomyzid flies. Crickets are more common in the twilight zone, heleomyzids more common in the dark zone, but neither extend far into the dark zone. Pickerel frogs shelter in both aquatic and terrestrial habitat.

The main food supplies are dung from raccoons and other mammalian visitors, wooden debris introduced by beavers (and to a lesser extent humans), and gray bat guano from colonies which inhabit three caves. Beaver activity in caves has rarely been commented on, but they are a highly significant factor in the ecology of caves within the study area, and probably throughout the Ozarks. Rarer localized food sources include corpses. Pipistrelles and cave crickets introduce small quantities of unlocalized guano. Localized food sources may be extensive, as in the case of gray bat guano piles, or raccoon latrine areas.

Decomposer community species appear to be generalists; the same mix of species occurs in both dung and wooden debris. The clearest distinction was that the common fungus beetle *Ptomophagus cavernicola* was far more likely to be collected from dung and carrion than from wood. Fungivores form the base of the invertebrate food chain. These include Oribatid mites and a wide variety of springtails, including common surface forms, the troglophiles *Folsomia candida*, *Arrhopalites pygmaeus*, and *Tomocerus flavescens,* and troglobites such as the rare *Pseudosinella espana* and undescribed species of *Onychiurus*. Larger detritus feeders usually include the troglobitic millipede *Tingupa. pallida*, the troglophilic fungus beetle *Ptomophagus cavernicola*, the tiny troglobitic fly *Spelobia tenebrarum*, an unidentified phorid fly, sciarid fungus gnats, and various fly larvae. Somewhat wider ranging but usually seen in the vicinity of food sources are troglobitic diplurans. The predators include an interesting assemblage of mites from the families Laelapidae, Parasitidae, and Rhagidiidae, the pseudoscorpion *Hesperochernes occidentalis*, the small rove beetle *Atheta troglophila*, occasional larger rove beetles, *Quedius erythrogaster,* and rove beetle larvae. The predatory fungus-gnat larva *Macrocera nobilis* builds webs in the general vicinity of food sources. Larger, wide-ranging predators are the cave, grotto, and long-tailed salamanders. Of these, the primary dark-zone terrestrial predator is probably the troglobitic grotto salamander. It competes with the cave salamander, which overlaps from the twilight zone into deep cave sites.

The gray bat guano communities are distinctive, consisting of a variety of fungivorous mites of the groups Oribatida, Laelapidae, Dithinozerconidae, and Pygmephoridae, large numbers of fungus gnat larvae of the family Sciaridae, and lower numbers of troglophilic springtails (*Arrhopalites pygmaeus*). The most conspicuous predator was the pseudoscorpion *Hesperochernes occidentalis*, present in far larger numbers than in other organic material. A correlation between gray bat caves and grotto salamander populations has been observed elsewhere (e.g. Johnson, 1987), but this seems not to be the case within the study area. Grotto salamanders, although present in the gray bat caves, are not especially prevalent there, while the largest population of grotto salamanders was in a small non-bat cave, Dobbs Spring.

Dark Zone*—Aquatic:* Most of the cave streams have low levels of nutrients and the communities consist of small numbers of a few cave adapted species. Even within these limitations, the community makeups are remarkably diverse. Like the terrestrial habitat, the stream habitat is patchy; within the same stream, superficially similar riffles or pools may have very different population densities.

The most prevalent detritivore is the troglobitic isopod *Caecidotea antricola,* a common Ozark endemic present in almost all of the stream caves. Troglobitic amphipods (*Stygobromus onondagaensis* or a closely related undescribed species) are very sparse but widespread; both these species are Ozark endemics of limited range, and are on the Missouri watch list. Amphipods and isopods were observed far more often in the short stretches of rocky and gravelly riffles than in pools with finer sediments. Amphipods were occasionally observed in mud or sand bottomed pools, where they can escape predation by burrowing, including predation by cave biologists—hence, their presence in this habitat may be understated. The troglobitic amphipods are confined to deep cave sites. Near-entrance communities may or may not include the troglophilic amphipod *Crangonyx forbesi.* These extend into the dark zone, but do not penetrate farther than 50 m or so upstream from an entrance. The principle predators are salamander larvae and adults, primarily long-tailed salamanders. Salamander numbers vary greatly; Walters Spring Cave is noteworthy for its exceptionally large population of long-tailed salamanders.

Other species may be added to this mix. The tiny troglophilic snail *Fontigens aldrichi* appears in two streams. Large omnivores and predators, respectively the crayfish *Cambarus hubrichti* and the southern cave fish *Typhlichthys subterraneus*, are found at some sites. Both species usually inhabit deeper pools. Some of the streams with fish or crayfish are enriched with bat guano (Dead Man, Turner Spring) while others (Greer Spring, Falling Spring, Posy Spring (Figure 25)) are not. Interesting nutrient enriched streams occur in the two Adams Caves, where small streams are almost choked with beaver den debris, leading to an aquatic community based on large numbers of troglophilic amphipods and much smaller numbers of troglobitic isopods, together with large populations of salamander larvae and predatory diving beetles (*Agabus sp.*).

Drip Pools which are isolated from stream channels occasionally contain troglobitic amphipods, usually *Stygobromus onondagaensis* or *n.sp.* but in two cases a rare undescribed species of *Bactrurus* was found. Most of the pools were tiny with often only a single amphipod present. Presumably, the amphipods are entering the cave via the feeder drips from overlying flooded or partly flooded channels. This

Figure 25: Entrance to Posy Spring Cave, Oregon Co., Missouri. (*Photo by Mick Sutton*).

habitat is evidently not continuous, since in any particular cave only one of the three species turns up in the drip pools. Cropper Cave has a unique stream community, which includes troglobitic crayfish and banded sculpins, a fish which appears to be somewhat cave adapted.

Environmental Concerns

Of major concern is the potential for damage to the groundwater quality in one of the most highly karstic areas in Missouri. If the present round of mineral exploration leads to lead and zinc mining, cave ecosystems might be threatened in several ways. Spills of lead ore and toxic ore processing chemicals could result in rapid contamination of subsurface streams. Mine dewatering activity can readily disrupt natural flow patterns, draining some channels and overloading others with water which may contain high levels of toxins. It is difficult to envision a failure-proof tailings pond within the study area, since all of the upland valleys are drained by subsurface channels into which water flows via cryptic sinks filled with coarse alluvium. Failure of the bottom of a tailings pond would result in massive siltation of aquatic habitat, and long-term contamination with metals.

Sinkhole collapses in karstic regions have been correlated with mine dewatering; for example, several catastrophic collapses and many subsidences were recorded in association with gold mining in Far West Rand, South Africa, in an area underlain by a thick residuum mantle on top of dolomite interbedded with chert, a setting strikingly similar to the study area. (Brink *et al*, 1969). Amongst other deleterious effects, the potential for sinkhole collapse threatens a rare, biologically important karstic feature—the sinkhole pond.

The potential for damage is especially high because the general area overlies the major trunk conduits of the largest subterranean rivers in Missouri, and probably in North America. The geological factors (which probably include deep-seated, long-range fracture zones) that have permitted the development of this unique concentration of trunk groundwater streams may also provide ready paths for the introduction of contaminants into those streams. While the trunk rivers are of concern, the other end of the hydrological system is at least as important. Culver & Fong (1991) note that "from an ecological perspective, the entire upstream portion of a drainage needs protection to minimize chances of extinction due to groundwater contamination. From an evolutionary perspective the entire drainage system needs protection in order to maintain the integrity of the gene pool. Implications for cave protection include increased emphasis on upstream sections of cave drainages...and increased emphasis on aquifer protection.".

Although the threat to the terrestrial habitat is less immediate, it cannot be discounted. For example, bats foraging over tailings ponds might be prone to lead uptake from ingesting contaminated insects. If industrialization leads to a human population increase, increased cave visitation may result. The caves are in generally good to excellent condition, largely because they are remote from population centers, are not well known, and have not received much visitation. Those caves such as Kelly Hollow which are better known are suffering the usual effects of vandalism. .

Acknowledgements

Agencies cooperating in this project were the Mark Twain National Forest, U. S. Environmental Protection Agency, U. S. Fish and Wildlife Service, Ozark National Scenic Riverways, Missouri Department of Natural Resources, Missouri Department of Conservation, and Missouri Speleological Survey, Inc. Major funding was provided by the Mark Twain National Forest; additional funding was provided by the U.S. Environmental Protection Agency and the Missouri Speleological Survey.

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Observations on the Distribution and Ecology of *Antroselates spiralis* in Southern Indiana

by Julian J. Lewis and Ann Marie Lewis

In 1963 Leslie Hubricht described the troglobitic snail *Antroselates spiralis* from specimens collected at Echo River Spring, in Mammoth Cave National Park (MCNP). Besides the type-locality, this species was also listed from Echo River in Mammoth Cave, a cave and spring in Cedar Sink (MCNP) and Sibert's Well Cave, Crawford County, Indiana.

In 1992 we received funding from the Indiana Department of Natural Resources to investigate the occurrence of *Antroselates spiralis* in Indiana for possible addition of the snail to the state's list of threatened and endangered species. This study included two parts: (1) bimonthly census of the Sibert's Well Cave stream community to establish the population level of the snail, and (2) reconnaissance of other Indiana caves and springs in search of other populations of the snail.

Sibert's Well Cave is found at the base of the ridge containing the much larger Wyandotte Cave. The cave is entered by climbing down an old stone well casing about ten feet deep. At the bottom, ducking into the cave gives access at about the midpoint of 300 feet of stream passage. The passage ranges from belly crawl to walking height in size. The cave contains the largest stream known under Wyandotte's ridge, but the stream is only a fraction of the size of the snail's habitat in Echo River. A section of the stream downstream from the entrance was chosen for study because it lies beyond a short belly crawl which discourages casual disturbance of the area. The stream in the census area is typically about six feet wide and up to a foot deep. The stream floor is comprised of clay and pebbles, about a dozen larger (greater than 12 inches in length) pieces of breakdown and numerous smaller ones. Downstream a few hundred feet from the enterable passage the stream emerges from a spring on the edge of the Blue River (Figure 26). The enterable cave passage lies approximately 100 feet from the edge of the sewage field receiving waste from the Wyandotte Cave's visitor center on the ridge above (Figure 27).

Figure 26: The entrance to Sibert's Well Cave on 26 December 1992. The forest opening located about 100 feet beyond the entrance is the sewage treatment field for Wyandotte Cave state Recreation Area. (*Photo by J. Lewis*).

Table 1 lists the results of four community censuses that have been conducted since the beginning of the project in October, 1992. Two censuses in Sibert's Well Cave have been performed and have revealed a community which is numerically dominated by the isopod *Caecidotea stygia*, with *Antroselates spiralis* present in smaller numbers. Other species present are the cave fish *Amblyopsis spelaea*, cave crayfish *Orconectes inermis*, an undescribed amphipod *Crangonyx* sp., an unidenti-

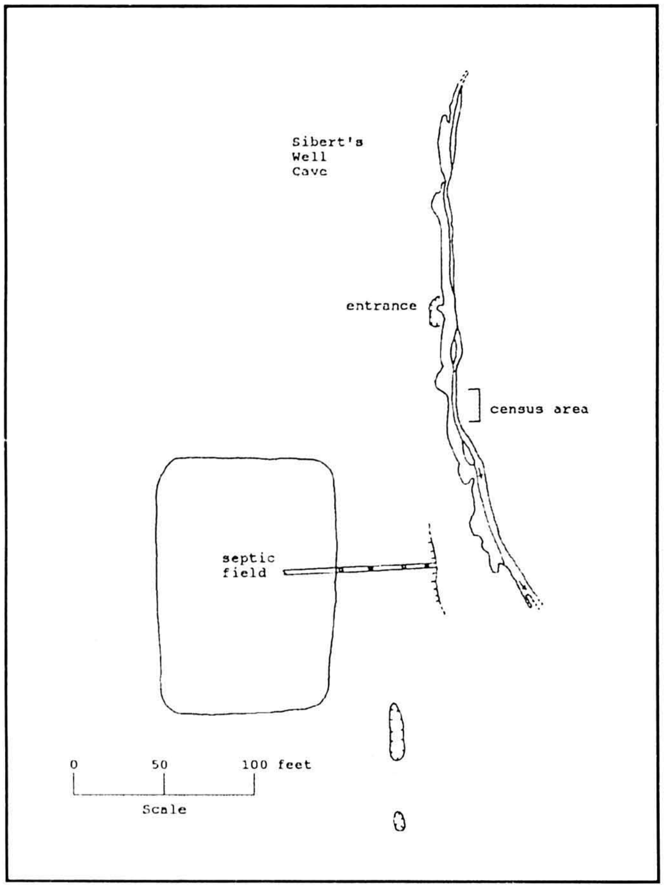

Figure 27: The relationship of Sibert's Well Cave to the septic field receiving waste from the Wyandotte Cave State Recreation Area (cave map by D. Black and D. Dible, M. Lewis, 26 December 1992). The sewage enters the septic field via a pipeline that emerges from the side of the ridge.

fied flatworm, probably *Sphalloplana weingartneri*, sculpin *Cottus* and an unidentified epigean crayfish. The property manager at Wyandotte Caves State Recreation Area, Roger Gleitz, has provided water sampling data indicating coliform bacterial contamination of the cave's stream and a nearby well.

A comparison census taken at the upstream boat landing on Echo River, Mammoth Cave revealed a population of about twice as many of the snails present. All of the snails in both Mammoth and Sibert's Well caves were found on the undersides of pieces of limestone breakdown at least five inches in length (Figure 29). Crawfish Spring, in Wyandotte Cave was also visited to search for the snails. This tiny stream was barely more than a trickle on the day of our visit, but flowed into a long, wide mud-bottomed pool in which troglobitic amphipods *Crangonyx* sp. and the isopod *Caecidotea stygia* were the only species present (*Orconectes inermis* has also been reported from the pool).

Thirty other sites have been searched for *Antroselates* in Harrison, Crawford and Washington counties. These sites included a variety of aquatic habitats including various size cave streams, springs, drip pools, rimstone pools and isolated mud-bottomed pools. *Antroselates spiralis* has been discovered at four new localities (Figure 28): (1) Sharpe Spring Cave, (2) Firetail Spring, (3) Harrison Cave Spring and (4) Bussabarger's Cave.

The snails were found under breakdown in the spring orifices of Sharpe Spring Cave and Firetail Spring, whose cave passages are accessible only to divers. The snail was most common at Harrison Cave Spring, where there is no access to a cave stream passage (Harrison Cave, above the spring, is short and dry). In Bussabarger's Cave *Antroselates* was found under a piece of breakdown in the stream flowing into the cave's deep terminal pool.

The five known Indiana localities of *Antroselates* are in the lower Blue River drainage. The snails were absent from seemingly suitable habitat in Fredericksburg Cave, in Washington County about 15 miles north of the known populations of *Antroselates*. The search for new populations will continue in caves and springs along Blue River and suitable habitats in the adjacent Indian Creek drainage in Harrison County.

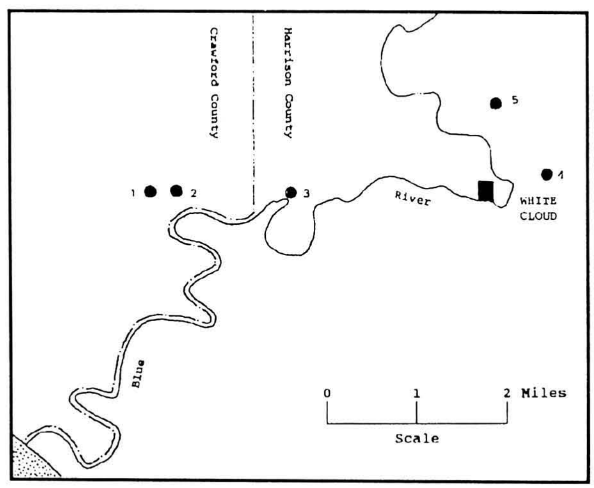

Figure 28: Population localities of Antroselates spiralis in the lower Blue River drainage in Harrison and Crawford counties, Indiana: (1) Sharpe Spring Cave, (2) Sibert's Well Cave, (3) Firetail Spring, (4) Bussabarger's Cave, (5) Harrison Cave Spring.

Figure 29: The stream passage in Sibert's Well Cave. The undersides of pieces of breakdown in the stream pools of this small cave is the preferred habitat of *Antroselates spiralis*. (*Photo by J. Lewis*).

Acknowledgments

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Table 1: Results of census of cave streams in Mammoth Cave, Sibert's Well Cave and Wyandotte Cave.

	Amblyopsis	*Orconectes*	*Caecidotea*	*Antroselates*	*Cottus*	*Crangonyx*
Sibert's Well Cave (20 foot transect)						
10/7/92	1	1	58	8	2	0*
12/7/92	2	1**	28	5	2	1
Wyandotte Cave Crawfish Spring (18.5 foot transect)						
11/5/92	–	0	30	–	–	37
Echo River, Mammoth Cave (20 foot transect)						
10/9/92	0	0	30	17	–	–

* a zero indicates that the species is known to be present in the habitat, but was not present at the time of census.
** unidentified female of an epigean species.

ARCHAEOLOGY

Cave Research Archaeological Project

by Patty Jo Watson

Current archaeological research in Salts Cave and Mammoth Cave is focused upon extending the radiocarbon chronological framework, while also refining our knowledge of the early agricultural system developed and maintained by the prehistoric population who first explored the world's longest cave (see *1991 CRF Annual Report*, and also Mary Kennedy's summary in the November 1992 *CRF Newsletter*, pp. 3-4).

During the 1992 Labor Day Expedition, four of us (M. Kennedy, D. Kluth, E. Monroe, P. Watson) collected 12 human paleofecal specimens for AMS dating and several other analyses. The localities were chosen to maximize our understanding of when indigenous people first entered the cave, which portions of the system were explored at what times, and when they ceased exploring and working there (Table I).

The paleofecal specimens were photographed *in situ* by Dave Kluth, then were taken to Washington University where they were photographed again (in color and black-and-white, one by one, portrait-style) by Fusun Ertug (Figures 30 and 31), before a small portion was removed from each one for AMS dating. The small samples destined for dating were examined by paleo–ethnobotanist Gayle Fritz and biologist Jacky Ng (and, in two cases, manually cleaned of mold by Ng).

Members of the Mammoth Cave National Park Division of Science and Resource Management (Jeff Bradybaugh, Chief; Bob Ward, Cultural Resource Specialist) are collaborating with us, and will finance two of the dates. The rest of the determinations will be paid for by the CRF Archaeological Project with funds

Table 2: Radiocarbon samples being processed at NSF-Arizona, Tucson.

Lab No.	Field No.	Location
AA10079	MCF #1 a (with mold)	Wrights Rotunda
AA10080	MCF #1 b (without mold)	Wrights Rotunda
AA10081	MCF #2	Black Chambers
AA10082	MCF #3A	Jessup Avenue
AA10083	MCF #4	Ganter avenue
AA10084	MCF #5	Ganter Avenue
AA10085	MCF #6	Lower Ganter
AA10086	SCF #1	Middle Salts
AA10087	SCF #2	Upper Salts
AA10088	SCF #3	Upper Salts
AA10089	SCF #4 a (with mold)	Upper Salts
AA10090	SCF #4 b (without mold)	Upper Salts
AA10091	SCF #5	Neville Passage
AA10092	SCF #6	Middle Salts

MCF = Mammoth Feces SCF = Salts Cave Feces

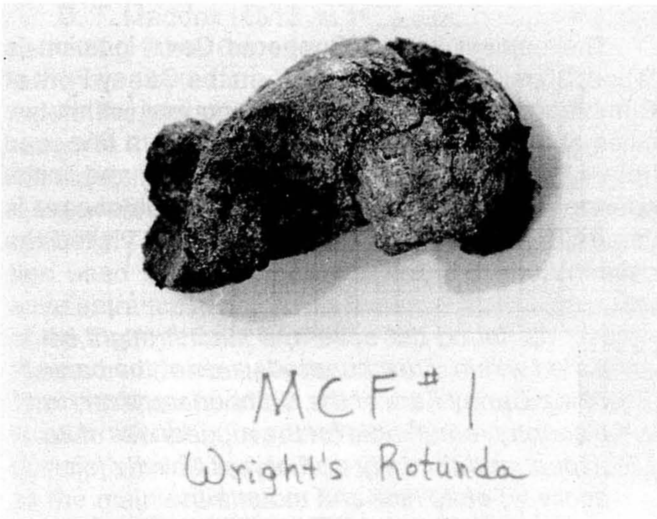

Figure 30: Paleofecal specimen from Wright's Rotunda, Mammoth Cave. (*Photo by F. Ertug*).

Figure 31: Paleofecal specimen from cut-around near Dismal Valley junction Salts Cave. (*Photo by F. Ertug*).

from Washington University and from a contribution to the Project by a private donor, Olga Munsterman. All dating is being carried out at the University of Arizona NSF-AMS facility.

In addition to the dating program, several other analyses aimed at elucidating Terminal Archaic/Early Woodland plant cultivation will take place. Each specimen will be bisected by Ohio State University paleoethnobotanist Kristen Gremillion, and half of each specimen will be curated as a control and voucher sample. The other halves will be analyzed for macrobotanical remains by Gremillion, for parasites by Charles Faulkner (University of Tennessee), for pollen by Kristin Sobolik (University of Maine), and for hormone chemistry by Patricia Whitten (Emory University).

Other activity of CRF Archaeological Project personnel (G. Crothers, M. Kennedy, P. Watson) during 1992 involved consulting and physical support to the photo crew working on the National Geographic Society TV special, *Mysteries Underground*. Crothers, Watson, and Kennedy are also cooperating with Jeff Bradybaugh, Bob Ward, and Ken Tankersley (Illinois State Museum) on an Earthwatch - NPS collaborative project to document and inventory archaeological remains in Mammoth Cave. Once adequate and efficient techniques are devised and implemented by the Earthwatch project, they should be applied to all other parts of the system where archaeological remains are present.

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Search for the Copperas Cave of Mummies, Tennessee

by Angelo I. George

During the pioneer era before 1815, caves out of economic necessity were exploited for saltpeter, alum, epsom salts, copperas, and gypsum. In the course of soil excavation; giant Pleistocene bones, Indian skeletons, mummies, and artifacts were accidently unearthed. Never again would discoveries of this nature, in so great a frequency, and in this quantity be made in caves of the mid-west.

One of these caves "was the vast limestone cavern in Tennessee" (Flint, 1826, p. 126), called Copperas Cave that produced two Indian mummies on September 2, 1810 (Cassedy, 1810). By about the same time in the following year, "many human Bodies have also been found in the Nitre Caves of the Cumberland Mountains similar to that of the Child" mummy just discovered from Short Cave in Kentucky (Clifford, 1811, in George, 1990, p. 68). Copperas Cave would produce six or more mummies prior to 1815 (Cassedy, 1810; Fisk, 1820; and Haywood, 1823). Archaeologically, this nationally prominent cave is probably one of the most important human burial sites in context with perishable grave goods made during the Speculative Period (1661-1847). Search for the Caney Fork Copperas Cave site is the subject of the present investigation.

Marion O. Smith (1988, p. 4) suspected Copperas Cave was actually Johnson Cave, a known saltpeter site in Copper Cave Hollow of DeKalb County. This was the first attempt in 178 years to identify this important mummy cave to a specific recognizable site! The cave entrance was flooded with the construction of Center Hill Lake Dam in 1948. Smith used the second earliest location for the cave as situated in "Warren [County]...on...the Cany [sic.] fork of Cumberland river, 10 miles below the falls" (Cassedy, 1810, in Miller, 1812, p. 147). Charles Cassedy, the antiquarian, had not yet visited the site; and he considered the information supplied by his informant to be of spurious worth (Cassedy, 1829). Using straight line direction from the Great Falls brings one to the head of Copper Cave Hollow.

Geographic descriptions for Copperas Cave are several whole orders better than those available to target the early location of Mammoth Cave, Kentucky. Copperas Cave was well known to the pioneers at a time period when scarce road maps were nothing more than straight lines connecting principal towns. Without accurate maps, distance reckoning was achieved as mileage along roads or river miles calculated along its course. If one were to travel along Caney Fork down stream from the Great Falls, would require 26 miles to reach the mouth of Copper Cave Hollow.

The *Map of Tennessee* (Rhea, 1832) is the earliest map with enough geographic detail to act as a study working base. The map scale is not always accurate because of "recomposition" from existing maps and surveys of different scales.

The earliest known Copperas Cave location is "about 30 miles from Carthage, on the Caney Fork of Cumberland river...lies in Warren county, within two miles of a boatable stream, there is also a fine road from it" (Anon., 1809). The discoverer and initial operator of the alum, copperas, and saltpeter cave is James Bryant. Charles Cassedy (1829), visited the cave in April 1811; he reports:

> *We found the cavern, if such it might be called within a few hundred yards of the bank of the Caney Fork of the Cumberland river, in a country remarkable for the ruggedness of its aspect and the lofty and abrupt aclivity [sic., acclivity] of its hills and mountains.*
>
> *The cavern itself was situated near the top of a gorge or deep ravine, formed by the junction of two lofty and almost impracticable hills which, approaching each other nearly at right angle, formed a junction at and below the cavern, and opened to the westward. The top of the cave was a projecting flat rock, impervious to water, which rested on the uppermost junction of these hills, and seemed to be incorporated with both. Over the outer edge of this rock, from some fountain which neither the Doctor nor myself had leisure to examine, a small cascade...about six or seven feet below the smooth surface of the projecting rock, we found the bottom of the cave.*

Cassedy indicates the entrance at the dripline was six or seven feet high, in the wall of a deep gorge, and the entrance faced in a westwardly direction below the saddle of the upland and hills.

Haywood (1823, p. 163), the historian, records the location as "about 13 miles southwest from Sparta, and 20 from McMinnville." Using Rhea (1832), I interpret half of Haywood's (1823) direction as keying into the immediate environs of Big Bone Cave of Van Bruen County. Measurements along the old wagon road shows about 12 miles from Sparta and 13 miles from McMinnville. Haywood's 20 miles is possibly a typographical error for 12 miles. His 20 mile straight line distance leaps beyond the locality of Johnson Cave by 2 miles. Even when the known location of Big Bone Cave is discussed, a typographical directional mistake in Anonymous (1821) focuses the location as "13 miles S.W. from M'Minville and 13 from Sparta" (emphasis added). Again half of the direction location is accurate.

D. T. Maddox (1813, p. 175), first to use the place name Big Bone Cave; says, "the road leading to it, terminates in the angle of two mountains, forming as it were, the foot and ancle [sic.] of the great Cumberland range; in the ancle [sic.] of which yawns the mouth of the hideous cavern." He mentions the sun was setting in the west and was shining directly into the entrance opening. This is essentially the same kind of description used by Cassedy (1829). Although Cassedy's cave entrance is not "a few hundred yards of the bank of the Caney Fork." More like two miles northwest of the cave entrance as reported by Anonymous (1809). The entrance is within 400 feet of a small sinking stream. On-site inspection verifies the geographic descriptions of Anonymous (1809) and Cassedy (1829) as the main entrance to Big Bone Cave.

For years the Copperas Cave site and its mummies was considered to be a separate locality. Comparative geographic analysis suggest Copperas Cave to be the earliest place name for Big Bone Cave in present day Van Bruen County, Tennessee.

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CRF FELLOWSHIP AND GRANT SUPPORT DURING 1992

Each academic year, the Cave Research Foundation sponsors a Karst Fellowship competition supported by the CRF Endowment Fund. The Foundation may award as much as $6000 distributed among one or more Karst Research Fellowships and as one or more Grants for graduate research in karst-related fields of study. The truly exceptional proposal may receive a Karst Research Fellowship (limit $3500.00); meritorious proposals that do not receive a Karst Research Fellowship 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, some of whom may also serve on the CRF Science Committee and some of whom 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. Proposals are judged on the basis of relevance and timeliness, technical quality of the proposal, and use of resources.

The Fellowship program cycles in phase with the academic year. In September, an announcement of the competition is mailed to graduate departments nationwide. This document specifies the requirements and deadlines for applications, including the contents of the proposal package. The deadline for receipt of the proposal and all supporting documents including letters of reference is January 31. Awards are made between mid-April and late May, depending on the efficiency of the reviewers and the Chairman of the Science Committee.

The Foundation attaches but two strings to its awards: (1) Each year until the study is completed, the awardee prepares a summary or progress report of the research for publication in the CRF Annual Report, and (2), upon publication, that the Foundation be acknowledged as a supporter of the research.

In 1992, the Cave Research Foundation received 9 proposals. Of these, one proposal was awarded a Fellowship and two proposals received Grants. A total of $6,000.00 in awards was distributed.

The recipient of the award, the recipient's graduate school, the title of the proposal and a synopsis of the research are given below for each funded proposal.

1. For his proposed research entitled "***Investigation of a chemoautotrophic ground water ecosystem in southern Dobrogea, Romania***", Mr. Serban Sarbu, Department of Biology, University of Cincinnati, Cincinnati, Ohio, 54221-0006, is awarded a 1992 CRF Karst Fellowship in the amount of $3000.00.

   Mr. Sarbu's research addresses a chemoautotrophic cave environment in Romania, where studies indicate that cave-dwelling microorganisms are using thermomineral waters rich in hydrogen sulfide as a fundamental life-supporting energy source, in contrast to the "normal" karst ecosystem where transport of carbon under ground constitutes the fundamental processes underlying the food chain.

2. For his proposed research entitled "***An analysis of the speciation process in cave spiders of the genus Nesticus***", Mr. Marshall C. Hedin, Department of Biology, Washington University, St. Louis, Missouri, 63130-4899, is awarded a 1992 CRF Karst Research Grant in the amount of $2,000.00.

Mr. Hedin's research addresses the nesticid spiders of the Appalachian region. These organisms are a recently diverged, diverse lineage affording sound prospects for studying speciation from geographic and populational contexts and perspectives. Inferences will be drawn from comparative analyses of the amount, rate of change, and the geographic pattern of genetic variation as indicated by mitochondrial DNA and nuclear DNA genetic systems.

3. For his proposed research entitled "***Karstic subsidence and the origin of groundwater-sustained lakes—upper Cenozoic of the southern Great Plains***", Mr. S. Christopher Caran, c/o University of Texas at Austin, Department of Geological Sciences (51640), P.O. Box 7909, Austin, Texas, 78713-7909, is awarded a 1992 CRF Karst Research Grant in the amount of $1000.00.

Mr. Caran's research addresses a system of heretofore poorly understood lakes sustained by groundwater where karstic subsidence ascribable to intrastratal dissolution of Permian evaporites is an important process driving the evolution of the region's geomorphology; these processes span from the Late Miocene to present.

The Science Committee and the Board of Directors of the Cave Research Foundation congratulate each recipient and wish them a speedy and successful quest with their outstanding karst-related research.

Research summaries and progress reports authored by these recipients and reports by other CRF investigators are published elsewhere in this volume. Please refer to those summaries for a perspective on the diverse scientific activities of the Foundation and feel free to contact the respective authors (see addresses of contributors, this volume) to obtain additional details concerning their research.

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EDUCATION

Figure 32: Mike Horsley in Pruett Saltpeter Cave, Warren County, Kentucky. (*Photo by Chris Groves*). (See article on saltpeter, page 55).

Saltpeter Industry*

by Stanley D. Sides

Saltpeter, as potassium nitrate was commonly known to the settlers of Kentucky, was—like common salt (sodium chloride)—a chemical vital for their survival. Just as the preservation of food depended on common salt, production of gunpowder required saltpeter, derived from calcium nitrate found in dry caves and rockshelters. Since both chemicals were difficult to transport, pioneers made good use of Kentucky's natural sources of both.

Monk Estill, a slave, was one of Kentucky's first manufacturers of saltpeter, which he supplied to Fort Boonesborough and Estill Station for gunpowder as early as 1780. By 1805, twenty-eight saltpeter caves and rockshelters were being mined in Kentucky. The first scientific description of Kentucky saltpeter production was a paper read in Philadelphia in 1806 by Samuel Brown, M.D., professor of chemistry, anatomy and surgery at Transylvania University. His subject was *Great Saltpeter Cave* in Rockcastle County, where saltpeter was produced by leaching calcium nitrate, or niter, from dry soil.

Saltpeter production reached its peak during the War of 1812, when a blockade of U.S. ports under the British embargo of 1807 cut off imports of saltpeter from India. The resulting inflation in the price of saltpeter encouraged the exploration of many caves and rock shelters. Mammoth Cave was among the most important sources of saltpeter in Kentucky. After Mammoth Cave and the adjacent Dixon Cave were identified as saltpeter sources in 1799, ownership changed frequently as the value of saltpeter increased.

By 1808, saltpeter was being produced using wooden V-vats at the entrance to Mammoth Cave. Large square vats were later constructed at Booth's Amphitheater and the Rotunda of the cave. Log pipes carried water into the cave to leach calcium nitrate from the soil, and the "mother liquor" leachate was pumped to the surface, treated with wood ashes, and boiled in large iron kettles near the cave entrance to cause the saltpeter to crystallize. Production declined after 1811, when the soil containing niter was depleted, and the works were damaged by the New Madrid earthquakes of 1811-1812. Statewide, Kentucky production topped 300,000 pounds of saltpeter in 1812.

Imports of saltpeter resumed after the end of the war and the price fell from a high of one dollar per pound to fifteen cents per pound. Saltpeter works in the caves were abandoned, and further production in Kentucky went for local consumption. Today, 133 Kentucky caves and six rockshelters have been identified as former saltpeter mines. Tours at both Mammoth Cave and Saltpeter Cave in Carter Caves State Resort Park allow visitors to study the remains of saltpeter works preserved for close to two hundred years.

See Burton Faust, "The History of Saltpetre Mining in Mammoth Cave, Kentucky," *FCHQ* 41 (1967): 5-20, 127-40, 227-62, 323-52; Carol A. Hill and Duane DePaepe, "Saltpeter Mining in Kentucky Caves," *Register 77* (Fall 1979): 247-62.

*This article appears in *The Kentucky Encyclopedia* (1992), which was published in honor of the state of Kentucky's 200th anniversary.

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The Hamilton Valley Project*

by Mel Park and Red Watson

For decades, CRF has been seeking a location for a permanent headquarters. Through the financial generosity of a few longtime JVs, we have taken a good first step toward making this a reality. Our beginning days were on Flint Ridge. We are already well on our way toward settling now permanently on Flint Ridge.

At the end of 1992, the Foundation purchased some 200 acres of land that encompasses Hamilton Valley, just east of the Salts Cave Entrance. The valley is one of the most beautiful in the region. Everyone who has seen it has fallen in love with it. The valley overlies part of Salts Cave and is an important part of the Pike Spring drainage. On the southwestern border of the property is a projection of sandstone-capped highland. This knoll provides an extraordinary building site with one of the finest views of karst landscape in the world. CRF is building there our national headquarters and a karst field research station.

The building project is conceived in two parts: first, construction of a Central Kentucky Karst Field Station, and second, expansion of the facilities to serve as CRF National Headquarters and Karst Research Center.

The first phase consists of three buildings, a main building and two bunkhouses. An architect—Rod Henmi of St. Louis—has already designed these facilities. The main building includes a common room 42x20 feet that will serve as dining hall, lounge, and conference hall. The kitchen will be state of the art restaurant quality. At the entrance will be separate men's and women's toilets and showers. The cartography room is 20x20 feet, and among other rooms is the expedition leader's office (see plan). The building will be surrounded by an outdoor porch, and the main view will be out a window the length of the common room, down the length of Hamilton Valley, a view that is nothing less than spectacular.

The county has improved the county road into the property for us, and has constructed a turnaround at the edge of our property. We have drilled a well 425 feet deep that gives 7 1/2 gallons a minute. Our private road from the turnaround to the building site plus power line access is to be constructed during the fall of 1993. Power line access has been worked out and will soon be installed.

Two bunk houses have been designed, each with 5 rooms sleeping 4 people on built-in bunks. We hope—depending on contributions—to be able to build all three of these buildings during the summer of 1994.

Figure 33: Hamilton Valley provides an idyllic setting in which CRF hopes to build permanent facilities to accommodate present and future needs. (Drawing by R. Henmi).

Completion of this first phase will be fine for basic expedition needs, cartography, and limited support for scientists. However, we are planning for the second phase, the building of a field laboratory and facilities for resident scientists. We have learned a great deal from experiencing the strengths and weaknesses of both the Austin House and Maple Springs facilities, so generously provided to us by the National Park Service. Our new facilities will be very good.

The land will be managed to preserve it as a natural water-

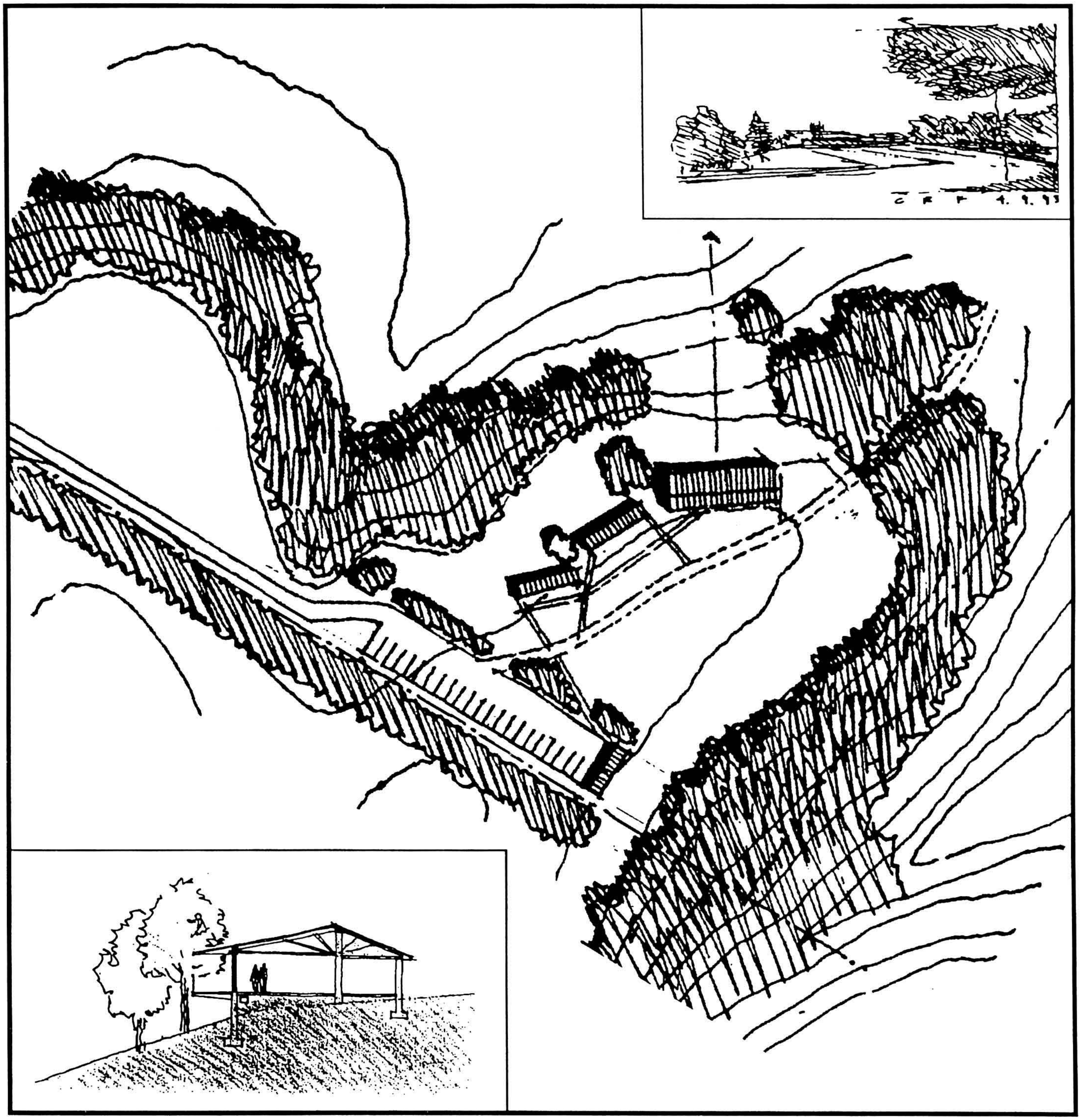

Figure 34: Architectural renderings of the proposed future home of CRF on property owned in Hamilton Valley, just outside Mammoth Cave National Park boundaries in Kentucky. (*Drawings by R. Hemni, architect*).

shed of the world's longest cave. A large number of JV workers have been helping to remove fences and in general to try to bring the land back to a natural state.

The Hamilton Valley Center will have a major impact on our operations in Mammoth Cave and in the Central Kentucky Karst. However, we also intend for it to have a major influence in supporting cave science throughout the country, and indeed, as far away as China. There is considerable experience in CRF concerning the support of scientists, particularly university faculty and their students, and that knowledge is being used in the present design.

CRF led to a blossoming of cave science in the USA, but for a number of years we have not been able to support scientists well for lack of facilities. The archaeologists, biologists, geographers, and geologists who were part of the beginnings of CRF are now senior scientists, and they—and even their first generation of students now scientists themselves—need facilities and support for their students. These home grown scientists constitute the strength and reputation of CRF, and the amount of CRF-related cave science is very large and extremely important. Beyond our need to continue to support such university science, there is now a need for more practical karst work, karst engineering in Kentucky, environmental surveys required by the federal government, and research contracts. The Hamilton Valley Project is designed to put CRF in a position to engage in all these science activities. And the key is our own land, our own field station, and our own field laboratory. The Hamilton Valley project constitutes a major step forward in the support of karst science by the Cave Research Foundation.

Figure 35: Back (north) view of proposed main hall at CRF's future research station. (*Drawing by R. Henmi*).

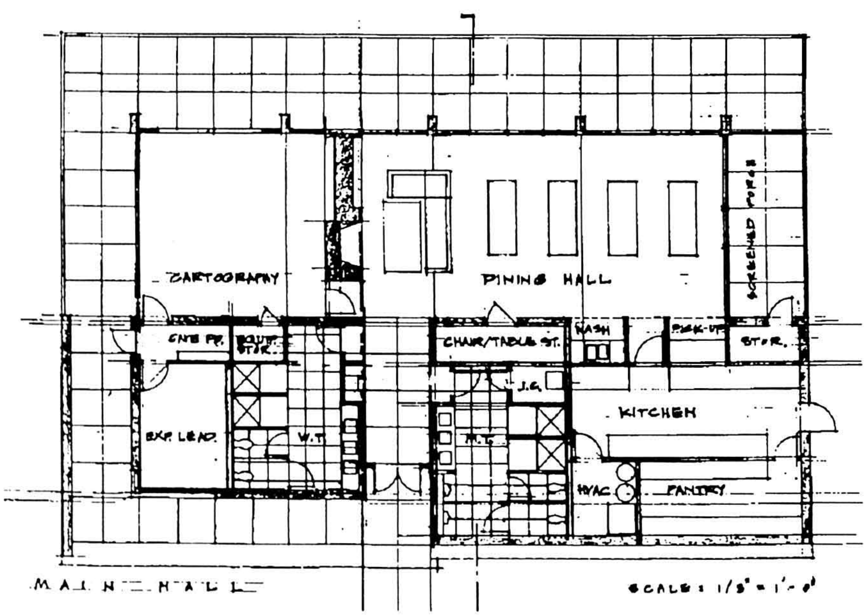

Figure 36: Plan view of proposed main hall. The interior is 2960 sf with 1530 sf of covered exterior, making a total of 3725 sf. (*Drawing by R. Henmi*).

Finally, the estimated cost of the first phase is $500,000. We need contributions, big and small, lots of them. But also, we need your help in fund raising. If every JV worked hard to try to find contributions from local foundations, banks, friends, and relatives, we would certainly meet our funding needs quickly. So please help CRF build a home of its own, for cave science, for all future JVs, and for you.

CRF is a nonprofit foundation incorporated in 1957 in Kentucky. When listing your contribution for tax deductions, cite the CRF number: I.R.S. Code Sec. 501(C)1954), I.D. No. 31 6052842 (12-18-64).

*See CRF Newsletter (August) and related information on pages 4 and 65

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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
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 is 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 supports 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 primary support for 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. Reports and books published by Cave Book are listed on the following pages.

(continued)

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.

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CRF MANAGEMENT STRUCTURE 1992

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Janet Sowers	Michael Sutton

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Field Station Maintenance ....Ron Kerbo
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Hooter editor ....Duke McMullan

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Area Manager ....Danny Vann
Project Cartographers ....Gary R. Schaecher, Jack Regal, Mike Pearson

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Medical Officer ....Stanley D. Sides
Safety Officer .... Bill Putnam
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Expedition Finance Officer .... Kay Sides

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Chief Cartographer ....Peter Bosted
Field Station .... Mike Spiess
Medical Officer .... Roger Mortimer, M.D.
Personnel Officer ....James Lakner
Safety Officer .... Howard A. Hurtt
Science Officer ....John W. Hess

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Personnel Officer .... David Cowan, Sandra Cowan
Cartographers .... Mike Sims, Bruce W. Rogers

Missouri Project Management

Operations Manager ....Scott House

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*	Thomas L. Poulson, *Chief Scientist*	William P. Bishop
David J. DesMarais	John W. Hess	Carol A. Hill
Francis G. Howarth	Thomas C. Kane	Kathleen H. Lavoie
Arthur N. Palmer	Margaret V. Palmer	Mark Perkins
Janet M. Sowers	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 316052842. 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	Kevin Downs
Sue Hagan	Dave Hanson	Joyce Hoffmaster
Karen Lindsley	Rich Wolfert	Mick Sutton

Hamilton Valley Project

The Hamilton Valley Project is overseen by two working groups—the Land Management group and the Building working group, and by a fund-raising committee.

Fund Raising: Red Watson, *co-director*
Mel Park, *co-director*

Building Committee: Paul Hauck, Red Watson, Richard Zopf

Land Management: Roger McClure, *chairman*, Jim Borden, Doon Coons, Rick Olson, Stan Sides

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