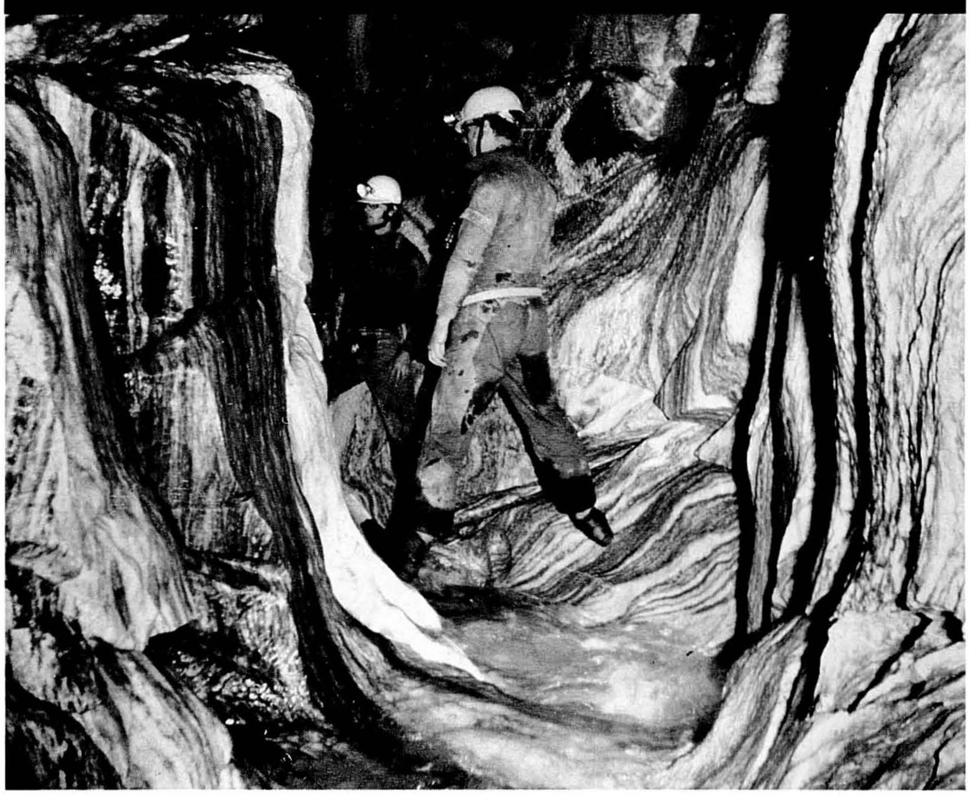
CAVE RESEARCH FOUNDATION 1977

Annual Report



CAVE RESEARCH FOUNDATION

Cave Research Foundation

1977 Annual Report

Cave Research Foundation
306 Sandia Road, NW
Albuquerque, New Mexico 87107

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

Cover: Stream passage carved in banded marble of Lilburn Cave, King's Canyon National Park, California. CRF researchers are conducting detailed hydrologic, geologic, and cartographic investigations in Lilburn Cave. Photo by G.E. Hedlund.

Printed by
ADOBE PRESS
Albuquerque, New Mexico

TABLE OF CONTENTS

CAVE RESEARCH FOUNDATION DIRECTORS

January, 1978

W. Calvin Welbourn
President

Rondal R. Bridgemon
Secretary

Roger E. McClure
Treasurer

Steve G. Wells
Chief Scientist

Charles F. Hildebolt
Central Kentucky Area Operations Manager

R. Pete Lindsley
New Project Operations Manager

Elbert F. Bassham
Guadalupe Escarpment Area Operations Manager

Roger W. Brucker

Patty Jo Watson

Acknowledgements

Many of the projects outlined in this report have been conducted within the National Park System. The support and encouragement of the Superintendents and staffs at Mammoth Cave National Park, Carlsbad Caverns National Park, Guadalupe Mountains National Park, King's Canyon National Park, Buffalo National River, Big Bend National Park, and Grand Canyon National Park have contributed greatly to the success of these projects, and their assistance is gratefully appreciated.

Dr. Thomas L. Poulson's biological research was supported in part by The National Science Foundation.

Dr. Steve G. Wells' hydrologic research was supported in part by an RAC Grant, University of New Mexico. Field assistance from the Bureau of Land Management, Roswell District, personnel is acknowledged.

Dr. Patty Jo Watson's archeological research was supported in part by the National Endowment for the Humanities and the Washington University Faculty Research Grant.

Highlights of 1977

This past year was highlighted by the initiation of three new short-term projects at Buffalo National River, Big Bend National Park, and Grand Canyon National Park. These projects will provide the National Park Service with baseline data for the management of their cave resources.

Exploration in Flint Ridge lead to major breakthroughs in 1977. More than 3000 feet of upperlevel passage were found above Grund River Trail Waterfall. Work in the Ralph's River Trail, Ruth's Room area, revealed cave everywhere including a new base level stream, Blind Fish River, which terminates under Great Onyx Cave. No connection yet. Work in Carlsbad Caverns National Park concentrated on a detailed survey of the Big Room of Carlsbad Caverns.

There were a significant number of scientific and interpretive publications during 1977. A complete list can be found later in the report including a book, two theses, 36 scientific articles, 5 papers at professional meetings, 5 special publications and more than 30 professional and interpretive talks during 1977.

Several briefing and training sessions by CRF personnel were conducted at Mammoth Cave National Park and Carlsbad Caverns National Park for staff and visitors.

Ten proposals were submitted for CRF Fellowship support from across the United States and Canada. One Fellowship and two grants were awarded:

Fellowship

"Geomorphology and Hydrology of the Edwards Plateau Karst Central Texas". Ernst H. Kastning, University of Texas.

Grants

"Ecological Genetics of Cave and Spring Populations of Isopods from Western Kentucky, Southern Illinois and Indiana." Edward Lisowski, University of Illinois.

"Fossil Packrat Deposits in the Horseshoe Mesa of the Grand Canyon, Arizona." Kenneth Cole, University of Arizona.

An additional grant was awarded to Duane DePaepe for his research on the "Economic Geography of Mammoth Cave National Park Regional Saltpetre Industry".

Research projects at Lilburn Cave, Kings Canyon National Park are off to a good start with several reports included in this report.

President's Report

In 1977 the Master Plan for Mammoth Cave National Park was signed by the Southeast Region Director of the National Park Service. The plan is evolutionary and farsighted. When the plan was first published, a CRF study team examined and analyzed it. Reservations about some of the water and sewage utilities were discussed with National Park Service officials in Atlanta. As a result, the Park signed a contract with an outside water company to supply potable water and has joined the regional 201 sewage facilities study required by the EPA. The Master Plan promises an extension of the Park Service's protection of the cave system far into the future.

Cave Research Foundation will continue to press for prompt removal of the Great Onyx Job Corps Camp from Flint Ridge. Termed "a dangerous intrusion" by the Master Plan, the camp continues to be a source of sewage pollution of the caves, and it also is a base from which Job Corps members conduct repeated acts of theft and vandalism against CRF facilities and personnel and repeated break-ins to the cave.

A variety of in-house studies are in progress or nearing completion. While these are described in detail elsewhere, special note should be made of two of these. CRF formed a unique partnership with the National Park Service in undertaking an assessment of the karst resources of the Buffalo National River in Arkansas. In addition to carrying on descriptive studies in the field, CRF workers have attempted to encourage local cavers to participate and develop a base of stewardship toward the cave resources. The descriptive study has proceeded on schedule, but the latter objectives have proven more difficult to achieve. Our approach may be wrong, or perhaps local cavers have other fish to fry.

The second project is the completion of the long-awaited Ogle Cave Symposium scheduled for early publication in the *NSS Bulletin*. This multi-disciplinary study will be accompanied by a large map. It represents a perseverence and determination by the investigators to make sure that the fruits of research are reported, despite obstacles.

The Foundation's Endowment Fund stands at $4300. A decision has been reached by the Fund's trustees to reinvest the interest until the Fund reaches a total sufficient to support the CRF Annual Fellowship. Donations are welcome!

W. Calvin Welbourn became the sixth President of CRF on November 12 at the Foundation's Annual Meeting in St. Louis. Cal succeeds Roger Brucker, who remains a Director of the Foundation. Roger E. McClure was elected a Director and Treasurer of the Foundation. Dr. Patty Jo Watson was elected a Director of the Foundation. Dennis Drum has retired as Treasurer and has joined Stanley D. Sides, M.D., in retiring as a Director. We are grateful for past support and are confident that the new officers and directors will continue to challenge the Foundation to promote innovative and risky research.

Roger W. Brucker

Roger W. Brucker
Past President

SCIENTIFIC PROGRAMS

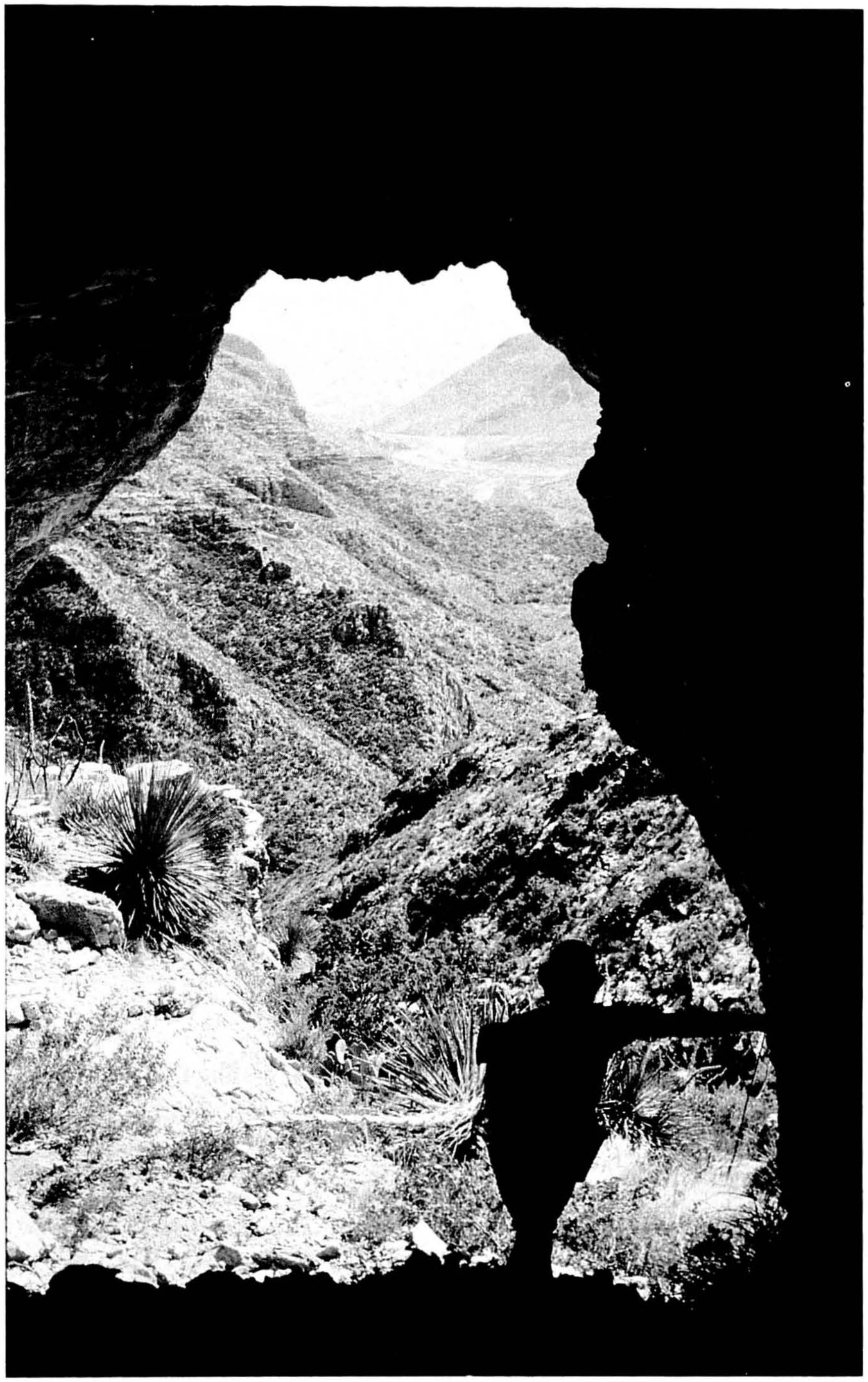


Figure 1. View towards the mouth of Slaughter Canyon, Carlsbad Caverns National Park. Photo by W. C. Welbourn.

Cartographic Program

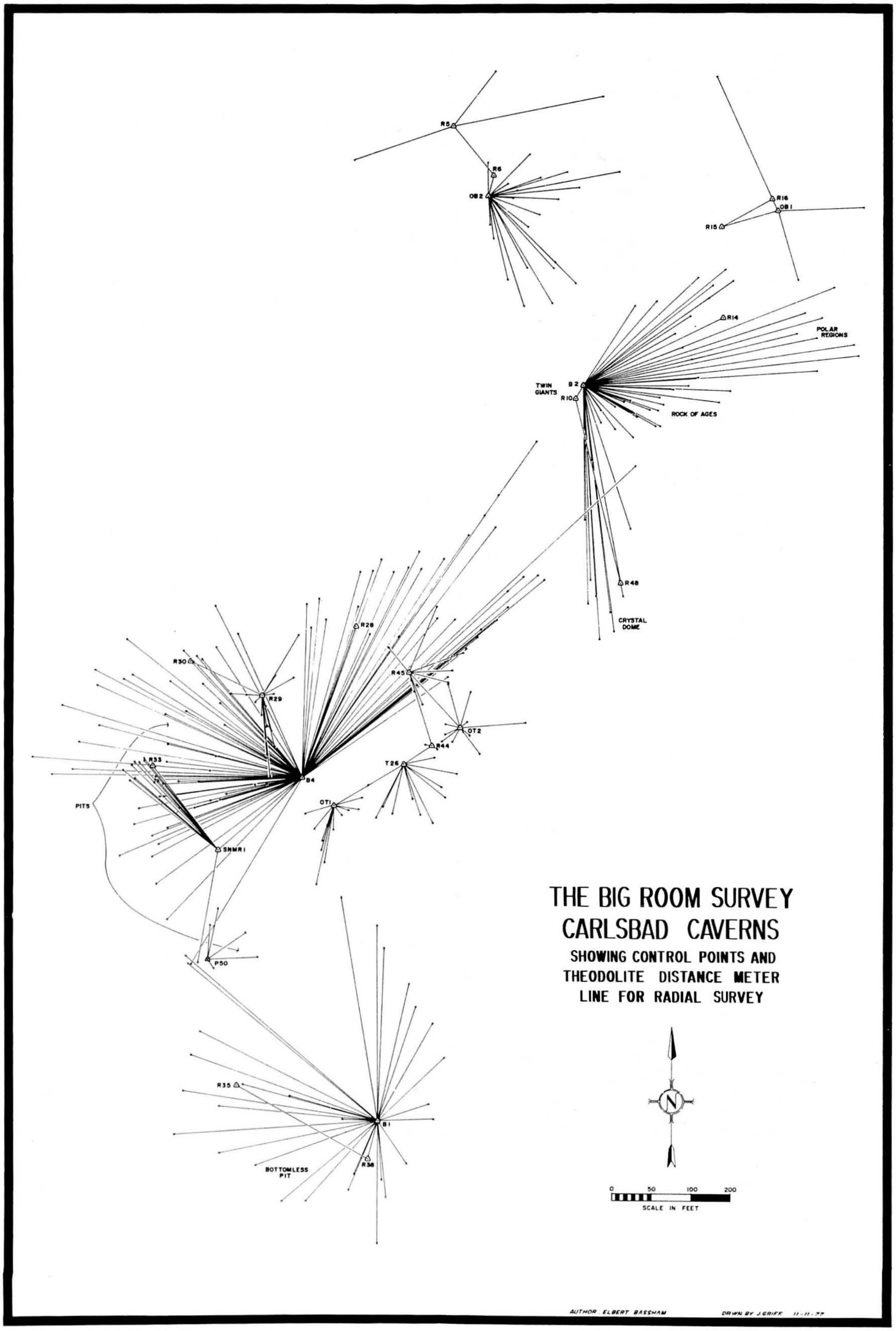


Figure 2. Control network for detailed survey of Big Room, Carlsbad Caverns, New Mexico.

Central Kentucky Areas

Patricia P. Wilcox, Richard Zopf and Roger W. Brucker

The Flint Mammoth Cave System, as of November 1, 1977, was 306.95 km long (190.77 miles). Of this total, the Mammoth Cave part of the system was 150.76 km (93.70 mi) and the Flint Ridge part of the system was 156.19 km (97.07 mi). On August 7, 1977, the Flint Mammoth Cave System passed the one million foot mark (304,800 m).

During the 61 month period between September, 1972—when the two cave systems were linked—and November, 1977, 74.61 km (46.37 mi) of additional passageways have been surveyed. The average rate of survey additions to the cave length has been 1.22 km/month (0.76 mi/mo). The overall rate of surveying is slowing down as new discoveries are found farther away from entrances.

Exploration and Survey in Flint Ridge

Exploration efforts in 1977 yielded major breathroughs in Flint Ridge. The Grund Trail Waterfall climb led to 914 m (3000 ft) of high-level passage. Some leads remain to be explored. Systematic resurvey of the Ralph's River Trail-Ruth's Room complex turned up new cave everywhere—2.4 km (1.5 mi) of it this year. A new base level stream (Kulesza Creek) accounts for a mile of this. It terminates directly below Stairway Crawl in Great Onyx Cave. To the frustration of the explorers, no connection between the two caves has been found. The newest discovery as of mid-November, 1977, has not been examined fully. It appears to be a major trunk passage above Pohl Avenue, perhaps on the Turner Avenue level, that leads about 90 m (300 ft) to a vertical shaft. Beyond the shaft the passage appears to head west for a long distance. A significant segment of river passage was also discovered in the lower levels of Salts Cave.

Exploration and Survey in Mammoth Cave

Surveys in Mammoth Cave encompassed the expanding network of passages above Cathedral Domes. New connections were found between Cathedral Domes and Edna's Dome, and Pilgrim Avenue. Other significant surveys continued earlier surveys in Miller Avenue and Carlos' Way. Many other areas were surveyed as well in diverse locations. A major passageway was discovered off Big Avenue in New Discovery. It has not yet been surveyed.

Exploration and Survey in Great Onyx Cave

A project begun and continued through the year is an accurate pedestal survey of Edwards Avenue and Cox Avenue. That survey was completed at the end of the year. There are hundreds of feet of unmapped branches and cutarounds, a descriptive survey of junctions and passage terminations, and a connection with the Flint Ridge Cave System remaining to be undertaken.

World Standards for Measuring Cave Length

Length measurement standards used during the 7th International Speleological Congress call for total traverse length. This method in effect adds the altitude of vertical pitches and slope distance of non-horizontal passages to the length of horizontal passages to calculate grand total length.

Lengths reported by the Cave Research Foundation are corrected horizontal lengths, which are a by-product of survey data reduction for cartographic purposes. Thus, the altitude of vertical shafts and slope distances have not been figured in, so the Flint Mammoth Cave System length is understated by world standards.

How much might vertical shaft altitudes add? A rough guess would be 6000 m (20,000 ft). Since the passages are largely horizontal or of gentle slope, the addition of slope distances would contribute little to the total.

Cartography in 1977

The Beavercreek, Ohio drafting facility is fully operational. Cartographers meet each Wednesday evening and have made a beginning on drafting a full set of field maps for the Flint Mammoth Cave System. Field maps were drawn of the Carlos' Way area in Mammoth Cave, and Ralph's River area in Flint Ridge. Field maps are compilations of individual survey plots covering a large area of the cave. Unlike computer plots, they contain cross-sections and feature detail, notes, and topography superimposed.

All of the field survey notebooks (nearly 1300) and their log sheets were copied in microfiche form. Several sets of the survey data were distributed to mappers in Boston, Pennsylvania, Kentucky and Ohio. Three microfiche readers were acquired.

Two weekend data processing parties brought computer files up to date for Carlos' Way, Ralph's River Trail, and Cathedral Domes. Three new keypunch operators were trained.

William Mann and John Robinson have converted the cave data processing and plotting programs to Fortran and have increased the utility and power of the system. The program now prints loop closures and schematic diagram information, will accept a foresight and backsight for each shot, will cross-reference surveys by book number, and will perform several other tasks.

Future Program

A program is under development to plot schematic diagrams of survey networks on the Calcomp plotter. A second plotter may be used to prepare maps during 1978. Also during 1978, it is expected that the computer files will be brought up to date by eliminating an 18 month backlog. When the computer file is completed, a new base map will be plotted. This will serve as the base for a projected poster map of the Flint Mammoth Cave System being planned by Walter Lipton and Roger Brucker. Preliminary sketches show cave passages glowing in color on five levels, against a black background. The Proctor Cave manuscript map is nearing completion. All surveys are plotted, and an issue is planned for 1978.

Pat Wilcox has resigned as Cartographer, although she will continue to work on as many cartography projects as before. Richard Zopf has been appointed Cartographer with responsibility to coordinate the effort.

TABLE 1.

1977 summary of cave surveys for the Central Kentucky Karst

Cave	New Survey		Resurvey		Total Length	
	m	*ft*	*m*	*ft*	*km*	*mi*
Mammoth	5830.8	19,130.0	961.2	3,153.4	150.76*	93.70*
Flint Ridge	5098.1	16,726.2	3185.8	10,452.1	156.19	97.07
Proctor	117.7	386.2	--	—	10.23	6.36
Great Onyx	135.3	443.8	1878.5	6,163.0	4.47	2.78

Total survey, October 31, 1976 through November 1, 1977, 17,207 m (56,454.7 ft), or 17.207 km (10.692 mi).

*718.17 m (2356.2 ft) of the Mammoth Cave total duplicates passageways shown on the Kaemper and Nelson maps.

Guadalupe Escarpment Area

W. Calvin Welbourn

Most of the field work in 1977 was concentrated in Carlsbad Caverns with the goal of completing survey for the 1" = 200' scale map of the Caverns. Additional survey was done in eight other caves in Carlsbad Caverns National Park. Survey was completed in six of these caves, with additional survey needed in the other two. Survey totals are listed below.

Work continued in Three Fingers Cave (Lincoln National Forest) and Wind Cave (Bureau of Land Management). In the gypsum karst (Bureau of Land Management) southeast of Whites City one cave was surveyed and several were located.

Maps finished this year include Musk Ox Cave, Recluse Cave, Fence Cave, and Corkscrew Cave. Several maps are in the final stages of preparation including Jurnigan #1, Jurnigan #2, Doc Brito, and Wind Cave. The 1" = 200' scale map of Carlsbad Caverns has progressed very well with the addition of Left Hand Tunnel, Bat Cave, New Section and most of the Big Room. Plans are to have Lower Cave, Scenic Rooms, and Main Corridor ready to add to the map soon.

Survey in Edgewood Caverns (Santa Fe County, New Mexico) reached the 3.04 mile (16,076 feet) mark with no end in sight.

Plans for 1978 include publishing a 1" = 200' scale map of Carlsbad Caverns, finishing and field checking several of the backcountry caves, continuing ridge walking in the backcountry, and the complete cataloging and indexing of all survey data.

TABLE 2

1977 Survey totals for the Guadalupe Escarpment.

Carlsbad Caverns National Park		
Carlsbad Caverns		
Left Hand Tunnel		740.6 feet
Lower Cave		2,111.1
Big Room		57,783.36
Bat Cave		796.6
Spider Cave		141.1
Musk Ox Cave		74.2
Goat Bell Cave		52.9
Light at the end of the Tunnel - Goat Trap Cave		249.5
Recluse Cave		351.5
Fence Cave		303.4
Deep Cave		3,171.0
Scout Cave		1,042.0
	Total	66,817.26 feet
Surface Survey		
Carlsbad Caverns		20,645.0
New Mexico, Eddy Co.		
Bureau of Land Management		
Wind Cave		842.8
Doc Brito Cave (Surface)		518.5
Squirrely Curley Cave		74.0
	Total	1,453.3
Lincoln National Forest		
Three Fingers Cave		647.1
New Mexico, Santa Fe Co.		
Edgewood Caverns	Brunton	1,324.0
	Plane table and sketch	3,461.0
	Total	4,785.0

The Big Room Survey, Carlsbad Caverns

Elbert Bassham

The Big Room of Carlsbad Caverns was surveyed many years ago by NGS using a transit and tape for control and a plane table survey for wall detail, features and topography. About 11 years ago, Tom Rohrer extended a control network into the Big Room using a theodolite and very careful chaining. At a later date he checked and extended this network using a theodolite and an electronic distance meter.

A resurvey of the Big Room began in March, 1977 using methods and equipment different from the usual cave survey. Utilizing Rohrer's control net, approximately 90% of the Big Room was surveyed from only four instrument points (Fig. 2). These points were occupied by a theodolite-distance meter combination. The theodolite was used to measure a horizontal angle to the right from a line with a known azimuth and to measure a vertical angle. The theodolite has a resolution of ± three seconds of arc. The electronic distance meter was used to measure the slope distance. The distance meter has a resolution of one part in 100,000.

The precision of this theodolite—distance meter combination is perhaps an overkill since the location of cave walls is admittedly open to personal interpretation. The capability to measure across pits, pools and other perilous places quickly and precisely was the deciding factor.

The method used was as follows: first, a centrally located, high point was selected for maximum visibility. This point was then tied to Rohrer's control net by angles and distances. This point was then occupied by the theodolite-distance meter. An instrument-man and noteman worked at this point. A targetman and sketchman traveled around the walls and trail placing the reflector target at strategically located points, usually projections or indentations of the walls and bends of the trail. These points were selected close enough to give good control for the sketch. This method also allowed great volumes of cave to be surveyed with speed and ease. On the next expedition the accuracy of the survey was visually verified in the cave and noted discrepancies were removed. This portion was then ready to be added to the final map.

The survey work to date has been done on six expeditions, spaced about a month apart. These expeditions have all been weekend trips where the cave was entered after the last commercial tour on Saturday night and work continued until just before the first tour Sunday morning, or exhaustion, whichever came first.

Volunteer help from NPS employees has been encouraged and welcomed. The resulting experience has been fruitful in improving the CRF-NPS relationships at Carlsbad Caverns National Park.

TABLE 3
Expedition dates and survey lengths for the Big Room in Carlsbad Caverns

Date	CRF	NPS	Survey Length (feet)
19-20 March	2	3	8335.38
2-3 April	4	1	2776.38
18-19 June	7	3	6302.55
23-24 July	4	6	18,433.55
20-21 August	9	2	12,199.45
24-25 September	10	3	9736.05

One more big overnight push with a theodolite—distance meter crew and two Brunton crews should carry the survey to the Lunch Room, thus completing the Big Room Survey.

Geoscience Program

Figure 3. The Great Bend (140°) in trunk passage of Smith Grove Cave, Kentucky. Cave is approximately 30 m below Sinkhole Plain surface in the Central Kentucky Karst. Photo by S.G. Wells.

Radon and Carbon Dioxide Abundances in Lilburn Cave Air, King's Canyon National Park, California

David J. DesMarais and Stanley R. Ulfeldt

Lilburn Cave has developed in banded marble in Redwood Canyon, Kings Canyon National Park, California. The cave's approximately eight miles of surveyed length include lower active stream conduits and upper-level, maze-type passages. The cave temperature is typically 7°C; its relative humidity is 100 percent and air circulation is generally low.

The radon daughter and the carbon dioxide (CO_2) concentrations in the cave air were monitored extensively during the spring and summer of 1977. A spatially complex pattern of radon working level (W.L.) values ranged from 1.2 (near an entrance) to 4.2 (a small, confined room); the average W.L. was 3.2. The CO_2 concentrations were comparatively constant, ranging from 0.17 percent (near an entrance) to 0.30 (in an active domepit); a typical concentration was 0.21 percent.

Measurements of radon daughters and CO_2 were designed to evaluate potential sources of these gases, namely groundwater, cave sediments, forest soil and bedrock. A graphical plot of W.L. versus cave passage elevation does not reveal consistently higher W.L. values closer to the bottom level stream, suggesting that the stream's radon contribution to the entire cave is of secondary importance. Nonetheless, the W.L. values were consistently high in the room where the cave stream first enters the cave.

The cave sediment radon contribution was assessed by sampling a 160 liter air pocket enclosed in a sediment pit covered with a plastic sheet. The W.L. values of the air pocket at the time it was covered, one day later, and eleven days later were 2.75, 1.16 and 0 respectively. These data, together with similar results from another air pocket, suggest that the cave sediments are not a significant source of radon.

The radon contribution from forest soils and other biologically active deposits was assessed by comparing W.L. to CO_2 concentrations both in the cave and in a covered pit dug in the forest soil. Carbon isotope values of the cave air CO_2 are very constant throughout Lilburn and are identical to the isotope value of the forest soil CO_2. These observations suggest that the cave CO_2 derives from biological activity in the forest soil. The W.L. values do not correlate with CO_2 levels in the cave, except near cave entrances (Fig. 4). The CO_2 concentration in the soil pit air

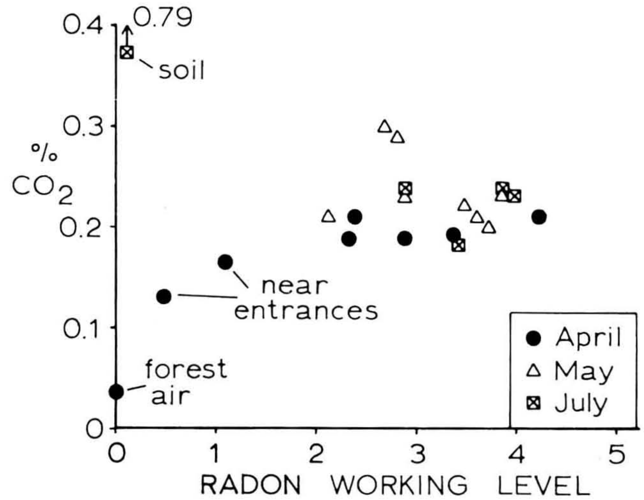


Figure 4. Plot of radon W. L. versus percent CO_2 in Lilburn Cave air. No significant relation between these two parameters is evident, except in the vicinity of cave entrances.

was very high (0.79 percent), whereas the W.L. value was below 0.05. These data suggest that biological activity in the forest soil does not promote a measurable radon gas release.

Certain areas in the cave with high ratios of bedrock surface area to passage volume, such as maze and breakdown areas, tend to contain higher radon daughter levels. This observation suggests that rock surfaces are a significant source of radon gas in Lilburn Cave. Unfortunately, difficulties in quantifying this observation, together with numerous unexplainable variations in W.L. in the cave as a function of time, indicate that considerable future work on the origin of the cave's radon is warranted.

The authors gratefully acknowledge the assistance of Luther Perry, Howard Hurtt and others in this investigation.

Geochronology and Paleoclimatology of Speleothems from Mammoth Cave National Park

Russell S. Harmon

During 1977 work on the geochronology and paleoclimatology of speleothems from Mammoth Cave National Park was mostly limited to the preparation of the 1974-1976 work for publication. A new program directed toward understanding the detailed chronology of the Flint-Mammoth Cave System was initiated in April and will continue over the next two years.

Mineralogy of the Second Parallel Passage, Cottonwood Cave, Guadalupe Mountains, New Mexico

Carol A. Hill

The Second Parallel Passage of Cottonwood Cave has an exceptional display of cave minerals, among the most unique in the world:

Sulfur

Bright, canary-yellow, native sulfur (S) occurs along the left wall below the Sand Pile and also on the ceiling near the Chandelier Room. The Sand Pile sulfur is crystalline (1-2mm) and occurs in pockets within a massive gypsum block. The sulfur may be primary, thus deposited along with the massive gypsum under locally reducing conditions, or, the sulfur may be secondary and derived from the gypsum by sulfur bacteria activity (Davis, 1973).

Sulfates

Gypsum Stalactites The largest gypsum ($CaSO_4 \cdot 2H_2O$) stalactites in the Second Parallel Passage are known collectively as the "Chandelier." When first discovered, the Chandelier was 4-5m long and extended almost to the passage floor; the Chandelier is now 2-3m long (the lower extremities have been vandalized: Jerry Trout, personal communication)*.

Gypsum Stalagmites The Chandelier stalactites have their counterpart stalagmites, but these have been almost covered by dirt kicked from the nearby path. Other, smaller, porous, warty-looking gypsum stalagmites occur along the path beyond the Chandelier.

Gypsum Crust The gypsum crust in the Second Parallel Passage is massive granular rather than tabular or fibrous (Hill, 1976). The crust occurs either as "blisters" on cave walls or as thin coatings over carbonate speleothems. Some of the thin coating have been deposited within the past year (Jerry Trout, personal communication). The gypsum coatings are transparent when first deposited, but then turn an opaque white. A few of the thin gypsum crusts are peeling off the sides of the carbonate speleothems.

Gypsum Needles The gypsum needles are unusual in that they form on cave *walls* as well as in floor soils. Floor needles are small (a few cm), but long, thin needles (up to 1m in length) used to occur in these same floor soils (these long needles delicately swayed as a person walked by). Gypsum needles reach 0.3m in length and 1cm wide at the base in high, protected nooks and pockets. When the cave passage was discovered in the early 1960's, wall needles grew up to 1.8m long. Free hanging, they would bend toward the floor; upon touching the floor, they would carve a zig-zag path in the soil. Both the floor and wall needles have regrown since entry to the Second Parallel Passage has been restricted by the Forest Service.

Gypsum Rope A gypsum rope (3-4m long and 2.5cm in diameter) used to spiral down from a ledge and reach almost to the cave floor. There has been no regrowth of this vandalized gypsum rope.

Gypsum Flowers When the Second Parallel Passage was first discovered, gypsum flowers were found growing only on the right wall of the passage and gypsum needles were found only on the left wall (going into the cave). Almost all of these once-present flowers have been vandalized and no new growth has occurred. A few exquisite flowers (10cm long) remain in a small room beneath floor breakdown.

Massive Gypsum Massive gypsum blocks, similar to those in Carlsbad Caverns and many other caves in the Guadalupe Mountains (Hill, 1973), occur in dry, non-dripping areas, mainly in an alcove off the Rattlesnake Room. The texture of these blocks is massive granular, but in places it is locally fibrous. The profuse display of sulfate speleothems in the Second Parallel Passage may derive from dissolved massive blocks that once existed in overlying cave passages.

Epsomite Stalactites Epsomite ($MgSO_4 \cdot 6H_2O$) conical stalactites and soda-straw stalactites, up to 2½m and 10cm long, respectively, occur in the Epsomite Room.

Epsomite Stalagmites Epsomite stalagmites up to 3½m high have formed below the epsomite stalactites. The epsomite is transparent at first but becomes opaque after depositing solutions cease flowing.

Epsomite Helicite An epsomite helicite 1½ cm long and 0.5cm in diameter spirals horizontally outward from the side of an epsomite soda straw. This is the first reported observation of this speleothem (Hill, 1976).

Epsomite Flowers Epsomite flowers occur in the gypsum needle area; some of these flowers have grown approximately 10cm since July, 1975 (Jerry Trout, personal communication).

Epsomite Cotton Epsomite cotton and "angel hair" fill many cave wall recesses in the winter months when humidity is low. By late spring, the higher cave humidity dissolves these delinquent speleothems. Only a few cottony mounds could be seen at the very back of wall recesses in May. Ground temperature in the Epsomite Room in late May was 12.2°C and relative humidity was 80%.

Carbonates

Typical carbonate speleothems such as stalactites, stalagmites, helictites, draperies, flowstone and rimstone shelves decorate the Lake Room and Rimstone Room of the Second Parallel Passage. The Rimstone Room is located directly underneath the entrance of the cave and descending rainwater is responsible for its actively growing speleothems.

Shelfstone Unusual composite stalactite-shelfstone speleothems known as "coke tables" or "candlesticks" are present in the Lake Room. Solutions flowing down the sides of a stalactite form as shelfstone upon reaching a pool surface; solutions issuing from the stalactite's central tube create bulbous subaqueous shapes beneath the shelfstone. One unique "coke table" named the "wine table" used to have a candle-shaped stalagmite in its center, but the "candle" has been vandalized.

Subaqueous Coralloids A most unusual type of subaqueous coralloid resembling "Spanish moss" occurs near the Rattlesnake Room. The moss-like speleothems are milk chocolate brown, porous, and very fragile-looking. Natural cross-sections reveal an inner stalactite core overlain by a porous subaqueous "war club" covering. The "Spanish moss" coralloids drape over the "war clubs" and were possibly formed from solutions oozing through the porous "war clubs." Small gypsum flowers and "angel hair" cover the "Spanish moss" in a few places. This is the first reported occurrence of this variety of subaqeous coralloid (Hill, 1976).

---

* Jerry Trout, cave resource specialist for the Forest Service, was on the discovery trip into the Second Parallel Passage; all descriptions of speleothems, pre-vandalism, are referenced to Jerry Trout, personal communication.

REFERENCES

Davis, D. G. (1973). "Sulfur in Cottonwood Cave." *Natl. Speleol. Soc. Bull.*, **35(3)**:89-95.

Hill, C.A. (1973). "Mineralogy of Carlsbad Caverns and caves of the Guadalupe Mountains." *Cave Res. Found. Annual Rept.* **#15**: 29-30.

Hill, C.A. (1976). *Cave Minerals*. Natl. Speleol. Soc., Huntsville, AL, 137 p.

Niter and Soda-Niter in a Lava Tube, Socorro County, New Mexico

Carol A. Hill

The Socorro County lava tube caves are located approximately 60 km south of Socorro, New Mexico. These tunnel caves are developed in Quaternary basalt flows and extend 2.4 km southward from a volcanic crater. The caves, once part of a single tube, have since collapsed into about six separate sections. Each segment has a roof thickness of 6-9 m. Bat guano occurs on the floor of all the caves. One cave, Main Bat Cave, presently has a large colony of bat inhabitants and was actively mined for guano between the years 1899-1902. Temperature and relative humidity in Main Bat Cave in May were 15.5°C and 43%.

Both niter (KNO_3) and soda-niter ($NaNO_3$) occur in Main Bat Cave; these minerals are either regrowths or remnants of abundant nitrates that once existed in the cave. J.R. DeMier of Las Cruces, New Mexico, reportedly told Mansfield and Boardman (1932): "I mined in one place about 125 tons of potassium nitrate that I blasted out. It looked like thick rock salt; was so pure it melted in the rocks and looked like thick syrup."

Niter

The niter occurs as a wall crust near the floor of Main Bat Cave (along the right wall). The crust extends up to a line marking a former bat guano level. A small amount of niter also fills vesicles in the basalt just above the niter crust. The niter is massive granular, transparent and colorless to light brown (tinted by impurities from the bat guano); taste is saline and cool, crystal size averages approximately 1.5 mm. Crystal faces are not well developed due to partial dissolvement, and some of the crystals have embayed edges. The niter was identified by X-ray diffraction and contains no nitrocalcite, nitromagnesite or ammonia-niter.

Soda-Niter

The soda-niter occurs in Main Bat Cave along the right wall, 6 m from the cave entrance. The soda-niter forms as a crystalline wall crust (0.6-2 m off the floor) and also as two small stalactites 1 cm and 3 cm long. One small (1-2 cm) nubin-shaped stalagmite occurs directly beneath the largest stalactite. Soda-niter crust is developed along small cracks in the basalt. The taste of the soda-niter is bitter, pungent and cooling; crystals (2-3 mm long) are massive granular, transparent, and colorless. Some of the soda-niter crystals are embayed while others have "melted" together to form clumps or aggregates of crystals. A few crystals show rhombohedral cleavage faces. Some concoidal fracturing was observed. No lines other than those for soda-niter were found in the X-ray pattern.

REFERENCES

Mansfield, G. R., and Boardman, L. (1932). "Nitrate deposits of the United States." *U.S. Geol. Surv. Bull.* **838**: 107 p.

Mineralogy of the Pink Caves, Guadalupe Mountains, New Mexico

Carol A. Hill

The "Pink Caves" are so named for the color of their speleothems. The pink color is derived from overlying limestones which are locally pink. The four largest pink caves are Pink Dragon, Pink Panther, Pink Palette and Damn Cave.

Pink Panther Cave Pink Panther Cave has an abundance of typical carbonate speleothems (stalactites, stalagmites, popcorn, draperies, flowstone and rimstone). A number of multi-tiered bell canopies also occur in the cave. In one place some crinkly moonmilk flowstone was found overlying a crystalline calcite column.

Damn Cave The main mineralogic attraction of Damn Cave is a series of approximately 15-40 cm high rimstone dams. These dams are sometimes completely dry or filled to overflowing, depending on surface precipitation.

Pink Palette Cave Pink Palette Cave contains only small, desiccated speleothems. In the back chamber, past the crawl to the left, the upper hemisphere of an approximately 1 m diameter shield (palette) occurs on the cave ceiling.

Pink Dragon In the terminal room of Pink Dragon Cave is an impressive display of vertical shields. Four of the vertical shields (80-85° from horizontal) are aligned approximately parallel to the passage direction (along a major joint trend) and one shield is oriented perpendicular to the direction of the other four shields (minor joint trend). These shields are spectacular in that they appear to "hang in thin air." Other impressive speleothems in Pink Dragon Cave are the "fried egg" stalagmites and the "moonmilk rivers," chalk-white strips of moonmilk overlying crystalline calcite. One "fried egg" has an approximately 5 cm diameter yellow "yolk" surrounded by white crystalline calcite. Three separate geologic events are indicated by the speleothems in the terminal room of Pink Dragon Cave: 1) subaerial period—the majority of carbonate speleothem growth occurred at this time, 2) subaqueous period—underwater popcorn coated the carbonate speleothems (a water line indicates the depth of this submergence), and 3) subaerial period—most recently, subaqueous coatings have peeled away from the carbonate speleothems and have dropped to the floor. In some locations, subaerial dripstone and flowstone have covered the subaqueous growth.

Saltpetre Caves of the United States

Carol A. Hill, Duane DePaepe, P. Gary Eller and Peter M. Hauer

Saltpetre caves are not located uniformly throughout the United States but exist only in the Southwest. The extent of known saltpetre caves is roughly south of the Mason-Dixon line, north of the four southernmost Dixie states (Alabama, Georgia, Mississippi and Florida) and east of the Mississippi River (with the exception of Missouri and northernmost Arkansas)(Fig. 5). Four questionable saltpetre caves exist in Texas (see list below) but these caves are in all likelihood guano, rather than saltpetre caves (Campbell, 1925; Phillips, 1901). Saltpetre earth is *not* the same as bat guano in content or in origin even though both deposits contain high quantities of leachable nitrate which can be made into gunpowder by the same conversion method (Hill, in preparation).

Table 4 is the first comprehensive list compiled on saltpetre caves of the United States. The authors would appreciate receiving any additions or corrections to this list.

TABLE 4
Comprehensive list of saltpetre caves in the United States given according to individual state.

Alabama	
Madison County	Sauta
Jackson County	Long Island Saltpetre
	Tumbling Rock
Arkansas	
Marion County	Saltpetre
Newton County	Saltpetre
Georgia	
Bartow County	Kingston
Illinois	
Jackson County	Cave Creek
Indiana	
Crawford County	Wyandotte
	Saltpetre (near Wyandotte)
	Sumnerville Saltpetre
	Saltpetre
Monroe County	Saltpetre
	Coon's
	Buckner's
Orange County	Saltpetre (near Valeene)
Washington County	Saltpetre
	Saltpetre
Lawrence County	Salts
Harrison County	Saltpetre (near Corydon)
	Big Mouth (or Rat Cave)
Kentucky	
Edmonson County	Mammoth
	Dixon
	Hundred Dome
	Long's
	Cedar Springs
	James
	Short
Rockcastle County	Great Saltpetre (or Crooked Creek)
	Owens Saltpetre
Hart County	Forestville Saltpetre
	Saltpetre (east of Horse Cave)
	Saltpetre (west of Horse Cave)
Wayne County	Wind
	Saltpetre
Jackson County	John Rogers Cave
Pulaski County	Petre Cave
Bath County	Daniel Boone Hut
Carter County	Saltpetre
	Saltpetre (in Carter Caves State Park)
? County	Lone Star Saltpetre
Maryland	
Allegany County	Saltpetre (near headwaters of Yohogany)
Garrett County	John Friend Saltpetre
Washington County	Hughes (near Hagerstown)
	Saltpetre (near Hancock)
	Saltpetre (foot of South Mountain)
Missouri	
Dent County	Saltpetre
Laclede County	Saltpetre
McDonald County	Saltpetre
Phelps County	Saltpetre
Pulaski County	Saltpetre
	Saltpetre
	Saltpetre
Ste. Genevieve Co.	Saltpetre
Stone County	Saltpetre
Texas County	Saltpetre
Maries County	Saltpetre
Callaway County	Saltpetre
Ozark County	Saltpetre
Pennsylvania	
Bedford County	Saltpetre
Tennessee	
Campbell County	Meredith (or Saltpetre)
	New Mammoth (or Cumberland Mammoth)
Coffee County	Saltpetre
	Riley Creek (or Duke)
Anderson County	Springhill Saltpetre
Claiborne County	Cumberland Mountain Saltpetre
	Tazewell Saltpetre
Carter County	Carter Saltpetre
Cumberland County	Grassy Cove Saltpetre
Cannon County	Robinson Ridge Saltpetre (or Window)
Dekalb County	Overall
	Avant
	Gracey
	Indian Grave Point

Table 4 (continued)

Fentress County	Copley Saltpetre
	Manson Saltpetre
	York
	Zarathustra
	Buffalo
Franklin County	Crownover Saltpetre
	Lost Cove
	Williams Saltpetre
Grundy County	Hubbard Saltpetre
	Fultz
	Payne Saltpetre
	Woodlee
Hawkins County	Sensabaugh Saltpetre
Hickman County	Only Saltpetre
Jackson County	Peter
Lincoln County	Kelso Saltpetre
Macon County	Saltpetre (or Lick Branch)
	Whiteoak Saltpetre
Marion County	Monteagle Saltpetre
	Nickajack
	Speegle Saltpetre
Maury County	Hobbs
	Southport Saltpetre
Montgomery County	Bellamy
Overton County	Allred Saltpetre
	Copeland Saltpetre
Pickett County	Eastport Saltpetre
Putnam County	Johnson Saltpetre
	Calfkiller Saltpetre
	Nash Saltpetre
	Petre
	Milligan
Roane County	Eblen
Robertson County	Robertson Saltpetre
Smith County	Piper
	Bridgewater
Stewart County	Tobaccoport Saltpetre
Sullivan County	Buzzard
Union County	Oaks
Van Buren County	Cane Creek Saltpetre
	Big Bone
	McElroy
Warren County	Henshaw
	Hubbards
Washington County	Keplinger
	Solomon Saltpetre
Wayne County	Ross Creek
White County	Cave Hill Saltpetre Pits
	Cherry Saltpetre (or Petre)
	Pollard Saltpetre
Wilson County	Anderson
	Valley
? County (N. Tenn.)	Abbot Saltpetre
Texas	
Bexar County	Cibolo Cave
Burnet County	Beaver Creek Cave
Uvalde County	Frio (or Verdi)
	Ney
Virginia	
Allegheny County	Mann's
Botetourt County	Perry Saltpetre
Madison County	Madison
Lee County	Minoc Saltpetre
	Neil's
Bath County	Breathing
Scott County	Lawson's
	Kern's
	Crackers Neck Saltpetre
	Parsons
Wise County	Faust Saltpetre
	Ridge
Pulaski County	Melbane Saltpetre
Smyth County	Little
	Buchanan
Rockbridge County	Saltpetre (at Natural Bridge)
West Virginia	
Pocahontas County	Lobelia
	Snedegar's
Monroe	Haynes
	Doane Ballard
	Dicksans Saltpetre
Randolph County	Crawford (or Wyner's)
	Fortlick
Logan County	Greenville Saltpetre
	Trout
Greenbriar County	Organ
	Lobelia Saltpetre
	Schoolhouse
	Alta Vista Saltpetre
	Knights Saltpetre
	Seldemirige
	Tory's
	Hoffman School
Grant County	Spring Run Saltpetre
	Cave Mountain
	Kline Gap
	Cave Mountain #2
Mineral County	Saltpetre
Hardy County	Dyer's
Pendleton County	Mill Run
	Peter Run
	Cave Knob

Figure 5. Distribution of saltpeter caves in the United States.

REFERENCES

Campbell, C.A.R. (1925). *Bats, Mosquitoes and Dollars.* Stratford Co., Boston: 262 p.

Phillips, W. B. (1901). "The Bat guano caves." *Mines and Minerals,* **21**:440-442.

Hill, C.A. (in preparation). Geology and mineralogy of cave nitrates: Univ. of New Mexico Masters thesis.

Geomorphology and Hydrogeology of the Edwards Plateau Karst, Texas

Ernst H. Kastning

The Edwards Plateau of central Texas is an upland surface formed by a thick sequence of Early Cretaceous limestone units. It represents the southern extremity of the Great Plains Province and covers an area measuring 300 by 600 km (Fig. 6). The karst region of the Plateau is comparable in size to the largest karst areas of the United States. Nevertheless, the Edwards Plateau remained the only one of these regions where extensive study and synthesis of karst landform development had not yet been done. The present research, the subject of a Ph.D. dissertation in geology at the University of Texas at Austin, and funded in part by the 1977 Cave Research Foundation Fellowship, is a systematic study and interpretation of the landforms of the

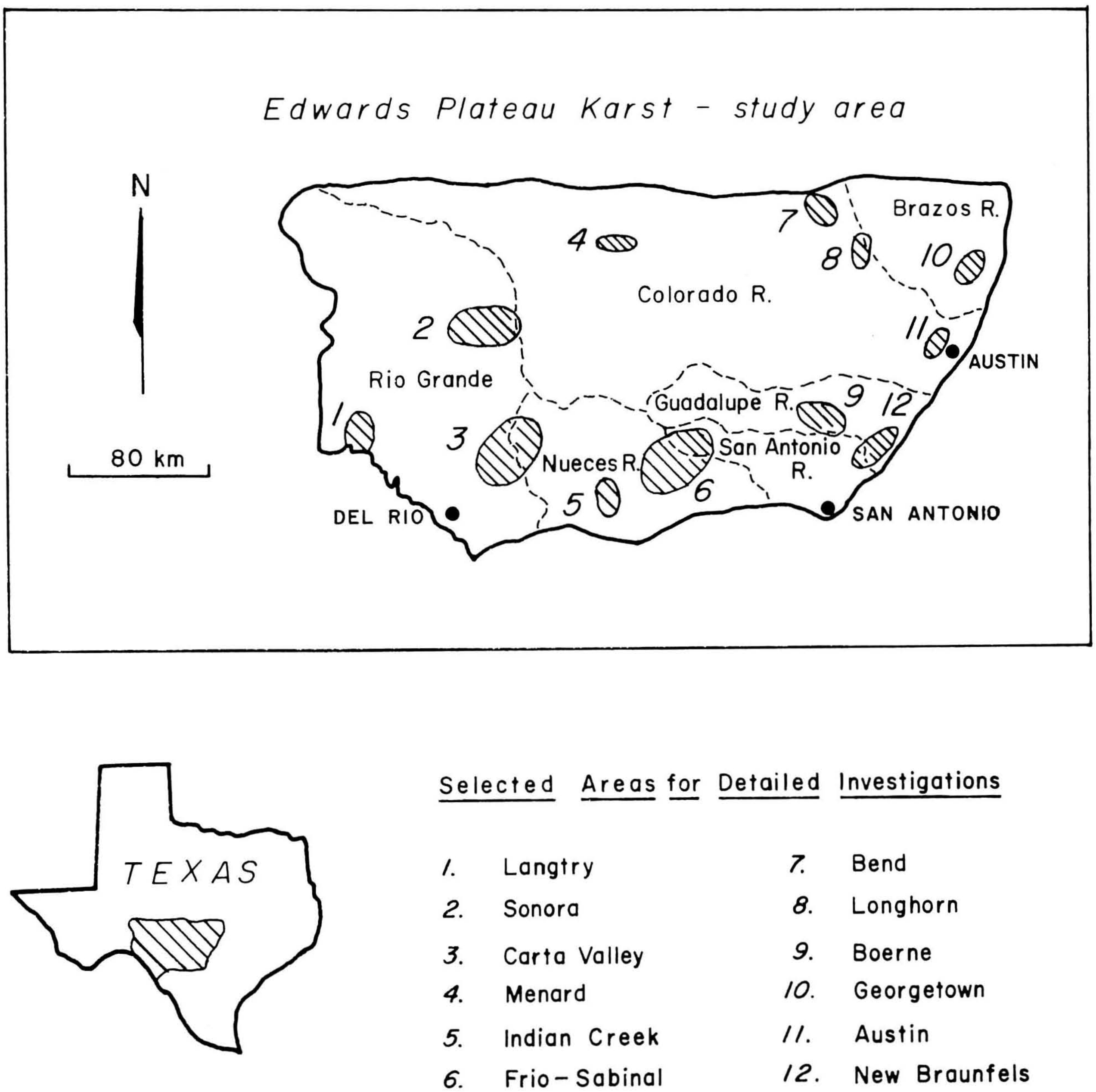


Figure 6. Edwards Plateau Karst of central Texas.

Edwards Plateau karst. The geomorphic and hydrogeologic processes during development of surface karst and caves are under investigation.

The great areal extent of the Plateau gives it a strong diversity in topography, soil cover, and hydrogeologic and climatic settings. The eastern and southern margin, marked by the Balcones Fault Zone escarpment, is deeply dissected. The northward and western interior portions are gently rolling to moderately dissected. The area is drained by six major rivers which flow toward the Gulf of Mexico. The inner part of the Edwards Plateau is geomorphically youthful and the Balcones Fault Zone marginal areas are more maturely dissected. Caves are generally irregular in form and short in length in much of the Plateau; however, long caves with active stream passages are found in areas of mature topography where efficient flow to base-level springs has developed. The study area is one of the most susceptible to catastrophic flooding in the U.S.

The large size of the study area (260 km by 210 km) makes it necessary to distribute field work into two levels of investigation. First, a dozen subareas within the overall study area have been chosen for detailed analysis (Fig. 6 and Table 5). These smaller areas contain significant karst features, particularly important caves, for which much suitable base data such as geological maps, cave surveys, hydrogeologic information, and the like are readily available. These sub-areas are distributed widely over the region and, as such, represent diverse geologic, hydrologic, and climatic settings.

Second, supplementary sites, interspersed among the sub-areas, are being investigated where they contribute significantly to the recognition of regional geomorphic trends, or where they contain isolated karst features of exceptional interest.

Present fieldwork includes mapping of caves and karst landforms. Significant progress has been made to date in the Menard, Frio-Sabinal, Bend, Boerne, Austin, and New Braunfels sub-areas. Quantitative analysis of surficial fluvial networks, structural features, and slopes is underway using topographic maps and aerial photography.

Future work will include the study of (1) topographic position of the caves relative to valley floors, (2) the role of stratigraphic position in cave development, (3) the role of karst cover and fluvial deposits on karstification and speleogenesis, (4) the possible significance of speleothem deposition and redissolution in interpreting climatic factors, and (5) the roles of semi-arid or humid climates as well as severe flooding on cave evolution.

TABLE 5
Selected geographic areas for detailed analysis in Edwards Plateau Karst. Areas correlate with those given in Figure 6.

1. *Langtry*—Some of the deepest caves of Texas have formed in the Devils River Formation, a complex of reefal and interreef materials deposited on shoals bordering the Maverick Basin. Important caves include Emerald Sink, Fisher's Fissure, Langtry Gypsum Cave, Langtry Lead Cave, Langtry Quarry Cave, and others.
2. *Sonora*—Large caves, such as the Caverns of Sonora and Felton Cave, have formed here. This area has undergone significant speleological reconnaissance in recent years, and many caves have been mapped in detail. It is typical of the semi-arid western part of the study area.
3. *Carta Valley*—Several large, structurally controlled caves are known from this area, including Deep, Punkin, Midnight, Dunbar, and Red Arrow Caves. The regional setting is similar to the Sonora area and together they represent the best known areas of the western Edwards Plateau karst.
4. *Menard*—This is the site of Powell's Cave, the longest surveyed cave in Texas (in excess of 16 km mapped). Nearby Silvermine Cave and Neels Cave, hydrologically related to Powell's, are presently under exploration and study, and a good chance exists for an integrated cave system in excess of 32 km. Preliminary geologic examination shows that these caves have experienced several distinct episodes in development.
5. *Indian Creek*—Indian Creek Cave is presently Texas' second longest cave (more than 6 km mapped). This cave is an important site for recharge of the Edwards Aquifer. Several other important caves are located nearby.
6. *Frio-Sabinal*—This area is within the most dissected part of the Plateau margin. The caves are generally small to moderate in size but many are located well above the present floors. There are many small karst springs at the bases of hills and ridges. The Balcones Fault Zone and related fracturing appear to have greatly influenced cave
7. *Bend*—This location is the site of several long caves genetically related to the incision of the Colorado River. Most notable is Gorman Falls Cave. Here, caves have formed in the Ellenburger Formation of Ordovician Age.
8. *Longhorn*—Like the Bend area, caves at this locality have developed in the Ellenburger Formation. However, they are located well above the present stream levels. Longhorn Cavern, a Texas State Park, is the most notable example.
9. *Boerne*—This area is largely within the Guadalupe River Drainage Basin and includes many long "base-level" caves such as Cave-Without-A-Name, Alzafar, Spring Creek, and Prassell Ranch Caves. Cascade Caverns, Cascade Sink Cave and Fair Hole are located in the nearby Cibolo Creek Basin.
10. *Georgetown*—Several interesting large caves have developed in this fringe area of the Edwards Plateau karst, including the extensive Inner Space Caverns. This area is within the Balcones Fault Zone.
11. *Austin*—The Austin area contains several long caves, such as Airmans Cave and Cave X. Balcones faulting has allowed extensive fracture control of cave development. Airmans Cave has many maze-like sections, perhaps indicative of flood-water development.
12. *New Braunfels*—This area is located on the Balcones Fault Zone and its caves are intimately related to recharge of the Edwards Aquifer, particularly along Cibolo Creek. Several large caves, such as Natural Bridge Caverns and Bracken Bat Cave, are located here.

Additionally, the study is (1) comparing the Edwards Plateau with other significant karst regions, (2) identifying and explaining regional trends in landforms, (3) integrating the Edwards Plateau geomorphic evolution to that of adjacent regions, (4) evaluating currently accepted concepts of karstification and speleogenesis as they related to the Edwards Plateau examples, and (5) applying the results of this study to environmental and water resource needs of the region.

The final product of the proposed study will integrate the geomorphic history of the Edwards Plateau, and, as such, will be an important step in understanding the geomorphology of the entire central Texas region. Moreover, there will be a sufficient local emphasis to enable direct application of the findings to specific parts of the plateau. This will provide basic data for further scientific studies and for water resources management of one of the country's most important karst aquifers.

Geology and Mineralogy of the Mariscal Mountain Caves, Big Bend National Park, Texas

Karen Lindsley and Carol A. Hill

Geology

The dense, gray, cherty Santa Elena limestone of the Big Bend area of Texas and Mexico contains many caves of small to medium size. In Big Bend National Park the main cave area is located along the southeastern flanks of the Mariscal Mountains near Solis. In this region seven caves occur—15 m below the top of the faulted, gently dipping Santa Elena escarpment. All of the Solis caves are small (less than 61 m), most are developed along one clay-filled (iron-rich kaolinite) bedding plane, and many trend along N50E vertical joints. The presence of solutional pockets throughout the caves and the lack of fluting or scalloping suggest a low gradient, phreatic origin for these caves. Slow moving waters near the top of the then present water table dissolved the caves along bedding plane, vertical joint intersections.

Mineralogy

Three previously unreported cave minerals were found in the Mariscal Mountain caves: darapskite ($Na_3(NO_3)(SO_4) \cdot 2H_2O$), anhydrite ($CaSO_4$) and bassanite ($CaSO_4 \cdot \frac{1}{2}H_2O$). Darapskite (intermixed with halite, NaCl) occurs as crusts, flowstone, stalactites, "flowers" and "hair." The source of nitrate, sulfate, sodium and chlorine for these speleothems is probably rat urine (amberat) that exists in close association with the darapskite-halite. The anhydrite and bassanite (with gypsum) occur as a white wall crust. Microscopic textural relationships indicate that the gypsum ($CaSO_4 \cdot H_2O$) dehydrated to bassanite and then to anhydrite. The extremely high cave temperature (maximum of 45°C) and low relative humidities (minimum of 10%) are responsible for the stability of darapskite, anhydrite and bassanite in the Mariscal Mountain caves.

Analysis of the Structural Control of Speleogenesis in Lilburn Cave, King's Canyon National Park, California

Gail McCoy

Lilburn cave is developed in a lens of marble, one of several metasedimentary lithologies that presumably are correlative with the Calaveras Formation of Clark (1976). The Calaveras Formation reflects a structural and metamorphic history that includes folding, faulting and intrusion by granitic plutons of the Sierra Nevada. This latter phase is represented locally by the Biğ Baldy granodiorite.

The karst in Redwood Canyon is characterized by few outcrops of marble. The marble is largely buried by surficial deposits, chiefly alluvium derived from the adjacent granitic and metamorphic outcrops. However, the marble and its structural characteristics are well exposed in much of Lilburn Cave. These exposures will serve as the basis for a study of structural control of speleogenesis and development of the cave.

It is proposed to map the fractures exposed in the walls, floor and ceiling of the cave. The location, orientation, frequency, continuity and type of the fractures will be compared statistically with passage orientation, morphology, and locations of breakdown and sinkholes. Of interest will be any changes in fracture patterns from the surface downward and from place to place within major areas of the cave. Reconnaissance trips undertaken during 1977 indicate that the proposed research is feasible, in that exposures of fractures are abundant throughout the 400 foot depth of Lilburn.

REFERENCE

Clark, L. D. (1976). "Stratigraphy of the northern half of the Western Sierra Nevada Metamorphic Belt, California." *U. S. Geol. Survey Professional Paper* **923**: 26 p.

Speleogenesis in the Guadalupe Mountains, New Mexico: Gypsum Replacement of Carbonates by Brine Mixing

Arthur N. Palmer, Margaret V. Palmer, and J. Michael Queen

Caves of the Guadalupe Mountains, Carlsbad Caverns in particular, have posed one of the most baffling problems of cave origin in North America. Despite the application of rather conventional theories to the problem by numerous well-known geologists, no adequate explanation has previously been given for the unusual and almost unique pattern of certain Guadalupe caves. Carlsbad, for instance, consists of irregular chambers that interconnect in an almost haphazard way, rather like the pores in an enormous sponge. Joint control is prominent, but there seems to be no true solution conduits with well-defined water sources and outlets. Levels in the cave are crude at best and appear to be related more to surfaces of sediment fill within the cave than to external geomorphic control. Even the highly varied rock type has no obvious control on the cave pattern. Although most of the cave is located within the massive Capitan reef of Permain age, parts of it extend into the bedded, relatively impure back-reef formations to the northwest, as well as to the reef talus that forms an apron of coarse, consolidated breccia along the southeastern flank of the reef.

Guadalupe caves have been attributed almost exclusively to phreatic solution because of their sponge-like pattern and because the action of vadose water is limited mainly to the deposition of travertine. Vadose solution features such as flutes are very rare, with one exception: vadose drip holes are common within the massive gypsum that occurs in isolated, irregular patches within most Guadalupe caves.

Massive gypsum is not ordinarily found inside limestone caves. What is its source and how does it relate to the origin of the Guadalupe caves? It has been previously assumed that the gypsum was deposited as beds within the caves, possibly (if it is feasible to consider a Permain age for the caves) at the same time as the extensive beds of Permian gypsum that fill the Delaware Basin adjoining the Guadalupe Mountains on the southeast. Recent evidence shows that these assumptions are incorrect.

Geologic field work begun by J.M. Queen in the early 1970's in Cottonwood Cave, located within the back-reef beds, showed that the gypsum contains the same textural features as the surrounding carbonates. Where the gypsum has not been recrystallized, many of these internal structures, such as pisolites, can be traced across knife-sharp contacts from limestone bedrock directly into the gypsum. It is clear that the limestone has been replaced by the gypsum.

A close look at the so-called "bedded gypsum" in the Big Room of the Carlsbad Caverns shows that most of it actually consists of isolated blocks that have peeled off the overlying ceiling! The gypsum contains the same textural features, including laminated breccia blocks, that occur in the limestones of the cave ceiling. Along some of the lower walls of the room, remnants of gypsum are still in place in contact with the limestone. No gypsum was found within the pores of spongework in any of the caves. In places the gypsum contains alternating light and dark bands parallel to the walls, probably representing progressive stages of gypsum replacement.

Gypsum replacement had previously been observed in thin sections of rock from the Flint Mammoth Cave System, Kentucky, but in rinds measured in millimeters and apparently of vadose origin. In the Guadalupes some of the gypsum is 10 meters thick. It almost fills some of the passages in Cottonwood Cave.

Most, if not all, gypsum replacement must have taken place in the phreatic zone, as vadose water is dissolving the gypsum today. It appears that the replacement actually pre-dates the cave origin. The process probably took place in the interface zone between fresh water that infiltrated into the exposed limestones and the underlying gypsum-saturated brines adjoining the Delaware Basin, according to the following reaction:

$$CaCO_3 + SO_4^{=} + 2H_2O -- CaSO_4 \cdot 2H_2O + CO_3^{=}.$$

Irregular and perhaps isolated zones of gypsum were formed in areas of high permeability (particularly along joints) and where the geochemical environment was favorable.

Much of the gypsum was dissolved by fresh phreatic water as the Guadalupe Mountains were gradually uplifted (probably during the Cretaceous Period), forming the basic pattern of the major caves. Irregular, disoriented gypsum blocks were left in many places. Phreatic solution of the limestone modified the outlines of the caves with features such as spongework. Further uplift subjected the gypsum to solution by vadose water, which also deposited extensive speleothems in the caves. Later re-flooding has caused local solution of travertine, limestone bedrock, and gypsum.

The Guadalupe caves owe their basic shape to the original pattern of gypsum replacement of carbonate long before the present landscape developed, and not to any of the regimes of solutionally aggressive water to which most other caves are attributed. However unorthodox, this hypothesis is perhaps the only one that adequately explains the origin of caves so unrelated to the present hydrologic setting. A more complete account of the field observations and theory is contained in the Proceedings of the 7th International Speleological Congress, Sheffield, England, p. 333-336 (1977).

The Mineralogy of Lilburn Cave, King's Canyon National Park, California

Bruce W. Rogers and Kathleen M. Williams

The Lilburn Cave System is over 12 km long and is located at an elevation of 1600 m on the western slope of the Sierra Nevada. The cave is developed in a calcitic to dolomitic marble unit in a roof pendent of Triassic(?) age. A metalliferous tactite zone occurs along the marble-granite contact. Due to this geologic setting, an unusually varied mineralogy is present in the cave.

Speleothemic minerals include: aragonite, azurite, birnessite, calcite, goethite, gypsum, hematite, hydromagnesite, malachite, rosaite(?), and witherite(?). Petromorphic minerals include: axinite, chalcopyrite, chrysocolla, diopside, epidote, goethite, hornblende, sepiolite, sphalerite, and tremolite.

Sedimentology and Stratigraphy of Clastic Deposits in Lilburn Cave, King's Canyon National Park, California

John C. Tinsley

The objectives of this study are to describe and map the sediments in Lilburn Cave and to identify contrasts in paleohydrologic conditions, changes in environments of deposition and stratigraphic relationships that can be interpreted in terms of events or stages in the evolution of the karst in Redwood Canyon, King's Canyon National Park, California. An integrated field and laboratory approach is envisioned, an approach firmly rooted in the theory and techniques employed in modern analyses of sedimentary basins. The distribution, nature and thickness of sediments will be mapped on base maps provided by the cartographers. Deposits are to be classified according to provenance, texture, lithology, depositional environment and relationship to present or past hydrologic regime; where possible, relative stratigraphic designations will be proposed. Redwood Canyon exposes granitic and metamorphic terranes; the provenance of sediment supplied to the cave is readily apparent from the mineralogy of cobbles, gravel clasts and individual grains of sediment. Primary and secondary sedimentary structures and paleocurrent indicators provide clues useful for comparing past to present hydrologic conditions and for inferring directions of sediment dispersal.

The results to date stem from reconnaissance trips undertaken during April, July and October, 1977, to investigate the feasibility of this study and to learn to navigate the complexities of the cavern system. This investigation has shown that the distinctive, very thinkly laminated, varve-like deposits of silty clay and clay are apparently the oldest sediments preserved in certain, lower portions of the cave and that these banded clays are distributed more widely than had been thought to be the case. These deposits of banded clay have been dissected by the courses of present-day streams and locally are buried by thick deposits of medium to coarse grained sand, often including gravel and cobbles, that are believed to be artifacts of present-day activity of flooding cave streams. The banded clays are known to preserve a paleomagnetic record having a duration of several thousand years (D.R. Packer and S.R. Ulfeldt, pers. comm., 1977). To the extent that the paleomagnetic data facilitate correlations between widely separated localities characterized by deposits of banded clay, the efforts to define and delineate the basin that received the clay sediments will benefit from temporal control. Arrays of chains have been buried in the sandy beds of active streams and in sandy areas known to carry flood discharges. The intent is to obtain data pertinent to maximum depths of scour and fill achieved by streams during floods of various magnitudes. A noteworthy aside is that this experiment can succeed only if it should ever rain again in California.

Effort in the immediate future will concentrate on defining the limits of the basin in which the banded clays were deposited. Comparisons of textural parameters should show trends that reflect the upper and lower limits of the basin. It is anticipated that the banded clays will become more coarse towards the source(s). The details of the appropriate conceptual model best accounting for the deposition of the banded clay deposits remain speculative. It is anticipated that a map delineating the nature and extent of the clastic deposits of the central part of Lilburn Cave should be available by early 1979. This work will compliment directly the ongoing studies of the hydrology and the paleomagnetic record of Lilburn Cave.

Regional Geomagnetic Variations as a Dating and Correlative Tool in Cave Sedimentology: Preliminary Results from Lilburn Cave, King's Canyon National Park, California

Stanley R. Ulfeldt and Duane R. Packer

The declination of the Earth's paleogeomagnetic field has been shown to exhibit regular east-west fluctuations. At Lake Windermere, England, and at Lake Michigan, U.S.A. the period of these fluctuations is 2800 years and 2090 years respectively. It is believed that these fluctuations of declination are due to oscillation of the Earth's nondipole field. The nondipole field exerts only regional influence and is the residual field which remains after subtraction of the main dipole field. At Lake Windermere and Lake Michigan similar periodic fluctuations of inclination and intensity are not present.

Fine grained sediments record the direction of the Earth's magnetic field at the time of their consolidation by a process of detrital remnant magnetization. In the process of consolidation, magnetic particles which are oriented by the Earth's field become fixed and record the direction of the magnetic field present at the time. As the sediments accumulate, a record of the variation of the Earth's magnetic field is produced.

The paleomagnetic record can be read by measuring the direction and intensity of magnetization in a series of oriented samples, a core, from the sediments. The measurement of a sample is carried out in a stepwise process of reading the magnetization with a three axis cryogenic magnetometer; cleaning the sample of possible subsequent remagnetization with an alternating field demagnetizer; and remeasuring it. The level of the demagnetization is increased at each step until the magnetic direction stabilizes.

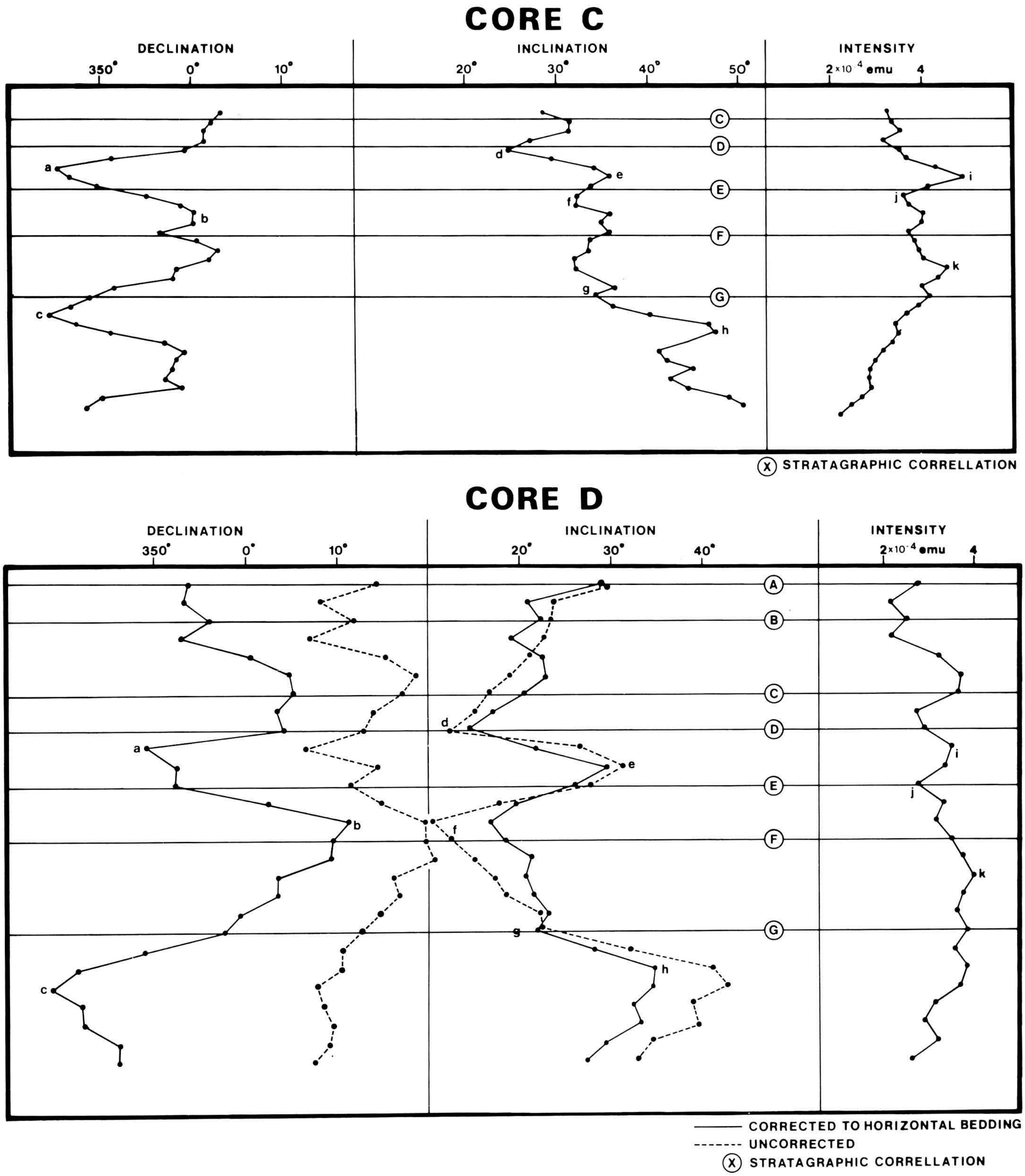


Figure 7. Plot of declination, inclination and intensity of paleomagnetic direction against depth of cores C and D from the Hexidendron Room in Lilburn Cave.

Oriented cores were collected from well stratified clays and silty clays from relict passage fills in Lilburn Cave. These cores were sampled continuously at 1 cm intervals. Plots of two of these cores at the 150 oe demagnetization level are shown in Figure 7.

Declination fluctuations of similar form to those from Lakes Windermere and Michigan are observed in these cores. Samples from one 30 cm core show at least four cycles of declination fluctuation, and samples from shorter cores from adjacent sediments contain similar fluctuations occurring at nearly the same stratigraphic positions. Fluctuations in inclination do not have as regular a period or the same period as the fluctuations of declination; however, the extremes of inclination also correlate between cores. Intensity measurements show no significant fluctuations within individual cores.

The age of the Lilburn Cave deposits is not yet determined. If the period of the declination fluctuations contained in the Lilburn Cave deposits is similar to those reported elsewhere, it is possible to derive rates of sedimentation for individual deposits in the cave. It may also prove possible to correlate the deposits throughout the cave on the basis of these declination and/or inclination variations. Both of these studies will lead to a much greater understanding of the deposition of sediment fill in caves. Also, if during further studies, material suitable for Uranium series, pollen, C14, or other age dating techniques are found, paleogeomagnetic fluctuations may provide the framework to unravel more of the cave depositional history.

Hydrology Program

Figure 8. Ephemeral discharge and recharge points in semi-arid karst of Chosa Draw, New Mexico. Note thick layers of Quaternary alluvium overlying evaporite bedrock. Photo by S. G. Wells.

Fluvial Geomorphic Responses to Ground-water Hydrology in Low Relief Karst

Steve G. Wells

INTRODUCTION

The Geomorphic System

Karst drainage basins are developed on thick sequences of carbonate rocks in the Pennyroyal Plateau of central Kentucky and on evaporite rocks in the Delaware Basin of southeastern New Mexico. These drainage basins are characterized by integrated surface and subsurface drainage. The headwaters of the drainage basins are drained by subaerial, or sinking streams; whereas, the lower portions of the basins are developed on low relief karst and are drained by solutional conduits near base level. These karst basins discharge at large springs on major surface streams. The fluvial system and its associated drainage basin developed in low relief karst are delineated in Table 6.

Conceptual Framework

The geomorphic evolution of fluvial systems developed in karst terrain is complex because changes in the hydrologic behavior of surface and subsurface drainage affect both fluvial and solutional landforms. Sinking streams discharge into subterranean drainage systems and provide a continuous source of energy for cavern development. However, changes in the hydrologic behavior of the subsurface drainage system will influence the fluvial processes and morphology of sinking streams. Thus, the concept of geomorphic feedback is applicable to fluvial drainage systems in karst: the outflow of energy of the drainage basin via ground-water drainage routes also acts as an energy input to sinking streams feeding the ground-water system.

Time and Space Aspects

Schumm and Lichty (1965) emphasize the importance of time and space considerations when evaluating cause and effect of fluvial landform development. The number of independent fluvial variables increases with shorter time spans and smaller areas considered. However, this concept is difficult to apply to fluvial systems in karst because of the integration of surface and ground-water drainage systems. That is, over long periods of time (i.e. Pleistocene), fluvial and solutional landforms are dependent upon climatic and tectonic variations which influence base level stability. However, even during shorter time periods (i.e. Holocene), the morphology of sinking stream valleys remains dependent upon the ground-water hydrology, and the morphology of the cave system is influenced by the discharge from these sinking streams. In low relief karst, fluvial and ground-water variables remain dependent upon each other with increasingly shorter time durations.

Purpose of Study

The purpose of this study is: (1) to elucidate the interdependence of surface and ground-water drainage systems through geologic time and (2) to delineate fluvial geomorphic responses to ground-water hydrology in low relief karst of varying climatic and geologic settings. This investigation is primarily concerned with ground-water effects on sinking stream geomorphology.

TABLE 6

Fluvial geomorphic systems in low-relief karst.

GEOMORPHIC SYSTEM	Process & Form
SINKING STREAM	Fluvial erosion; open channel flow; swallow hole; blind valley
BASE LEVEL CAVE	solutional denudation; conduit flow; sinkhole plain
TRUNK SURFACE STREAM	base level stability & lowering; alluviated or gravity spring

→ = outflow of energy   feedback mechanism = - - →

....

STUDY AREAS

Low relief karst which is characterized by integrated surface and subsurface drainage occurs in the Pennyroyal Plateau of central Kentucky and in the Delaware Basin of southeastern New Mexico. The low relief karst in Kentucky is developed on Mississippian carbonate strata, and the karst in New Mexico is developed on Permian evaporate strata. Both study areas are characterized by surface drainage in the form of sinking streams which discharge into ground-water drainage systems. The area of the sinking streams has little karst features; whereas, the area of the ground-water drainage is characterized by numerous sinkholes. Each sinking stream terminates in a blind valley where surface water is channelized through swallow holes into the subsurface drainage. Flow in the sinking streams of Kentucky is perennial for the larger watersheds. Runoff in the sinking streams of New Mexico is ephemeral and flashy.

RESULTS

The major results of this investigation to-date are summarized below:

1. The fluvial geomorphology of sinking streams has remained dependent on the hydrologic behavior of the ground-water through the Quaternary in the low relief karst of central Kentucky and southeastern New Mexico.
2. In the terminal reaches of the sinking streams the magnitude and frequency of flood events are increased as the flow capacity of the ground-water is often reached with moderate-sized rainfall events. The increase in the hydraulic head causes reduction of the sinking stream flow and the development of ephemeral lakes in the terminal reaches.
3. The increase in the magnitude and frequency of overbank events on sinking streams partially explains the dramatic increase in floodplain width near the terminal reaches of the sinking streams.

4. Base level lowering in the Pleistocene affected the ground-water levels and the longitudinal profiles of the sinking streams which grade to the ground-water level. Base level lowering and subterranean piracy resulted in the development of successive cave levels. Sinking streams farthest from the base level rivers project to the older, Pleistocene ground-water levels; whereas, the sinking streams closest to the major surface streams have adjusted to the lower, active ground-water level.
5. Arroyo incision and complex terrace sequences in south-eastern New Mexico are related, in part, to karst processes and subterranean piracy. Captured drainage results in complex cutting and filling of the arroyo downstream from the captured area. These fluvial responses accommodate the increased discharge and sediment load; thus, terrace sequences may vary in morphology and age along a given reach of an arroyo in low relief karst.

REFERENCE

Schumm, S.A. and Lichty, R.W. (1965). "Time, space and causality in geomorphology." *Am. Jour. Sci.* **263**:110-19.

Groundwater Hydrology of Evaporite Aquifers in Semi-arid Karst, Southeastern New Mexico

Steve G. Wells

Evaporite rocks of the Castile Formation (Permian age) are exposed subaerially in the semi-arid Delaware Basin, southeastern New Mexico. Dissolution of the Castile Formation during the Quaternary has produced well-developed karst and an integrated subsurface drainage system. These karst aquifers are recharged by ephemeral, flashy-flow of sinking arroyos and by slowly percolating water from a thick cover of Quaternary deposits (Fig. 8). These karst aquifers are controlled by vertical, extensional fractures in the headwater region and are controlled by bedding planes in the distal regions. Therefore, the hydraulic geometry of the solution conduits changes from high and narrow to low and wide down the groundwater slope. The karst aquifers have a regional slope eastward and northward toward the base level of Black River, a tributary to the Pecos River.

Vertical, extensional fractures which control groundwater flow in the headwater regions occasionally transect both the bedrock and overlying Quaternary deposits, thus indicating recent tectonic activity. These fractures, which are continuous through the bedrock and poorly consolidated Quaternary deposits, aid in the process of piping and the development of collapse sinkholes. Vertical piping produces cave systems whose ceilings are composed of the poorly consolidated Quaternary deposits rather than the evaporite bedrock.

The velocity of the karst groundwater during low discharge conditions is approximately 0.3 m /sec. Scallop sizes are being used to determine the groundwater velocity during high discharge when the conduits are filled. The specific conductance of the groundwater varies from 2100 to 2300 umhos at low flow, and the salinity is commonly 2.5 parts per thousand. Water temperatures of the groundwater range between 15° to 17° C.

Ecology Program

Figure 9. Eastern Wood Rat (*Neotoma* floridana) in its nest, at the Austin Entrance of the Flint Mammoth Cave System. Photo by W.C. Welbourn.

Fossil Packrat Middens from the Caves of the Horseshoe Mesa Area, Grand Canyon, Arizona

Kenneth L. Cole

Most dry caves in the southwestern United States contain deposits of amberat, the hardened debris left by packrats (*Neotoma* sp.). Ten caves with amberat deposits have been located in the Horshoe Mesa area of the Grand Canyon. Thus far, four of these caves have yielded deposits of late Pleistocene age.

Packrats are known to collect and store a wide variety of objects within their nests, including fragments of plants and animals living in the vicinity. Portions of the nest become middens; the rat will defecate and urinate on part of the nest, sealing plant and animal fragments within a hardened deposit of crystalized urine. If the midden is within a cave, protected from moisture, the deposit can be preserved for as long as 50,000 years. Because the rats collect a wide variety of plant and animal remains, each midden can contain 30 or more identifiable plant species and several animal species. Since the plant fragments can be radiocarbon dated, each midden provides an excellent paleoecological indicator for conditions in the vicinity of the site. In addition, the dating of packrat middens provides an insight into the past stability of the cave environment and the age of cave features.

Thus far, 16 *Neotoma* middens have been collected and analyzed from the caves of Horseshoe Mesa Area. Nine radiocarbon samples have been submitted from seven of the middens. Two dates on different materials from a midden found in Tse'an Bida Cave, 14,170 ± 470 on fir needles (A-1789) and 13,780 ± 240 on *Neotoma* pellets (A-1790), demonstrate that within the uncertainty of the radiocarbon method, this midden represents one stratigraphic event. A third completed date, 13,540 ± 170 (*Juniperus* twigs, A-1805), falls within the same late Wisconsin time range. More dates will be completed during the next year.

Tse'an Bida Cave and Crystal Forest Cave are both on the lower fringe of the Pinyon-Juniper Woodland Zone at 4700 feet (1300 m) on steep, westerly slopes. The fossil record from the packrat middens indicates a plant community very different from the modern plants in the vicinity. Around 14,700 Y.B.P. the vegetation surrounding Tse'an Bida and Crystal Forest Caves was dominated by Douglas Fir (*Pseudotsuga menziesii*) and White Fir (*Abies concolor*), although some Pinyon-Juniper elements were also present at the site. An analogous present-day plant community exists today at 7300 ft. (2030 m) on the west side of Grandview Point. The vegetational change thus represents a 2600 ft. (730 m) lowering of vegetation zones in the late Wisconsin.

The stability of at least one part of Crystal Forest Cave is indicated by the 13,540 Y.B.P. date on the midden found on a low rock bench 30 m inside the cave. Three other middens from different areas of the cave will provide additional information.

The lower entrance chamber of Tse'an Bida Cave will probably prove to be at least as stable. In addition to the 13,780 year old packrat midden, skulls and feces of the extinct Harrington's Mountain Goat (*Oreamnos harringtoni*) have been found. The mountain goat skulls, first noticed by Tom and Louise Strong, will provide the first direct radiocarbon date on this species since a Keratin horn sheath (a reliable material for dating) was still present on one of the skulls. In addition, fossil mountain goat feces will provide data on the animal's diet. Since the animal is thought to have been extinct for at least 11,000 years and was only buried 3 cm in cave floor sediment, it follows that lower chambers of Tse'an Bida Cave have been stable for at least that length of time. Also, it could be assumed that the lower chamber has been dry, with no active carbonate deposition, for at least the 13,780 years that the *Neotoma* midden has been preserved.

Studies of the Cave Crayfish, *Orconectes Inermis Inermis* Cope (Decapoda, Cambaridae). Part I: Growth

H. H. Hobbs III

Growth of decapod crustaceans is somewhat simplified to study, as it is accomplished stepwise following molting. However, data concerning growth of individual crayfishes are relatively few and have resulted almost entirely from laboratory studies, the works of Cooper and Cooper (1976) and Hobbs (1976) being the exceptions. Numerous parameters affecting growth make it difficult to interpret size increases and are briefly discussed below.

Growth data (restricted here to "increase in carapace length") for the blind, unpigmented, troglobitic crayfish *Orconectes inermis inermis* Cope were obtained from tagged individuals in Pless Cave, Lawrence County, Indiana (see Hobbs, 1971 and 1973 for a description of Pless Cave). The cave has been the site for population studies of cave crayfishes since October 1970, where mark-recapture procedures have yielded data for individual crayfish. Thus, knowledge of the growth rates of troglobitic crayfish in the cave is based on the recapture of unconfined animals in the natural habitat. As these crayfish were internally tagged, they could be recognized easily even following ecdysis. Time intervals between captures for each individual were neither constant nor predictable and growth data are based on only a single molt occurring between measurements of the carapace length (CL). Figure 10 summarizes these growth data for forty-five individuals of *O. i. inermis* (Hobbs, 1976 briefly mentioned growth based on these data). Increases were 0.2 to 3.1 mm in carapace length over a size range of 17.0 mm to 34.0 mm CL. For any specific carapace length there was a wide range in the amount of growth observed, with extremes occurring in individuals of 23 mm CL. However, the least-squares regressions demonstrate the marked decrease in growth increments that occurs as the crayfish increase in size. Furthermore, the displacement between the two regressions indicates that for any given size, females tend to increase in length significantly more at molting than males. The reasons for these differences in growth between sexes are not fully known at this time. However, data are available to indicate (unpublished data) that breeding males are much more active than females and that they are more likely to have intraspecific contacts with both sexes than are non-breeding males and females. Increased activity, aggressive behavior and occasional "clashes" with other individuals certainly dictate increased metabolic activity and thus

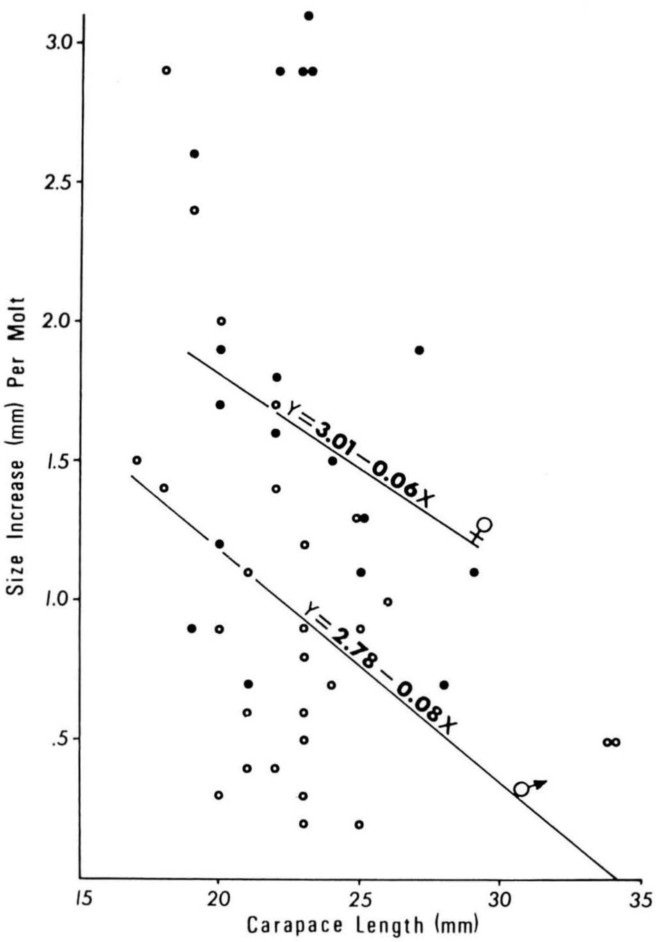


Figure 10. Scatter diagram of increase in size (mm) vs carapace length at molting for male (open circles) and female (filled circles) *Orconectes inermis inermis* in Pless Cave (lines on the least-squares regression).

increased energy demands. In addition, when contacts are made between males, appendages are sometimes lost (53 individuals—25% of tagged individuals—were males with damaged appendages). Those individuals (both male and female) with damaged or small appendages (indicating regeneration) tend to grow less than healthy animals. Also, it is apparent that females are not involved in reproducing new offspring every year as is evidenced by a lack of annual maturation of reproductive structures. However, males generally molt to Form I (breeding stage) during fall and early winter months, and in the Pless Cave population, a larger number of males than females molt twice a year, indicating higher frequencies of ecdysis and thus greater metabolic demands. Thus, due to increased physical activity associated with the reproductive cycle, generally higher frequencies of injury and molting, and production of spermatophores, male energy demands appear to be higher per year than for females. These points help explain the occurrence of numerous females of this cavernicole with a carapace length of 30 mm or more observed in many of the caves visited in southern Indiana. Moreover, in epigean species (i.e. *Cambarus (Erebicambarus) laevis* Faxon—also an inhabitant of caves) large females also are often more abundant than large males.

Specimens smaller than 20 mm CL (immatures) are underrepresented in these data. Regressive lines indicate, however, that their growth increments at molting are greater than for mature specimens, and they molt more frequently (Jegla, 1966). Hence, small and immature specimens would be expected to be present in a population only for a relatively short time following detachment from the female parent.

Until additional growth data are available for this troglobitic crustacean, no attempt is made to extrapolate typical growth increments for precise size groups nor is any attempt made to project the longevity of this species.

REFERENCES

Cooper, Martha R. and John E. Cooper (1976). "Growth and longevity in cave crayfishes." *ASB Bull.*, **23(2)**:52 (abstr.).

Hobbs III, H.H. (1971). "A study of the crayfishes and their epizootic ostracods in Pless Cave, Lawrence County, Indiana." *Ann. Rept. Cave Res. Found.*, **13**:20-21.

———— (1973). "The population dynamics of cave crayfishes and their commensal ostracods from southern Indiana." *Ann. Rept. Cave Res. Found.*, **15**:58-59.

———— (1976). "Molt cycle, size and growth in *Orconectes inermis inermis* Cope (Decapoda: Cambaridae)." *Virginia Jour. Sci.* **27(2)**:44 (abstr.).

Jegla, Thomas C. (1966). "Reproductive and molting cycles in cave crayfish." *Biol. Bull.*, **130(3)**:345-358.

Ecology and Evolution of Carabid Cave Beetles

Thomas C. Kane

This past year's work has included a continuation of field studies on *Neaphaenops tellkampfii* and three of the *Pseudanophthalmus* spp. as well as more detailed laboratory studies of the population genetics, feeding behavior and reproductive characteristics of some or all of these species. The genetic data collected to date on *N. tellkampfii* suggest that it has levels of variability and similarity consistent with those of surface invertebrates, and as such is unlike any other terrestrial cave invertebrate from central Kentucky yet studied. Preliminary results on feeding for *N. tellkampfii, P. pubescens* and *P. menetriesii* suggest that coexistence among these species may be maintained through size selective predation. If this indeed proves to be the case, it may support the observed body size character displacement reported by Van Zant and others.

Ecological Genetics of Cave and Spring Isopods

Edward A. Lisowski

Knowledge of the population genetics of cave animals is essential to the further development and refinement of the theories of the evolution of cave animals as well as the evolution of complex, stable communities. Caves, with their simple communities, are excellent natural laboratories in which to study the relationships between ecology and genetics. In a general sense, the effects of resource availability and utilization, ecological diversity, competition, and predation on the genetic structure of populations can be investigated.

This investigation is studying the relationships between the genetic structure of a population and specific ecological and geographic parameters. The relevant questions to be answered in this study include: (1) Do populations of aquatic cave invertebrates have lower genetic variability than populations of related epigean invertebrates? (2) Are there high levels of genetic similarity between conspecific geographically distant cave populations? Can the effects of gene flow and selection on these levels be distinguished? (3) What level of genetic difference exists between congeneric cave species and does this suggest that the species are monophyletic or polyphyletic in origin? and (4) What are the effects of ecological diversity and of resource availability and utilization on such aspects of genetic structure as heterozygosity and the number of alles at a locus? Is there character displacement of allele frequencies when congeneric cave species occur in the same stream?

In order to answer the questions presented above, the following techniques of investigation are being employed:

(1) Four spring populations of the epigean isopod *Lirceus fontinalis* Rafinesque and four cave populations of the hypogean isopods *Asellus alabamensis* (Strafford, 1911) and *A. stygius* (Packard, 1871) are being examined.

(2) For each of the species, two populations from the Central Kentucky Karst, one population from southern Illinois and one population from the Mitchell Plain of Indiana are being sampled.

(3) Thirteen protein systems of each individual are being assayed using the techniques of gel electrophoresis. The genetic variability in surface and in cave populations will be compared, and the level of genetic similarity among populations of the same species and among the cave species will also be examined.

Competitive exclusion, niche separation and genetic distance are of particular interest when the two hypogean species occur in the same cave stream. Thus, ecological data of each population are being collected, and the effects of resource availability and utilization and of ecological diversity on genetic structure are being investigated. This study will provide a firm basis for further electrophoretic studies of the evolutionary relationships of surface and cave isopods. With these additional studies it will be possible to determine if the cave isopods are monophyletic in origin or if they are the result of multiple invasions of subterranean waters by epigean forms.

This research is aided by a grant from the Cave Research Foundation.

A Tale of Two Spiders

Thomas L. Poulson

Two linyphiid spiders have a common ancestor but were restricted to caves at different times in the past. Different historical and current patterns of food and physical variability, predictability, and rigor are constraints which have resulted evolutionarily in different patterns of bioenergetics, foraging, and life history (Fig. 11). *Phanetta subterranea* occurs near entrances and is flexible in its rates of metabolism, development, and reproduction and can be said to be a time efficient r maximizer. *Anthrobia monmouthia* was historically faced with very restricted food supplies and now food influx is limited in its deep cave environment. It has low and relatively inflexible rates of metabolism, development, and reproduction and can be said to be a resource efficient species that minimizes its maximum losses.

In a past CRF Annual Report (1975, p. 39) I gave preliminary data on the spiders which showed body shape, egg size and number, size-frequency distributions, and rough responses to baiting which increased prey density. This last year's lab studies, in concert with continuing field studies of population size and structure, have given much more insight into the contrasts in species biology of what I have variously called r+ vs r− and time vs resource efficient and live fast, die soon vs live slow, die late and r-selected vs K-selected species. The major insight gained is that *Phanetta* is flexible and can be almost as resource efficient as *Anthrobia* when pressed. This is shown in Figure 12 for metabolic efficiency and in Figure 13 for reproduction.

Figure 14 shows that *Phanetta* is generalized, relative to *Anthrobia*, in habitat, community, and niche relationships. The seasonal fluctuation in habitat risk and the high proportion of large predators both make the high reproductive rate of *Phanetta* adaptive. The variability between and within caves in micro-climatic risk, predation, and prey abundance and type make their flexibility adaptive also.

Anthrobia is restricted to deep cave areas of permanently high humidity, and the substrate-community, predators and prey are much the same within and between caves. There is no expansion of habitat in areas where *Phanetta* does not occur, so this habitat restriction is probably because of the thin exoskeleton that makes *Anthrobia* subject to desiccation. The thin exoskeleton can be seen by the collapsed pedipalps and shrunken abdomen in Figure 15.

The long evolutionary isolation in caves for *Anthrobia* has resulted in decreased flexibility and extreme resource efficiency as well as in the reduced exoskeleton and eyes seen in Figure 15.

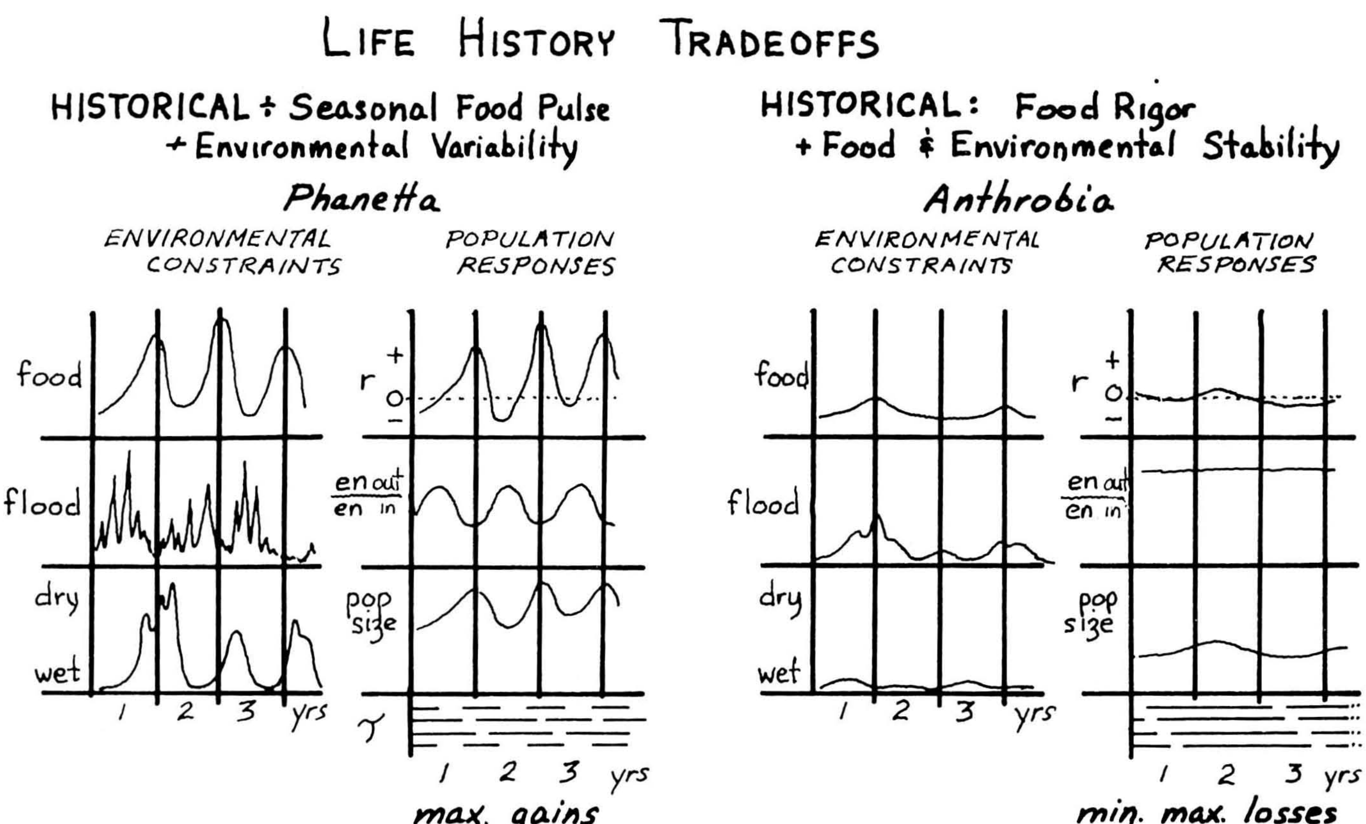


Figure 11. Under population responses r refers to the compound interest rate of population growth, en out/en in refers to efficiency of food conversion, and T refers to generation time (note how it fluctuates for *Phanetta*).

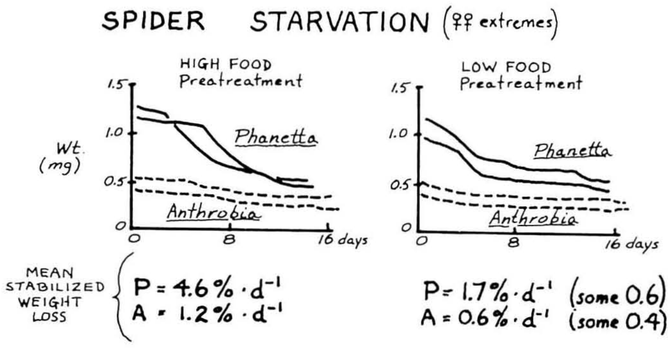


Figure 12. Rate of weight loss during starvation reflects the efficiency of energy conservation. The stabilized rates are calculated for the time after 6 to 7 days. The plateaus early in the experiment reflect use of fat which has a high energy yield per weight. Note that *Phanetta* is much more variable than *Anthrobia* but that some individual *Phanetta* are as resource efficient as the average *Anthrobia*.

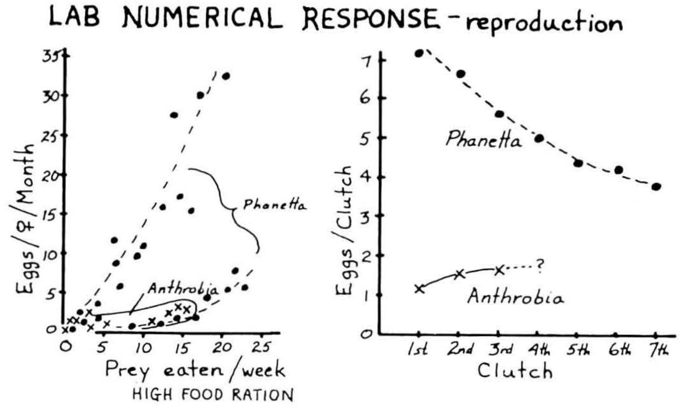


Figure 13. *Phanetta* is much more variable in its reproductive response than *Anthrobia*. This is partly due to decreasing clutch size with age for *Phanetta*. This is the simplest explanation for the low curve for fall-collected *Phanetta* as compared to spring-collected spiders shown in the left panel. Under low food rations *Anthrobia* does not change eff output, but, because of larger eggs is two times as efficient as *Phanetta* in weight of eggs produced per weight of prey eaten.

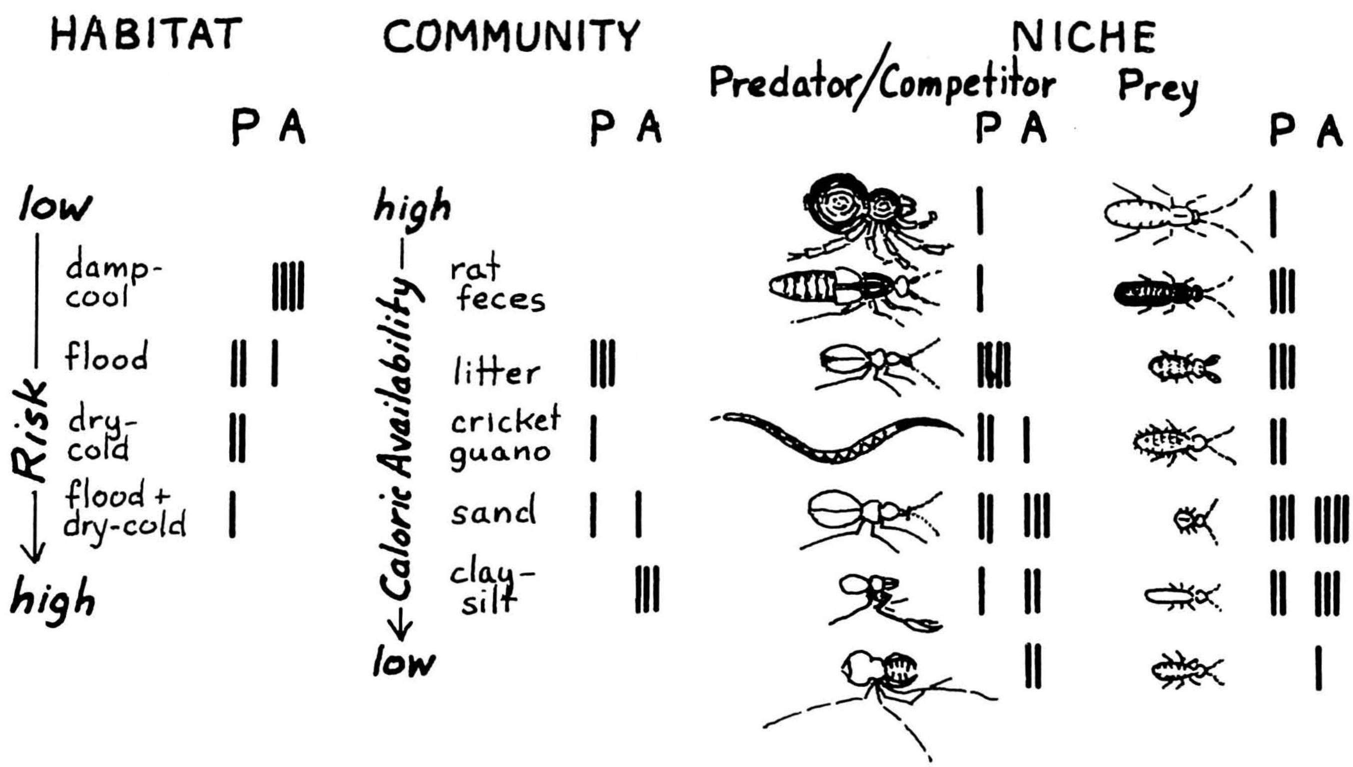


Figure 14. *Phanetta* (P) is broader than *Anthrobia* (A) in habitat, in occurrence across component communities, and in niche relationships. The high and variable reproductive response for *Phanetta* (Figs. 10, 12 and 14) is related to seasonal risk and to the types and abundances of predators which prey on adult spiders making their survival low and variable. Their collembola prey are larger and more numerous than for *Anthrobia*. Many of the predators that occur with *Anthrobia* are small and rare and as such are more important as competitors, especially with young spiders, than as potential predators.

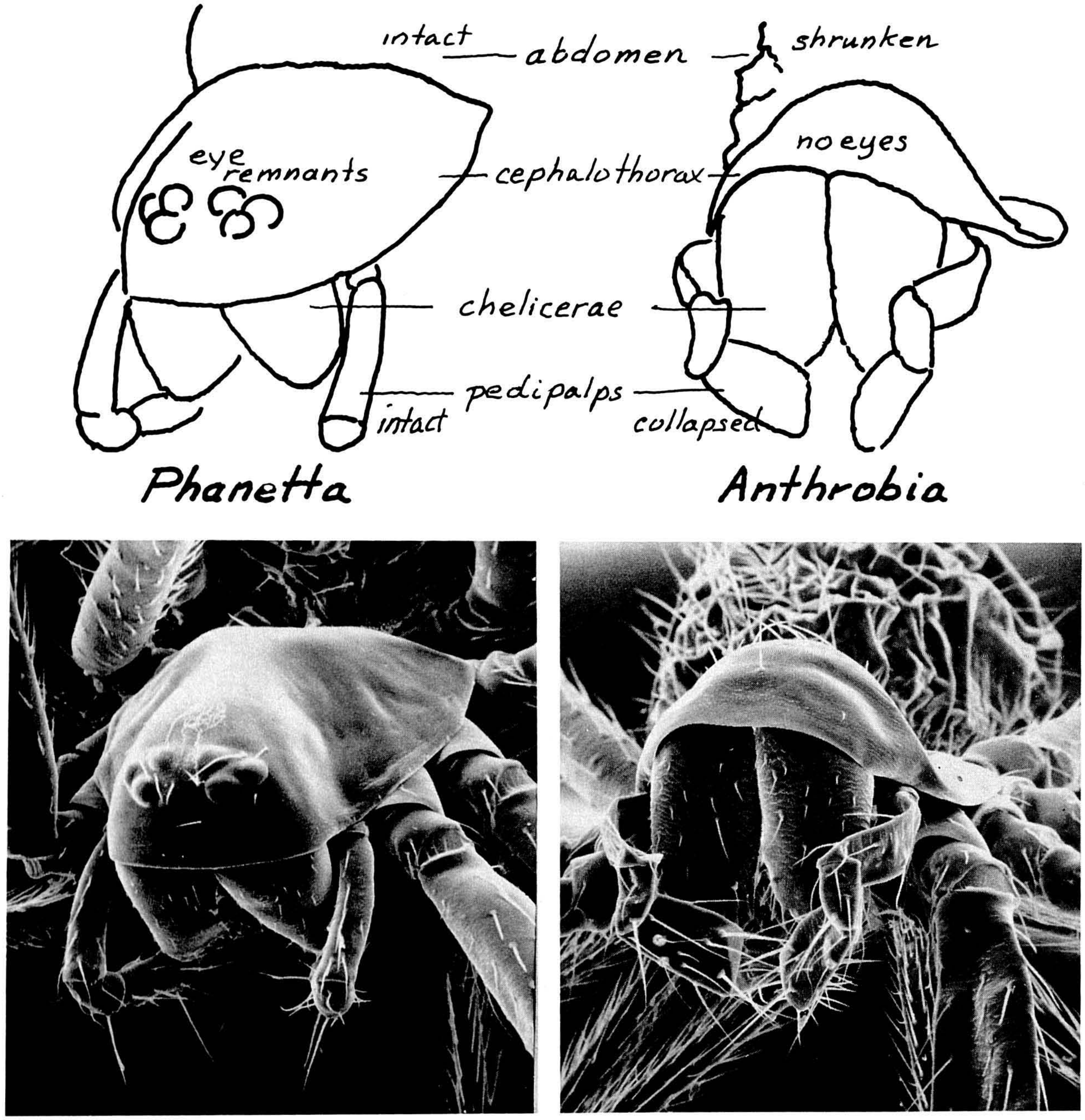


Figure 15. Scanning electron micrographs show the lack of eye remnants and thin exoskeleton, indicated by collapsed pedipalps and shrunken abdomen due to vacuum preparation for SEM, in *Anthrobia*. Both reflect the longer evolutionary isolation in the permanently dark and damp deep cave zones for *Anthrobia*. In live *Anthrobia* the thin exoskeleton is seen as a light body color and is important in restricting it to damp habitats.

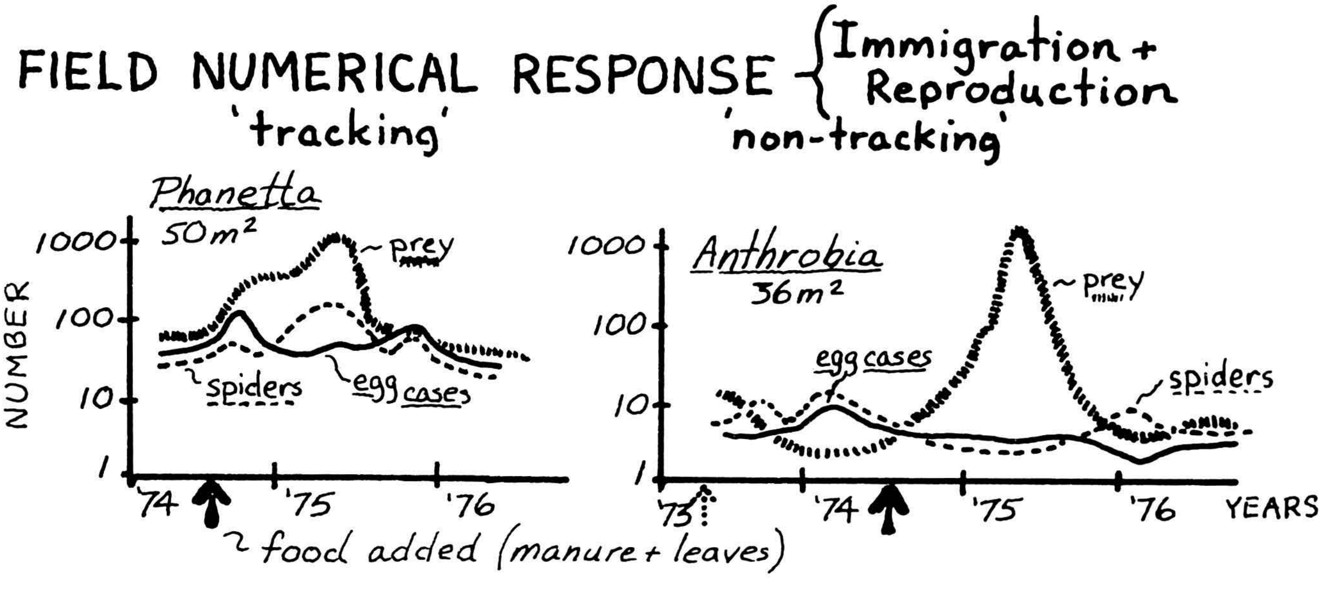


Figure 16. The lack of tracking of induced increases in food for *Anthrobia* is related to the low abundance and lack of seasonality of prey that they have been exposed to evolutionarily (see text) and to the risk of adult mortality by going to prey concentrations where many large predators occur. The prey are collembola and the predators are carabid beetles (Fig. 13).

This lack of flexibility, seen in Figures 12 and 13, is most evident in nature by the lack of immigration and reproduction when local prey densities are increased several hundred fold by addition of leaf litter and manure. The litter and manure are applied to areas about a meter away from a wall edge, which harbors one of the best known populations of *Anthrobia* (Fig. 16). Under similar conditions *Phanetta* shows its flexibility by obvious tracking, and other predators, such as carabid beetles, show a clear increase in density as collembola build up around the leaves and manure. The rationalization for lack of tracking by *Anthrobia* is based on the lack of high reproductive rate and associated long lifespan and resource efficiency that evolved under periods of even more extreme food lack in an earlier glacial epoch. As with other long-lived species, any extra mortality for adults will be selected against since population survival depends on adults spreading their reproductive risk through time. Thus, they avoid high prey densities because these are associated with high risk from predation. The reproductive risk must be spread because the perennially low food supply constitutes a severe energetic bottleneck for newly hatched spiderlings which, despite their relatively large size compared to *Phanetta*, cannot endure food deprivation anywhere near as long as adults. This problem is evidenced both by the relatively low number of young in relation to egg case density in the field and the problems of raising young in the lab.

Survey of the Cave Fauna of the Guadalupe Escarpment Region, New Mexico.

W. Calvin Welbourn

Twelve caves were examined in the Guadalupe Escarpment Region in 1977. Ten of these had not been previously examined. Five caves were in Carlsbad National Park, three in the Lincoln National Forest, and four on Bureau of Land Management lands.

With more than 65 caves in the Guadalupe Escarpment Region and 10 caves in other parts of New Mexico examined for invertebrate cave fauna, the number of species has reached to more than 125. Of these, more than 100 species have been found in the Guadalupe Escarpment Region.

This year the manuscript on the biology of Ogle Cave and Slaughter Canyon, Carlsbad Caverns National Park was completed. Work progressed slowly on the preparation of a comprehensive list of the cave fauna of the Guadalupe Escarpment Region and New Mexico.

Future work will be to complete a manuscript on the cave fauna of New Mexico and continue field work in the Guadalupe Escarpment Region.

Survey of the Cave Fauna of Buffalo National River, Arkansas

W. Calvin Welbourn

Twenty-four caves and two springs at Buffalo National River were examined for cave fauna during three field trips (March, July, and October, 1977). The field work in March was conducted by Mr. Donald E. Coons. Although many of the specimens are still being studied, there are at least 83 species, representing 4 phyla and more than 30 orders. 18 of these species were vertebrates, including the Grotto Salamander, *Typhlotriton spelaeus*. Several undescribed species were found.

The majority of the cave fauna were troglophiles (33%) and trogloxenes (32%), with troglobites (11%) and accidentals making up the remainder of the animals. Most of the vertebrates were trogloxenes; whereas, the majority of the invertebrate species were troglophiles and troglobites.

Small samples of soil and organic material (leaves, twigs, guano, etc.) were collected for berlese apparatus. Preliminary examination of these samples indicates considerable variation in species composition between each sample. All samples contained collembola, mites and insect larva along with other invertebrates.

Future plans are to complete identification of specimens collected in 1977. I hope to continue field work at Buffalo National River with emphasis on examining a few caves in detail.

Archeology and Anthropology Program

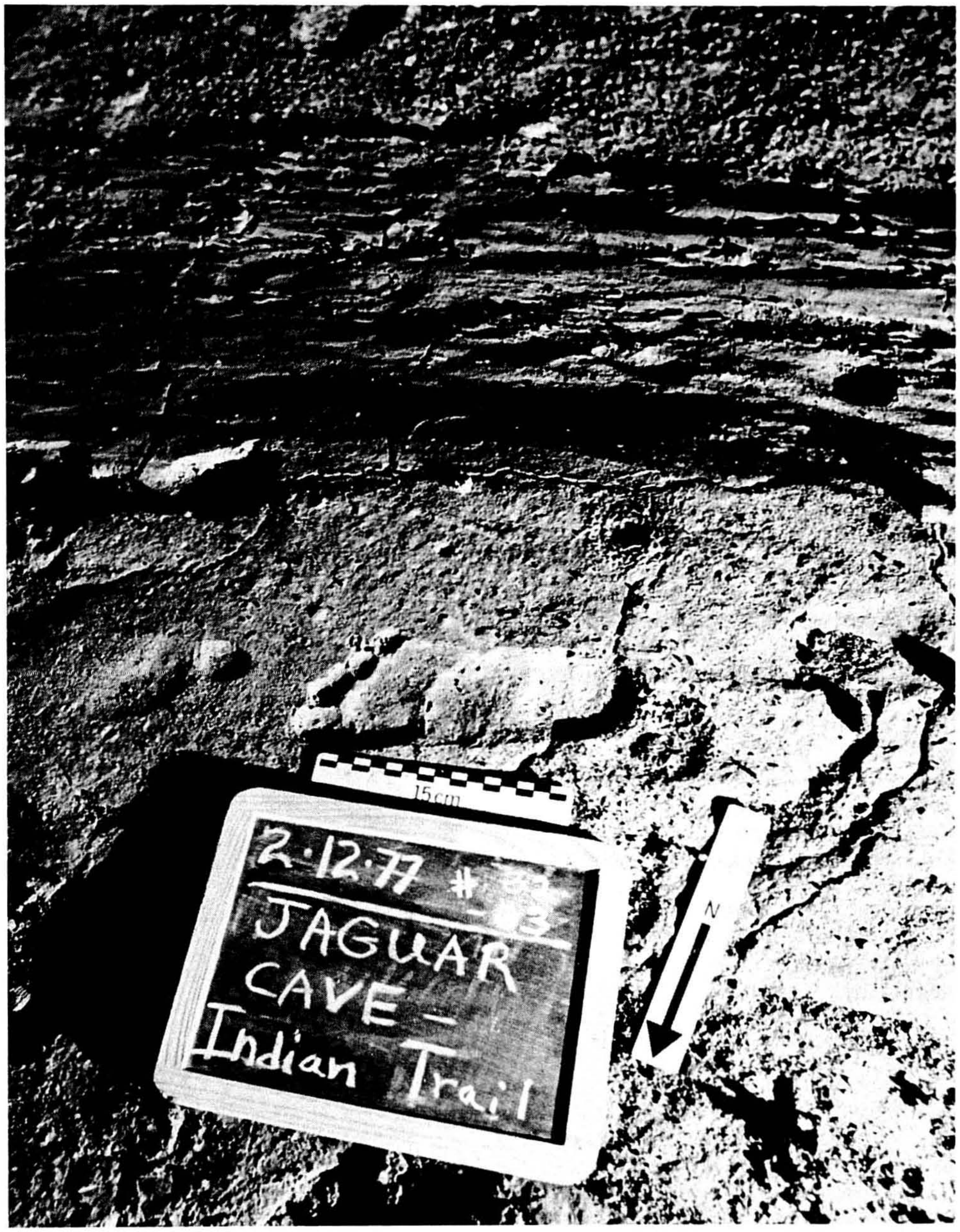


Figure 17. Prehistoric footprints along Indian Trail in Jaguar Cave, Tennessee. These footprints as well as other archeological remains are under study by Dr. P. Watson and Dr. L. Robbins. Photo by R. Brucker and M. Elliott.

Cave Research Foundation Archeological Project and Shellmound Archeological Project, 1977

Patty Jo Watson

In May, 1977, the combined projects received a grant (#RO-26228-77-371) from the National Endowment for the Humanities in support of our research in and around Mammoth Cave National Park and in the shellmound area near Logansport, Kentucky (the Big Bend of the Green River). The primary focus of our work is on the subsistence patterns of the prehistoric cavers and shellmound dwellers. We are especially interested in their use of plants because—as noted in the 1975 and 1976 CRF Annual Reports—the shellmound people were cultivating cucurbits (squashes or gourds; these are tropical plants originally domesticated in Mesoamerica several thousand years earlier than they appear in Kentucky) more than 4000 years ago. From the Green River shellmounds and from the somewhat later materials in the caves of Mammoth Cave National Park we have excellent evidence for prehistoric diet at the critical time period spanning the beginnings of horticulture in this region.

Archeological activities in 1977 were considerably varied but can be summarized as follows:

I. Mammoth Cave National Park

At the request of Superintendent Amos Hawkins, K. Carstens, W. Marquardt, and P. Watson directed archeological survey of three areas where NPS construction was scheduled to take place: two spots in the Residential Area, and the strip of territory that will be excavated to lay a water line into the Park from Park City. The work was done in December, 1976, and in March and June, 1977; no archeological materials were found on the surface in any of these zones.

On December 11, 1976, Mark Elliott led a photo trip into the N survey of Lower Salts (Figs. 18, 19, & 20) to document the size and shape of these complex, intertwined canyon passages, most of which have been explored by the Indians.

Two radiocarbon determinations for the Mammoth Cave mummy ("Lost John") were obtained by the Smithsonian Radiocarbon laboratory and relayed to P. Watson by phone (March 9, 1977) from Dr. Robert Stuckenrath:

SI 3007 A	matting from beneath the body	445 ± 75 B.C.*
SI 3007 C	intestinal tissue	A.D. 15 ± 65*

L. Robbins and P. Watson were given permission by Chief Interpreter Steven Smith to collect another small sample of matting to submit for chemical analysis. We suspect the preservative put onto the body may have contaminated the matting beneath Lost John and caused the discrepancy in the two dates. The matting fragment was collected on May 31 but results of the analysis are not yet available.

At the request of Chief Interpreter Steven Smith, two of Ken Carstens' students from Northern Kentucky University—Sheila Meuthing and April Kerley—donated their expertise and several days of their time during the last week of May, 1977, to reorganizing, cataloging, and stabilizing the historic and prehistoric study collections at the MCNP Visitor Center. On June 20, also at the request of Steve Smith, P. Watson presented a slide talk on archeology of the Mammoth Cave area at the MCNP Visitor Center.

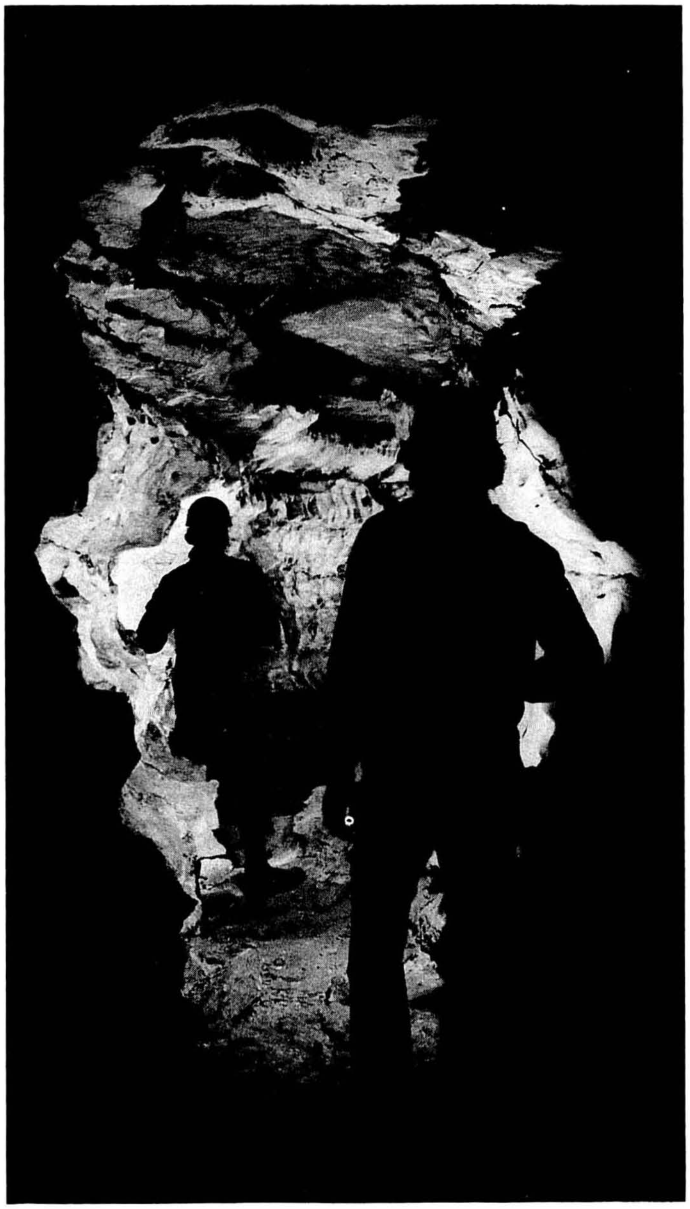


Figure 18. Passage in Lower Salts, Mammoth Cave National Park, in Kentucky. Photo by M. Elliott.

On October 9, 1977, palynologist Vaughn Bryant of Texas A and M was given a guided tour of part of Upper Salts. He is working on pollen from about 50 paleofecal specimens collected in Salts Cave and wanted to see the places from which they came.

---

* All radiocarbon determinations in this report are uncalibrated, based on the Libby half-life and 1950 base date.

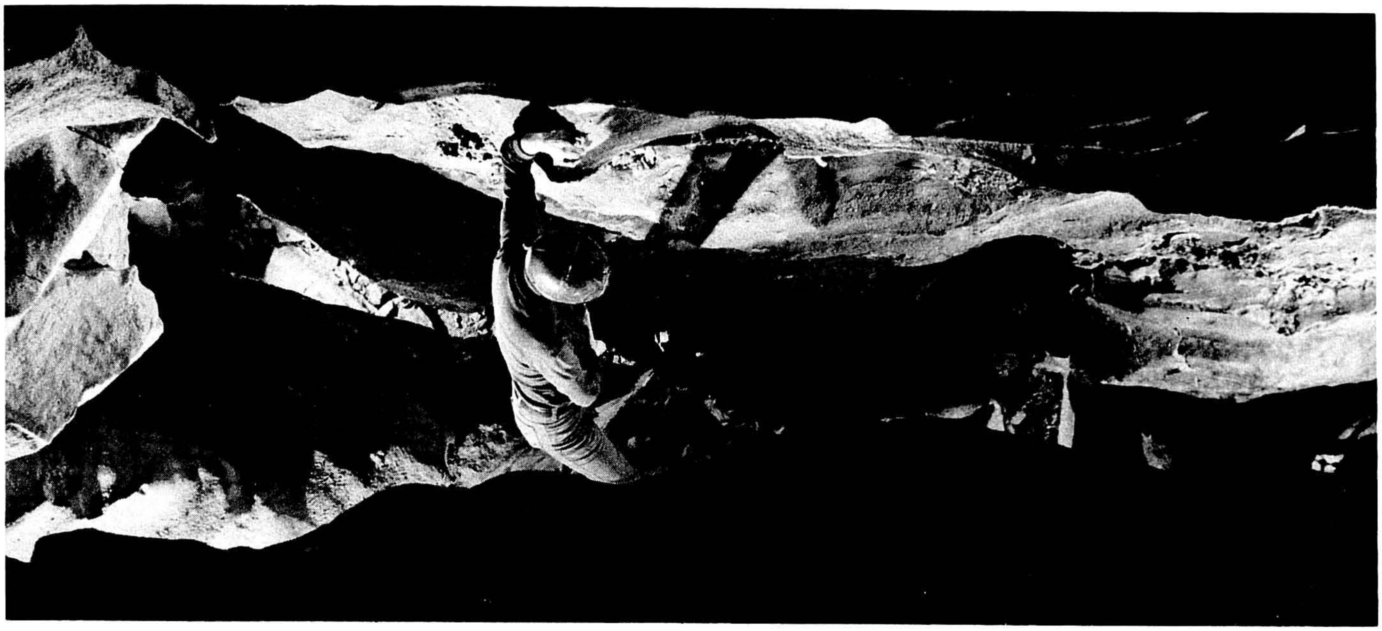


Figure 19. N Survey in Lower Salts, Flint-Mammoth Cave System. Photo by M. Elliott.

On November 2, 1977, the University of Georgia Radiocarbon Laboratory released (once again by phone, with a follow-up letter) a series of four radiocarbon dates on samples from archeological sites in and near MCNP. These are:

UGA 1837	GRS 18	Patch Shelter	1425 ± 100 B.P. A.D. 525
UGA 1838	GRS 12	Blue Spring Hollow Rockshelter	820 ± 80 B.P. A.D. 1130
UGA 1839	GRS 21	Crumps Cave, A-4-1	1920 ± 150 B.P. A.D. 30
UGA 1840	GRS 21	Crumps Cave, A-8-1	2365 ± 95 B.P. 415 B.C.

Ken Carstens was pleased to find the dates were close to what he expected and hoped, on the basis of the artifacts from the sites and levels in question.

II. Northern Tennessee

In November, 1976, and in February, May, June, and September, 1977, we made trips to Jaguar Cave—the Tennessee cave briefly described in the 1976 Annual Report (p. 46)—to continue recording the human footprints and the paleontological remains found by NSS cavers last year (Fig. 21). Ron Wilson organized the paleontological trips, and Pat Watson and Louise Robbins organized the archeological ones. Stalwart support was provided by several NSS cavers and CRF Joint Venturers, both regular and archeological. Pat and John Wilcox masterminded the first detailed mapping of the footprints on a highly successful trip (Feb. 19, 1977).

We have now measured a total of 127 individual footprints and have casts of feet belonging to 6 different individuals (there were probably 9 of these prehistoric spelunkers).

Three radiocarbon dates on bits of cane charcoal from Indian Trail (or Aborigine Avenue), as the footprint passage is called, and from the main trunk near the entrance to Indian Trail were released by the Smithsonian Radiocarbon Laboratory:

SI 3003	Indian Trail, survey stations 1815-1816-1817	4410 ± 75 B.P. 2460 B.C.
SI 3005	Tremendous Trunk between stations 403 and 404	4530 ± 85 B.P. 2580 B.C.
SI 3006	Tremendous Trunk between stations 403 and 404	4695 ± 85 B.P. 2745 B.C.

Excellent photos were taken of the footprint passage by Roger Brucker with the assistance of Mark Elliott (Figs. 17 and 22). We are very grateful to Bill Deane, Lou Simpson, and their caving colleagues for introducing us to this remarkable archeological situation and for providing us with guide service and maps. The owners of the land over the cave—Mr. J. C. Copley, Mr. J. L. Williams, and Ms.s Lera and Loma Pile—have been exceedingly kind and hospitable.

III. Indian Cave on the Mammoth Onyx property near Horse Cave, Kentucky

Thanks to the interest of Mrs. Ruth Pohl and William T. Austin, salvage excavation was carried out in a rock shelter on the Mammoth Onyx property during December, 1977. Unfortunately the deposits had been badly disturbed by vandals. However, a small flotation series was recovered as well as a few sherds, numerous chert flakes, and some fragments of animal bone. Near

Figure 20. Complex passages of N Survey in Lower Salts, Flint-Mammoth Cave System. Photo by M. Elliott.

the site is a chert outcrop, probably used by the aboriginal inhabitants of the rock shelter as a source of raw material. There is some interest now among archeologists and physicists in trying to find source areas for specific chert fragments in archeological sites by means of trace element analyses. We are exploring the possibility of obtaining such information for the MCNP area.

IV. Activities of the Shellmound Archeological Project [*SMAP*] *in the Big Bend of Green River near Logansport, Kentucky*

As indicated in the 1975 and 1976 Annual Reports, members of the CRF Archeological Project—under the direction of W. Marquardt and P. Watson—have been carrying out work in the Big Bend that is closely related to our projects in and adjacent to MCNP. On the present evidence, accumulation of the well known shellmounds along the banks of the Green River some 40 to 50 miles west of Mammoth Cave occurred prior to and during the time of maximum prehistoric spelunking and mining in the great caves within the Park. We first began work on the shellmounds to obtain botanical remains (by flotation of the archeological deposits; see pp. 61-63 of CRF Annual Report for 1975) that we could compare with the very interesting and detailed plant use information present in the dry caves of Mammoth Cave National Park. We were very surprised when project archeo-botanists, Gary Crawford, Clark Erickson, and Richard Yarnell found fragments of cucurbit rind in several levels of the two shellmound sites we test-dug in 1972 and 1974. Our radiocarbon dates and the locations of the cucurbit remains are summarized below (Table 7).

In May and June, 1977, SMAP was joined by a geo-archeologist, Julie Stein, who is an advanced graduate student in the Center for Ancient Studies at the University of Minnesota. She is working on the recent (geologically speaking) history of Green River, especially in the Big Bend area, and is concerned to relate that to the depositional history of the shellmounds. Her fieldwork to date (summer and early fall, 1977) includes a great deal of soil sampling on and around the mounds (Bt 5 and Bt 11; the Carlston Annis and the Russell mounds) by means of a hand-operated coring device; much geomorphological recon-noitering in and near the Big Bend; consultation with soils and geological personnel in Mammoth Cave National Park (Jim Quinlan and his assistants), Morgantown, Bowling Green, Lexington, and Louisville, and the collection of two sediment cores (each one well over 8 m in length) from the bottom of Taylor Lake (a cutoff meander of the Green River inside the Big Bend). Julie's advisor, Professor H. E. Wright, Jr., directed the

TABLE7. Proveniences of Cucurbit Remains and Radiocarbon Determinations for Bt 5 (the Carlston Annis site) and for Oh 13 (the Bowles site).

PRELIMINARY RESULTS: DATA NOT FINAL

Site	Cucurbit Proveniences (trench and level)	Radiocarbon Determinations & Proveniences (trench and level)		
Bt5	A IV-9 (possible seed, id. not certain) 85-100 cm below surface			
		A I-8 105-120 cm	4040 ± 180 B.P. 2090 B.C.	UCLA 1845B
		A I-10 135-150 cm	4250 ± 80 B.P. 2300 B.C.	UCLA 1845A
	C 1-3 (rind frags.) 40-50 cm			
	C 1-6 (rind frags.) 80-90 cm			
	C 1-20 (rind frags.) 220-235 cm			
		C 3-5 75-85 cm	3530 ± 80 B.P. 1380 B.C.	UCLA 2117B
	C 13-7 (rind frags.) 80-95 cm			
	C 13-8 (rind frags.) 95-110 cm			
	C 13-11 (possible seed, id. not certain) 130-140 cm			
		C 13-12 137-148 cm	4500 ± 60 B.P. 2550 B.C.	UCLA 2117I
		C 13-15 161-171 cm	2515 ± 80 B.P. 565 B.C.	UCLA 2117D
Oh 13		A 2-2 (burial just below plow zone)	1820 ± 300 B.P. A.D. 130	UCLA 2117E
	A 3-5 (rind frags.) 65-80 cm			
		A 3-7 93-100 cm	2420 ± 200 B.P. 470 B.C.	UCLA 2117F
		A 3-11 140-160 cm	3440 ± 80 B.P. 1490 B.C.	UCLA 2117G
	A 3-12 (rind frags.) 160-175 cm			
	A 3-15 (rind frags.) 200-210 cm			

(Botanical identifications by Gary Crawford and Richard A. Yarnell; radiocarbon determinations are uncalibrated, and are calculated on the basis of the Libby half-life and the 1950 base date. The dates were funded by a Washington University Faculty Research Grant).

Figure 21. Entrance to Jaguar Cave, Tennessee. Photo by R. Brucker.

highly successful coring operation which took place October 8, 1977. We do not yet know, however, how old the sediment is nor what its pollen content may be.

The most recent addition to the SMAP staff is Professor David Baerreis, an environmental archeologist from the University of Wisconsin, one of whose specialties is the use of tiny snails from archeological sites as climatic indicators. Professor Baerreis, together with several student archeologists, spent the weekend of October 14-16 collecting modern snails for a comparative collection from the Big Bend region.

As always, our work in the Big Bend was greatly enhanced by the enthusiastic interest and kindness of the residents of Logansport. In particular, we are grateful to the owners of Bt 5 and Bt 11—Waldemar Annis and Marvin Russell—for their active cooperation with our work, and we are deeply in debt to John L. Thomas, manager of the Thomas Grocery and Postmaster of Logansport, for his fathomless hospitality, aid, and assistance.

V. Future Work

We plan to continue the activities outlined in this summary report in both Mammoth Cave National Park and the Big Bend. We still have a great deal of recording of aboriginal debris to do in both Upper and Lower Mammoth, as well as some unfinished work in Salts Cave. In addition, as soon as Ken Carstens completes writing up results to date (his dissertation is scheduled for completion this year), we hope to continue archeological surface survey in and near Mammoth Cave National Park.

In the Big Bend we plan to undertake further excavation at one of the shellmounds and also to pursue with Julie Stein and David Baerreis the paleo-environmental work initiated in the last few months.

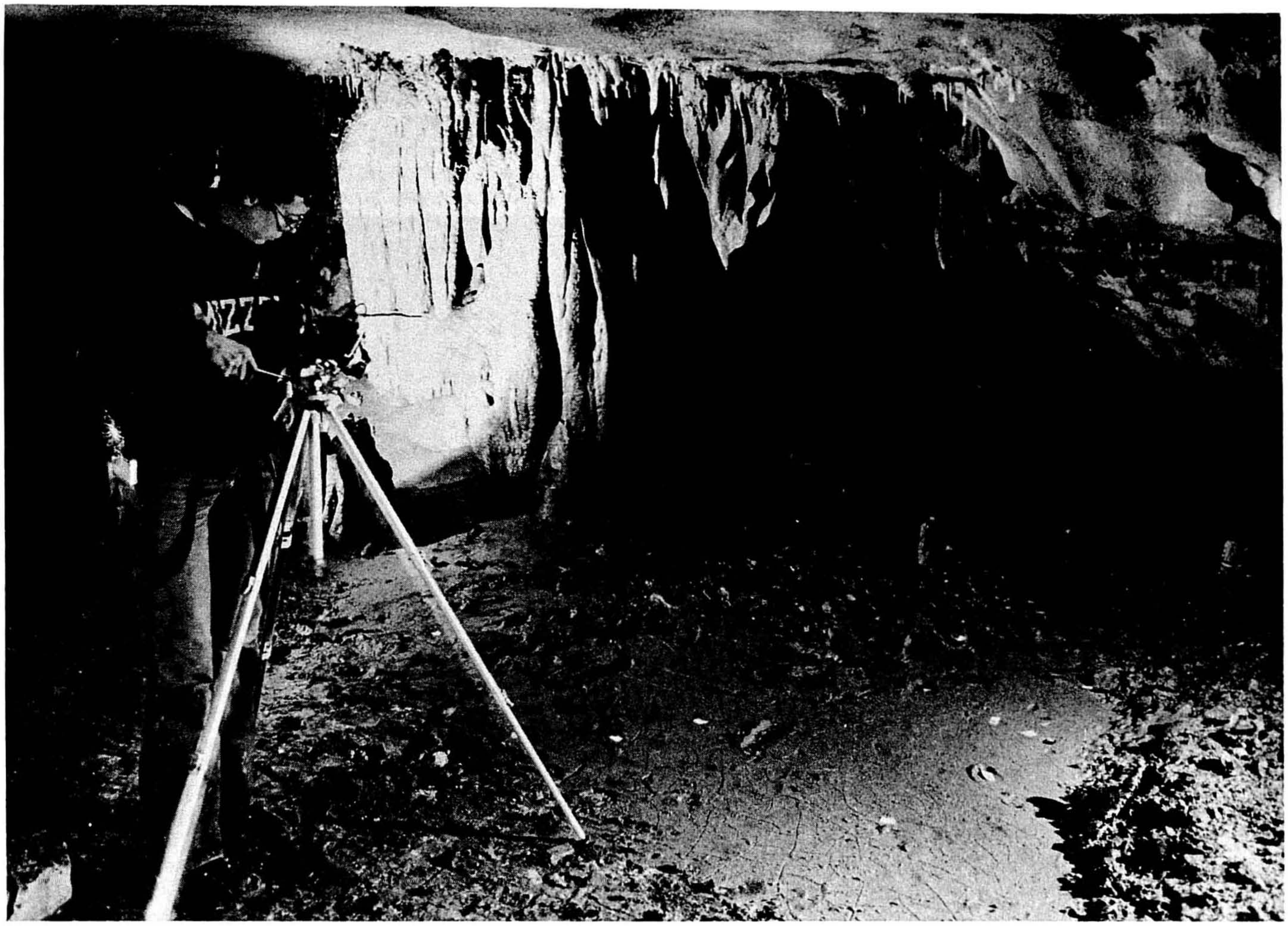


Figure 22. Prehistoric footprint area at end of Indian Trail in Jaguar Cave, Tennessee. Photo by R. Brucker.

History Program

Figure 23. Cave photographer Wade Highbaugh made this photo of Floyd Collins in 1924 or 1925. The original glass negative is in the possession of Ellis Jones, Cave City, Kentucky.

Historic and Cultural Aspects of Floyd Collins

Roger W. Brucker and Robert K. Murray

William Floyd Collins was born in 1887, lived his life on Flint Ridge, and died in Sand Cave in 1925. Perhaps the most widely known of Kentucky cave explorers, efforts to rescue him while trapped in Sand Cave resulted in sensational press coverage. This project is aimed at gathering together the widespread historical accounts of Floyd's entrapment, together with oral reports of Kentucky natives and others who knew Floyd.

Between 1957 and 1964 CRF members James Dyer, Louise Storts, E. Robert Pohl, and others conducted over 120 hours of interviews with area residents. Some 40 hours of this material relates directly to Collins, his early life, and life in general on Flint Ridge. During 20 years of exploration, nearly every passage that Floyd visited in the Flint Ridge area has been revisited (Floyd wrote his name on the walls). Old photos have been located. The cave itself has been studied.

What is emerging is an accurate, less sensational account based on historical research and investigation. The objective is to place Floyd Collins in a cultural context of the 20's and to strip away the distortions and myths from repeated tales of his adventures.

Saltpetre Mining Sites in Historic Mammoth Cave

Duane De Paepe

Little has been known of the areal extent of Mammoth Cave circa 1812 nitrate mining, and current investigations have been a compilation of fragmented data from multiple sources. Two research media were employed: primary literature search and careful field reconnaissance. Blane (1828), who probably received his information from the former superintendent of the saltpetre venture, stated that 500 pounds of saltpetre were manufactured daily at Mammoth Cave. Meriam (1844), directly involved in the nitre operations, wrote that the cave was extensively mined during the period 1810 to 1814. However, we now know that periodic cottage production had occurred in the entrance vestibule since the late eighteenth century, at which time Imlay (1797) declared that "this earth is discovered in greater plenty on the waters of Green River, than it is in any other part of Kentucky." Field observations continue in Mammoth and other park area caves to distinguish circa 1812 nitrate mining sites from later periods of excavations, which have continued into contemporary times. It is expected that these studies will lead to a saltpetre mining features taxonomy, which will help to distinguish these features from other types of cultural disturbance in cavern sediments.

Rock stacked walls, along one or both sides of a passage mined for "petre dirt" are a diagnostic trait of saltpetre mining. At one time, essentially continuous rock stacked walls spanned the distance from Houchin's Narrows to Methodist Church. Examples are still to be found along Broadway, Cyclops Gateway and Audubon Ave. Locally, Coach Cave and Dixons Cave also exhibit this feature. Sometimes, the on-site hand sorting of loose rock fragments from the dry "petre dirt" resulted in a shallow pit, ringed with the accumulated debris. Harvey's Ave. and Blue Spring Branch contain this type of mining evidence, as do several other area saltpetre caves. Regarding Harvey's Ave., Lee (1835) stated that "it is only remarkable for the heaps of broken stones in different places, which appear to have been sifted." Mid-way along Blue Spring Branch, investigation was conducted of the extensive shallow pit mining with attendant gravel sorting beds, a consequence of soil sifting. Sediments in the bottom of these excavations reacted strongly to a nitrate spot test. The shallow pit mining here is identical to sites in Harvey's Ave., with circular rock stacking. The Gothic-Gratz Ave. complex certainly was also heavily mined but intense visitor developments have since removed any evidence. Old reports (Anon, 1816) describe a plank bridge into Gothic Ave. from Main Cave, over which workers could transport heavy sacks to the hoppers below. Meriam (1844) notes "the earth dug up in the Gothic Ave", and Bird (1837) documents the interesting account of a lost miner working in the Salts Room off Gratz Ave. In the Gothic Ave. extension opposite Booth's Amphitheatre, investigations in July, 1977 discovered clear mattock marks, the only known nitre mining tool imprints in Mammoth Cave. The tool blade resembles those noted from Long Cave in the park and other examples from Kentucky and Indiana saltpetre caves.

A large scale, intensive labor effort was employed in the spacious cave avenues near the leaching hoppers, with similar methods being used simultaneously by the same management in adjacent Dixons Cave. Much smaller area mining ventures, such as Forestville Saltpetre Cave, were forced to expend efforts at mining in sinuous crawlways, thus greatly impeding profitability. It may be concluded that the most significant of Mammoth Cave's mining sites were in relatively close proximity to the two vat complexes. Main Cave, beyond the Star Chamber, was apparently unproductive because of massive floor breakdown. That new potential sites were sought out is illustrated by Bird (1837), who told of the miner lowered into Mammoth Dome from Little Bat Ave. in search of prospective deposits. An economic maxim applied to saltpetre mining mandates that leach water be transported to the collected "petre dirt," rather than conversely. In effect, the terminus of the leach water supply at the hoppers caused the location of the most significant mining sites. Only the advanced technology of the pumping stations permitted the successful application of this factor. The original pre 1812 saltpetre operation was highly restricted, as were most nitre caves of the period, because the miners were forced to carry the bulky cave sediments to the water source, in this case at the mouth of the cavern where the original vats were located. The owners of Mammoth Cave, stimulated with the profitability of their production, saw no loss in demand in the foreseeable future and were therefore prone to consider expansion of mining sites deeper into the cave. Again, the location of new leach water sources must have influenced their thinking. Following deeper

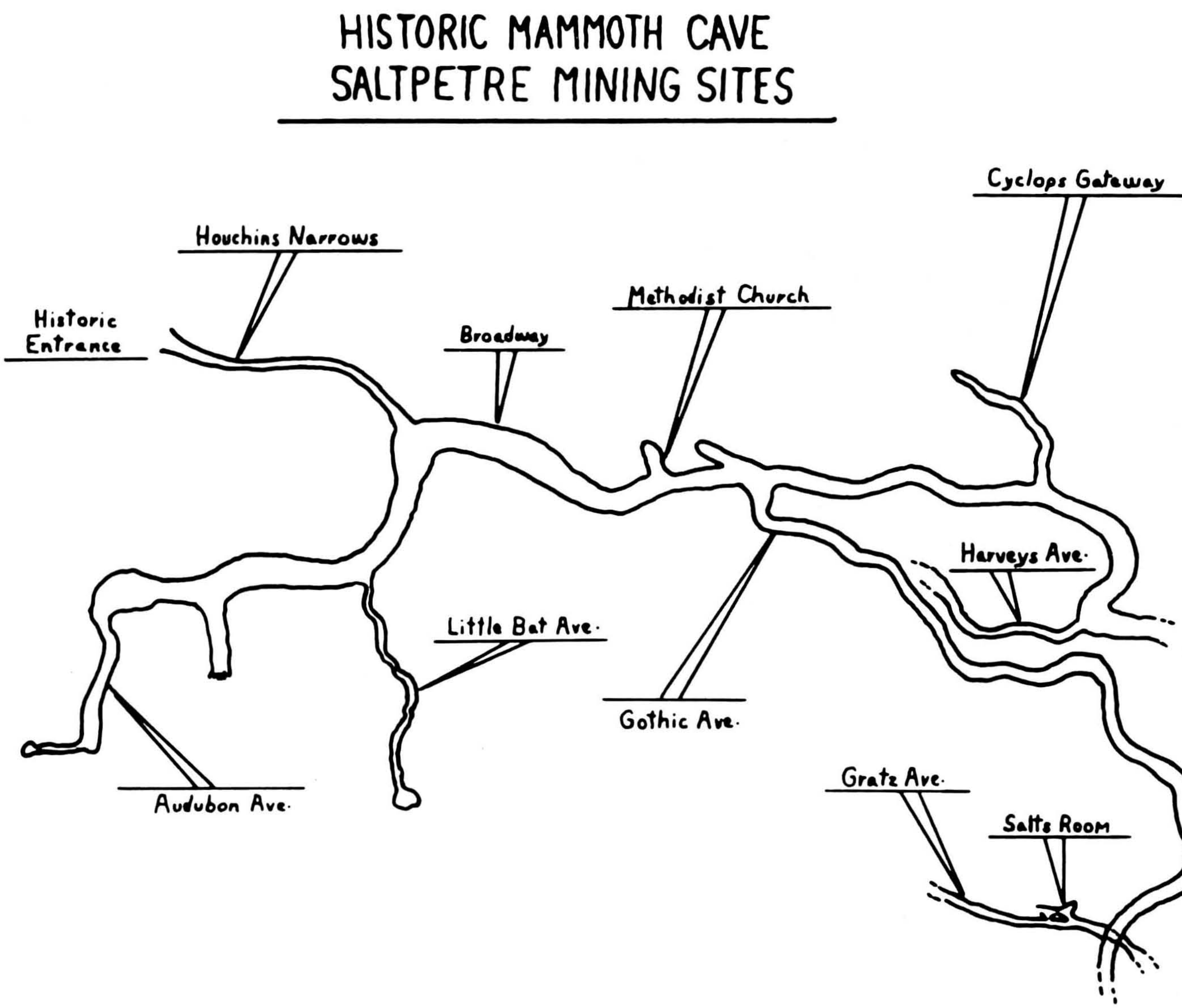


Figure 24. Historic Saltpetre Mining sites in Mammoth Cave.

into Main Cave, the Cataracts furnish the next possible water source and it is in this area where several mining sites were attempted. Several early accounts allude to saltpetre mining in distant extensions of the cave, and one detailed report (Anon, 1810) interestingly notes the "nitrate of lime in much greater abundance than before. . ." Blue Spring Branch is apparently the furthest penetration into the cave by mining activity. The Side Cuts along Main Cave were documented as also being mined by Hovey and Call (1912) but all signs of these dig sites have since vanished.

The locations of historic saltpetre mining sites are given in Figure 24. The survey of these saltpetre mining sites in Mammoth Cave has shown that their areal distribution corresponds rather precisely with that of the circa 1810 "Eye-Draught of the Mammoth Cave" map (De Paepe, 1976) which functioned as a prospectus to attract capital investment in an expansive exploitation of the nitrate resources.

REFERENCES

Anon (1810). "The subterranean voyage, or the Mammoth Cave, partially explored." *The Enquirer*, Richmond, Va., **6(109)**:61, April 20, 1810.

Anon (1816). "Mammoth Cave." *Massachusetts Spy or Worcester Gazette*, Worcester, Mass., July 17, 1816.

Bird, Robert Montgomery (1837). "The Mammoth Cave of Kentucky." *The Atlantic Monthly Magazine*, May-June, 1837: 434-530.

Blane, William N. (1828). *Travels Through the United States and Canada*, Baldwin and Co., London: p. 266.

De Paepe, Duane (1976). "Survey interpretation of the Circa 1810 'An eye-draught of the Mammoth Cave' map", *Cave Research Foundation 1976 Annual Report*: 49-50.

Hovey, Horace C. and Richard E. Call (1912). *Mammoth Cave of Kentucky*, John P. Morton & Co., Louisville: 60-67.

Imlay, Gilbert (1797). *Topographical Description of the Western Territory of North America*, Printed for Debrett, London: p. 135.

Lee, Edmund F. (1835). *Notes on the Mammoth Cave, to Accompany a Map*, James & Gazlay, Cincinnati: p. 23.

Meriam, Ebenezer (1844). "Mammoth Cave" *New York Municipal Gazette*, **1**: 317-321, Feb. 21, 1844.

Evaluation of the Hauer Collection, National Park Service

Duane De Paepe

The Hauer collection represents an important assemblage of saltpetre artifacts, now housed at Mammoth Cave National Park. An evaluation of the collection in consideration of the Scope of Museum Collection Statement for Mammoth Cave was made during July, 1977 to determine interpretive and research criteria. Examples of several implement types are directly applicable to the Mammoth Cave regional nitrate mining period. Among these are a short handled iron bladed mattock, tool imprinted clay samples, lighting materials, wooden pry bars and paddles. Specific specimens were recommended for inclusion in future visitor interpretive diaramas in the park.

The History of the Peoples and Caves of Flint Ridge, Kentucky

Stanley D. Sides

In 1971, an active field program was initiated to record systematically the names and dates written in the caves of Flint Ridge and to document their exploration history. An article resulting from this effort was published in *The Journal of Spelean History*. Colossal Cavern was seemingly discovered in July of 1895, when Pike Chapman or others discovered Grand Avenue by entering Adair-Woodson Cave and exploring beyond Colossal Dome. The history of commercial development beyond Colossal Dome, however, has remained problematic.

A deed filed in the Edmonson County Clerk's office on August 28, 1895, gives L. W. Hazen a one-third interest in Adair-Woodson Cave. The owners, in consideration of Hazen's exploring and clearing passageways in the cave, gave this interest and also total control of commercial development to Hazen. Four months later, Hazen sold his interest to the Louisville and Nashville Railroad, embroiling all parties in litigation.

Cave passages around Colossal Dome and the Pearly Pool Route were studied in 1977. Several significant dates were recorded at the top of the breakdown at the "Grand Avenue of Flowers" (Hovey, 1912 Map, Fig. 25). Apparent commercial visitor names and dates can be found from August, September, and October of 1895. No earlier dates have been found in the cave, except in the Bedquilt area. From this it seems clear that Hazen indeed developed this section of the cave quickly, and that the Passages in Adair-Woodson Cave were suitable for tourist travel in August, 1895. Visitors probably ended their tour at the breakdown, where their names and dates were recorded. The trail was later blasted and dug beyond into the Pearly Pool Route.

In 1978, Adair-Woodson Cave will be examined for names and dates in an attempt to further decipher the history of the development of commercialization of Colossal Cavern.

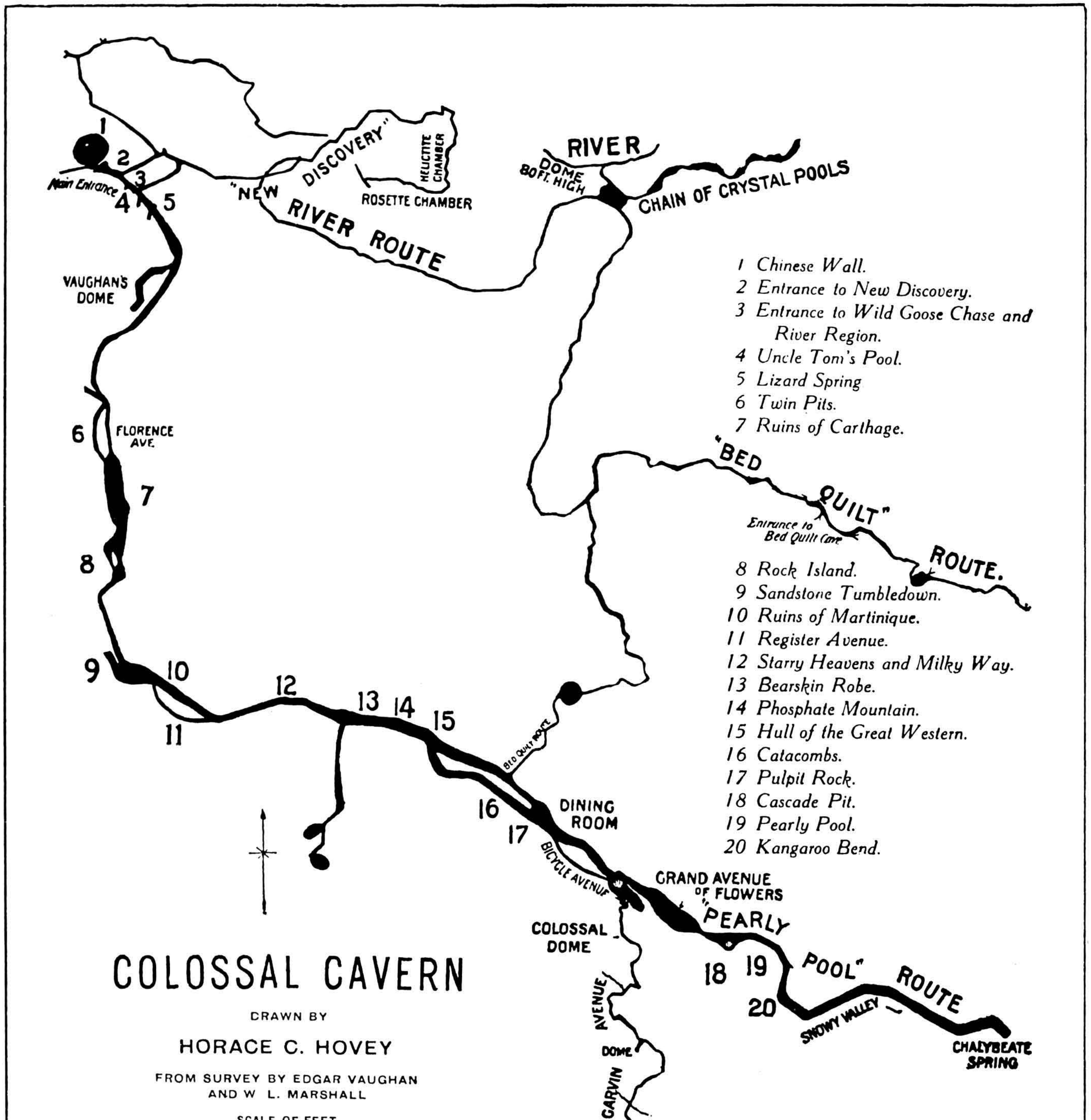


Figure 25. Map of Colossal Caverns, Mammoth Cave National Park, drawn by H. C. Hovey in 1912.

REFERENCES

Sides, Stanley D. (1971). "Early Cave Exploration in Flint Ridge, Kentucky: Colossal Cave and the Colossal Cavern Company." *Journal of Spelean History* **4**:63-69, 74.

INTERPRETIVE PROGRAM AND SPECIAL PROJECTS

Figure 26. Solutionally-enlarged fracture in Cretaceous limestones, Barra Honda Karst, Costa Rica. Photo by S. G. Wells.

Horseshoe Mesa, Grand Canyon National Park: Progress Report

Robert H. Buecher

In March, 1977, the Cave Research Foundation started a baseline study of the caves on Horseshoe Mesa, Grand Canyon National Park. The study is to run one year and the final report is due in March, 1978. The study is intended as a comprehensive, descriptive survey of all the caves in a restricted area of the Grand Canyon. The caves of Horseshoe Mesa are believed to be representative of those found throughout the Grand Canyon in the Redwall limestone. The study is expected to provide a data base to aid in the management and preservation of caves in the Grand Canyon. At the conclusion of the project, a report will be given to the Park Service. It will contain descriptions and comparisons of: the geology and mineralogy of all of the caves in the study area, the geologic and stratigraphic controls of the caves, the archeological significance of the caves, and fauna found in the caves.

Horseshoe Mesa was chosen for its accessibility, varied structural geology, and known caves. It is the easy accessibility that has made the Mesa a popular spot for hikers. This has led to increased management problems for the Mesa. At present, 10 caves are known on, or adjacent to, the Mesa (Fig. 27). Total aggregate passage is approximately 3700 feet. Survey work is concentrating on mapping all unmapped caves and upgrading existing maps to modern standards. To date, we have mapped five caves and upgraded two of the old surveys. Surface surveys are being done to provide the exact locations of each cave and to show the physical relationships between the caves.

Geology

Our work is beginning to show some of the relationships between the caves and bedrock geology. With the exception of Tse-an-Cho, all of the caves are located in the upper ⅓ of the Redwall limestone, 140 ft to 160 ft below the surface of the Mesa. Seven caves on the west side of the Mesa are associated with a minor fault. They stretch almost continuously for 1100 feet. Parts of the ledge near these caves appear to be the remains of an old cave passage, with old cave sediments and old flowstone exposed.

Archeology

Eight of the caves have been examined for archeological material. All but two have shown prior use, dating from mining/tourism use in the 1890's. These include dates, wooden ladders and modifications of entrances. Only two of the caves examined have shown any evidence of prehistoric use. Split twig figurines were found in one cave in the early 1950's. These figurines were dated at 3000-4000 B.P. Utilized flakes and ceramic fragments were found in the talus below one of the caves. Prehistoric use of the caves on the Mesa appears to have been quite selective. We hope to be able to determine the factors which attracted prehistoric man to certain of the caves.

Biology

Five caves have been closely examined for cave fauna. Eleven species of invertebrates have been found, including cave crickets, spiders, collembola, mites, psocopteran and beetles. One of the beetles is a new cave-adapted species described by Triblehorn in 1975 from specimens collected in 1953 and 1954. Results so far suggest that the cave fauna is limited by moisture rather than food input to the caves.

Survey and Assessment of Cave Resources at Buffalo National River, Arkansas

R. Pete Lindsley

The Buffalo National River is a new park with approximately one half of the lands presently owned by the National Park Service. Except for a handful of caves, the cave resource at the Park is almost unknown. The objective of this project is to provide the National Park Service with accurate information on the cave resources. Data gathered on the project will be used as an essential input to the management of the cave resource. In this way the cave managers can both provide safety to the Park visitors and preserve the unique underground ecosystems contained within the caves.

Goals of the Buffalo River Project include compiling existing data on the caves from literature and local cavers, describing and assessing the major caves, compiling a list of biological species within selected caves and providing data for each cave on a cave inventory form. A slide program on the cave resource has been prepared and several of the caves have been surveyed.

No new major caves have been discovered. However, numerous small caves have been inventoried and the possibility of major caves being found in the future exists. The majority of the caves checked have been located away from the river. By December, 1977, over 40 caves and other Karst features were inventoried, biological data were gathered on 25 caves, a list of cave fauna was compiled, and 48 miles on the Buffalo River were examined for caves. Future work will be to continue the cave inventory and survey of cave fauna.

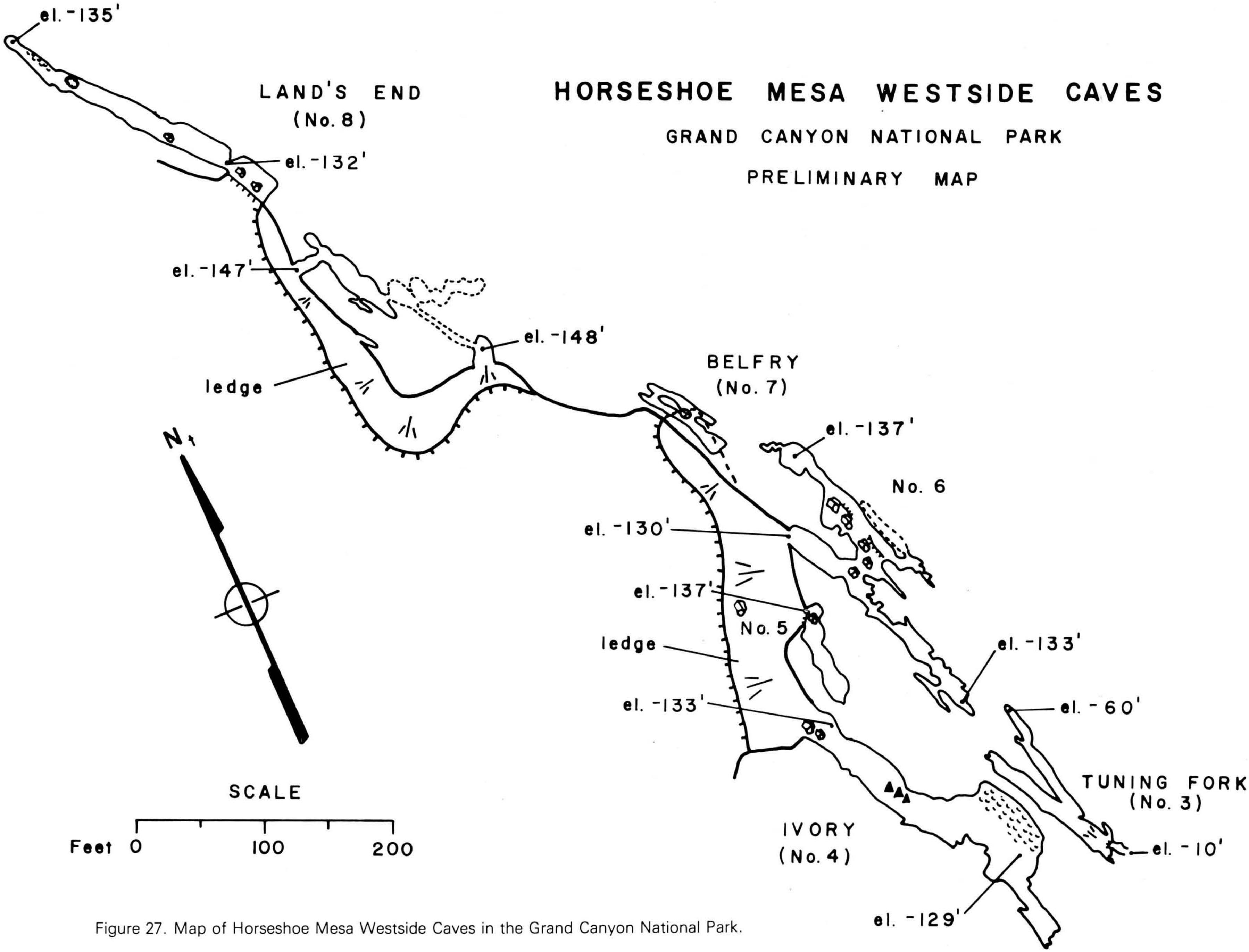


Figure 27. Map of Horseshoe Mesa Westside Caves in the Grand Canyon National Park.

The Lilburn Cave Project, King's Canyon National Park, California

Stanley R. Ulfeldt

Research in Lilburn Cave and the surrounding karst has been conducted under a National Park Service Natural Science Research Project from 1968 to 1976 and is continuing under Cave Research Foundation auspices.

Physical Setting

Lilburn Cave is situated in Redwood Canyon, Kings Canyon National Park, California. The Redwood Creek drainage is entirely within the park and has no habitation. The cave is situated at 5200 ft. elevation in the center of the canyon and drains the upper 12 sq. miles.

Lilburn cave is developed in a lens of black and white banded marble that occupies about 4 sq. miles in the floor of the canyon. It is bounded on the east by a granitic pluton and on the west by a metamorphic sequence, both forming ridges 2000 to 3000 feet above the canyon.

The known cave underlies about one fourth of the karst area and has about 8 miles of surveyed passage. The depth of the system is 407 feet. Major passage development is in a north-south direction parallel to the canyon. The system is characterized by high stream canyons with many smaller interconnecting passages. Most of the cave can be traversed without rigging from the traditional entrance, while the Meyer Entrance is a 40 foot pit. Big Spring, the resurgence of Lilburn Cave, is the only known ebb and flow spring with access to the upstream end via the cave. It has a base flow of 12 cfs with maximum pulse of 200 cfs.

Research

The science program is becoming more active with three new geologic studies initiated this past season. A coordinated research program with California State University at Fresno is being undertaken, and a paleontological reconaissance of the cave has been started under this program. Details on the other research projects are outlined in this annual report.

Cartographic efforts have been directed toward preparing detailed base maps needed for the scientific programs. Existing computer programs are being updated to run on a new computer system, complete with plotter, donated to CRF. The total surveyed length of Lilburn Cave stands at 38,969 feet slope distance. New survey this year was 1189 feet.

PUBLICATIONS AND MANAGEMENT

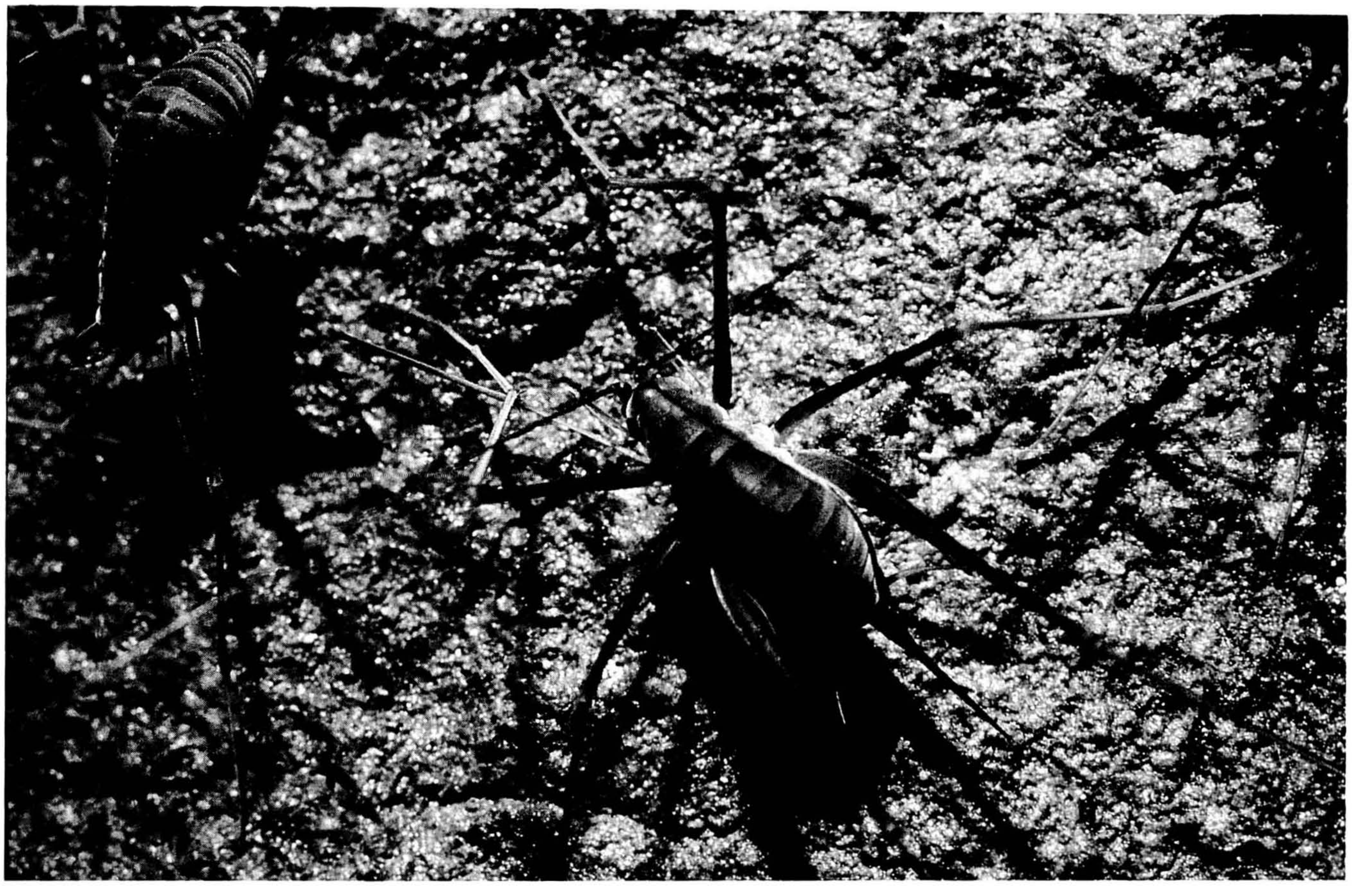


Figure 28. Cave crickets (*Hadenoecus* subterraneous) at the Austin Entrance of the Flint-Mammoth Cave System. Photo by W.C. Welbourn.

BOOKS

Meloy, Harold (1977). *Mummies of Mammoth Cave* Revised ed., Micron Pub. Co., 42 pp, 1 map, 8 illus.

THESES

Jagnow, David H. (1977). "Geologic factors influencing speleogenesis in the Capitan reef complex, New Mexico and Texas", MS. thesis, Univ. of New Mexico, Albuquerque, NM, 201 p.

Palmer, Margaret V. (1976). "Ground-water flow patterns in limestone solution conduits", M.A. thesis, State Univ. of New York, Oneonta, N.Y., 150 p.

ARTICLES

Giuseffi, S., T.C. Kane and W.F. Duggleby (in press). "Genetic variability in *Neaphaenops tellkampfii* (Coleoptera: Carabidae)." *Evolution.*

Harmon, R.S., H.P. Schwarcz, and D.C. Ford (in press). "Stable isotope geochemistry of speleothems and cave waters from the Flint-Mammoth Cave System, Kentucky: Implications for terrestrial climate change during the period 230,000 to 100,000 years B.P." *Journal of Geology.*

———— (in press). "Late Pleistocene sea level history of Bermuda." *Quaternary Research.*

———— (in press). "Interglacial chronology of the Rocky and Mackenzie Mountains between latitudes 40° and 62°N based upon $^{230}Th/^{234}U$ dating of calcite speleothems." *Canadian Journal of Earth Science.*

————, P. Thompson, H.P. Schwarcz, and D.C. Ford (in press). "Late Pleistocene paleoclimates of North America as inferred from stable isotope studies of speleothems." *Quaternary Research.*

———— and R.L. Curl (in press). "Preliminary results on growth rate and paleoclimate studies of a stalagmite from Ogle Cave, New Mexico." *NSS Bull.*

Hill, C.A. and P.G. Eller (1977). "Soda-niter in North Central Arizona Earth Cracks." *NSS Bull.* **39(4)**:113-116.

Hobbs, Horton H. III (1976). "Observations on the cave-dwelling crayfishes of Indiana." Pages 405-414 *in* James W. Avault, Jr., ed., *Freshwater Crayfish.* Baton Rouge, Louisiana: Louisiana St. Univ. Div. Cont. Ed.

———— (1976). "On the troglobitic shrimps of the Yucatan Peninsula, Mexico (Decapoda: Atyidae and Palaemonidae)." *Smith. Contrib. Zool.*, **240**:1-23 (with Horton H. Hobbs, Jr.).

———— (1976). "Molt cycle, size and growth in *Orconectes inermis inermis* Cope (Decapoda: Cambaridae)." *Virginia Jour. Sci.*, **27(2)**:44 (abstr.).

———— (1976). "The reproductive cycle of *Orconectes inermis inermis* Cope (Decapoda: Cambaridae) in Indiana." *Virginia Jour. Sci.*, **27(4)**:44 (abstr.).

———— (1976). "The freshwater decapod crustaceans (Palaemonidae, Cambaridae) of the Savannah River Plant, South Carolina." *Savannah River Plant Special Publication*, 1-63 (with James H. Thorp and Gilbert E. Anderson).

———— (1977). "Allochthonous matter in caves." *Bloomington Indiana Grotto Newsl.*, **12(4)**:51-53.

———— (1977). "A review of the troglobitic decapod crustaceans in the Americas." *Smith Contrib. Zool.*, **244**:1-183 (with Horton H. Hobbs, Jr. and Margaret A. Daniel).

———— (1977). "Organisms and ecosystems." *NSS News* **35(5)**:102.

———— (in press). "Biology of the cave crayfish *Orconectes inermis testii* (Hay) (Decapoda: Cambaridae) in Indiana." *NSS Bull.*

———— (in press). "A preliminary report on the history of biospeleology in Indiana." *NSS Bull.*

———— (in press). "Studies of the cave crayfish *Orconectes inermis inermis* Cope (Decapoda: Cambaridae)." Part II: Home ranges.

Kastning, Ernst H. (1976). "Cave hermits: vignettes of America's past." *Jour. Spelean History* **9(1)**:17-21.

———— (1977). "Cave hermits: vignettes of America's past." *in* Werner, E. (ed.), Proceedings of the 1976 NSS Annual Convention, Morgantown, West Virginia: West Virginia Speleological Survey, Morgantown, West Virginia, p. 35-37.

———— (1977). "Hydrologic and geomorphic aspects of karst features in the Blaine Gypsum (Permian), Red River basin, northwest Texas." *In* Werner, E. (ed.), Proceedings of the 1976 NSS Annual Convention, Morgantown, West Virginia: West Virginia Speleological Survey, Morgantown, West Virginia, p. 39-41.

———— (1977). "Granitic karst and pseudokarst, Llano County, Texas, with special reference to Enchanted Rock Cave." *In* Werner, E. (ed.), Proceedings of the 1976 NSS Annual Convention, Morgantown, West Virginia: West Virginia Speleological Survey, Morgantown, West Virginia, p. 43-45.

———— (1977). "Lester Howe's fabulous Garden of Eden Cave." *In* Sloane, B. (ed.), *Cavers, Caves, and Caving*: Rutgers Univ. Press, New Brunswick, New Jersey, p. 265-291.

——— (1977). "Karst landforms and speleogenesis in Precambrian granite, Llano County, Texas (U.S.A.)." *In* Ford, T.D. (ed.), *Proceedings of the Seventh International Speleological Congress, Sheffield England,* p. 253-255.

Marquardt, William and Patty Jo Watson (1977). "Current State Research: Kentucky. Shellmound Archaeological Project." *Southeastern Archaeological Conference Newsletter,* **19(2)**:4.

——— (in press). "Excavation and Recovery of Biological Remains from Two Archaic Shell Middens in Western Kentucky." *Bulletin of the Southeastern Archaeological Conference.*

Meloy, Harold (1977). "Stephen Bishop, The Man and the Legend." *In* Sloane B. (ed.), *Cavers, Caves, and Caving*: Rutgers Univ. Press, New Brunswick, New Jersey, p. 159-176.

——— (1977). "Little Alice and Lost John." *In* Sloane B. (ed.), *Cavers, Caves, and Caving*: Rutgers Univ. Press, New Brunswick, New Jersey, pp. 159-176.

Palmer, Arthur N. (1977). "Influence of geologic structure on groundwater flow and cave development in Mammoth Cave National Park, U.S.A." *Internatl. Assoc. of Hydrogeologists, 12th Memoirs*: 405-414.

———, Margaret V. Palmer, and J. Michael Queen (1977). "Speleogenesis in the Guadalupe Mountains, New Mexico: Gypsum replacement of carbonate by brine mixing." *Proc. of 7th Internatl. Speleological Congress, Sheffield, England*: 333-336.

——— (1977). "Geology and origin of the caves of Bermuda." *Proc. of 7th Internatl. Speleological Congress, Sheffield, England*: 336-339.

Poulson, T.L. and T.C. Kane (1977). "Ecological diversity and stability: principles and management." *Proc. II Natl. Cave Mgmt. Symposium*. Speleobooks, Albuquerque, N.M., 18-21.

Poulson, T.L. (1977). "A tale of two spiders." *Bull. Ecol. Soc. Amer.*, **58(2)**:57.

Watson, Patty Jo (1977). "Prehistoric Miners of the Flint-Mammoth Cave System." *Proceedings of the 6th Internatl. Congr. of Speleology, Olomouc, Czechoslovakia,* September 1973. Vol. VI, Sub-section Eb: 147-149.

Wells, Steve G. (1977). "Fluvial Geomorphic Response to Groundwater Hydrology in Low Relief Karst." G.S.A. Abstracts with Programs. **9(7)**:1220-1221.

Van Zant, T., T.C. Kane and T.L. Poulson (in press). "Body size differences in carabid cave beetles." *Am. Nat.*

PAPERS GIVEN AT PROFESSIONAL MEETINGS

National Speleological Society Meeting. (Alpena, Michigan, August, 1977)

Kastning, E.H.
"Early accounts of Howe's Cave, Schoharie County, New York: a review of the pre-1900 literature."

Meloy, Harold
"The legend of Stephen Bishop."
"Historic Maps of Mammoth Cave."

7th International Speleological Congress. (Sheffield, England, Sept. 1977)

Kastning, E.H.
"Karst Landforms and speleogenesis in Precambrian granite, Llano County, Texas (USA)."

Geological Society of America Annual Meeting. (Seattle, Washington, Nov. 1977)

Wells, S.G.
"Fluvial geomorphic response to groundwater hydrology in low relief karst."

American Institute of Biological Sciences (E. Lansing, Michigan)

Poulson, T.L.
"A tale of two spiders."

PROFESSIONAL, INTERPRETIVE, AND ADVISORY PRESENTATIONS

Brucker, Roger W. November, 1976. "The Longest Cave." Talk, Explorers Club, Fairborn, Ohio.

——— February, 1977. "The Longest Cave." Talk, Kiwanis Club, Xenia, Ohio.

——— March, 1977. "Ecology of the Flint-Mammoth Cave System." Talk, Glen Helen Association, Yellow Springs, Ohio.

——— March, 1977. "The Longest Cave." Interviews on several Louisville radio and TV stations.

——— March, 1977. "The Longest Cave." Talk, Hamilton Book Club, Hamilton, Ohio.

——— May, 1977. "The Mammoth Cave National Park Master Plan." A presentation by John P. Freeman, Kip K. Duchon, and Roger W. Brucker at the Southeast Region Office, National Park Service, Atlanta, Georgia.

——— September, 1977. "The Mammoth Cave National Park Master Plan." A discussion by Stanley D. Sides and Roger W. Brucker with a group of citizens from Park City, Kentucky at a breakfast meeting.

——— October, 1977. "Writing The Longest Cave." Talk, Yellow Springs Library Association, Yellow Springs, Ohio.

——— November, 1977. "The Longest Cave." Talk, Museum of Natural History, Cincinnati, Ohio.

De Paepe, Duane. July 2, 1977. "Saltpetre Mining in Mammoth Cave—The First American Gold Rush." Public lecture at Mammoth Cave National Park.

Hill, Carol A. December 10, 1977. "Mineralogy and the Caver—or What to do when you see a strange mineral on your next cave trip." Southwestern Regional, National Speleological Society.

Kane, T.C. March, 1977. "Resource Partitioning in Carabid Cave Beetles." Dept. of Biological Sciences, Northern Illinois University, DeKalb, Ill.

———. November, 1977. "The Ecology and Evolution of Cave Animals," Cincinnati Natural History Museum, Cincinnati, OH.

Meloy, Harold. May 29, 1977. "Early History of Mammoth Cave." History seminar for CRF and invited National Park Service personnel within Mammoth Cave, including talks at the Entrance, Narrows, Rotunda, Darnall's Way, Broadway, Gothic, Gratz, Pensacola, Ganter, and Audubon Avenues.

———. July 16, 1977. "Saga of Mammoth Cave." National Park Service seminar with public invited.

Palmer, Arthur N. July, 1977. "The story of the world's greatest caves." Public lecture, Mammoth Cave National Park.

———. November, 1977. "Speleogenetic provinces of the United States." Banquet address, Board of Governors meeting, National Speleological Society, Saratoga, N.Y.

Poulson, T.L. "Why is the Methusaleh Strategy so prevalent among aquatic cave animals?" Biology Department, Texas Tech. Univ., distinguished visiting scientist.

——— "Models of coevolution in prey/predator systems: Cave crickets (*Hadenoecus*) and cave beetles (*Neaphaenops*)." Biology Department, Texas Tech. Univ., distinguished visiting scientist.

——— "Mechanisms of regressive evolution in cave animals." Biology Department, Texas Tech. Univ., distinguished visiting scientist.

——— "Why is the Methusaleh Strategy so prevalent among aquatic cave animals?" Biology Department, U. of St. Louis.

——— "A tale of two spiders." Zoology Department, U. of Chicago.

——— "Mechanisms of regressive evolution in cave animals." Evolutionary Morphology Discussion Group, U. of Chicago.

——— "Biology and Ecology of cave animals." Talk given at Mammoth Cave National Park.

——— "Caves as natural laboratories: geology, mineralogy, biology, and archeology." AIBS Club at St. Xavier College, Chicago.

Watson, P.J. June 20, 1977. "Archeology of the Mammoth Cave Area." Talk presented at the Visitor Center, Mammoth Cave National Park.

———. November 4, 1977. "Late Archaic Shellmounds and the Beginnings of Horticulture in Western Kentucky." Lecture presented to the Department of Anthropology, Southern Methodist University, Dallas, Texas.

———, David Baerrels, William Marquardt, and Diana Path. October 15, 1977. "Cave Miners and Early Horticulturists of Western Kentucky." Lecture presented at the Logansport Community Center.

Welbourn, W. Calvin. January 1977. "Cave Fauna of New Mexico." Southwestern Region Meeting.

———. May 1977. "Cave Fauna of Carlsbad Caverns National Park." National Park Service Seasonal Training Session, Carlsbad Caverns National Park.

Wells, Steve G. July, 1977. "The World's Longest Cave." Presentation given to the Sandia Grotto, Albuquerque, New Mexico.

SPECIAL PUBLICATIONS

Carstens, Kenneth (1977). "Three Springs Pumphouse: An Assessment of Damage." Mammoth Cave National Park, Kentucky. Manuscript report assessing damage done to the Three Springs Pumphouse rockshelter by Job Corps vandals, winter 1976-1977; 34 pages.

Marquardt, William, Patty Jo Watson, Linda Gorski, and Alan May (1977). "A Cultural Resources Assessment for a Proposed Pipeline in Mammoth Cave National Park." Cave Research Foundation manuscript report submitted to the Superintendent, Mammoth Cave National Park, March, 1977.

Meloy, Harold (1977). "Historic Cave Tour, Mammoth Cave." (folded map with text) National Park Concessions, Inc., Mammoth Cave, Ky.

Watson, Patty Jo (1976). Report to the Superintendent, Mammoth Cave National Park, Kentucky, on an Archaeological Survey Conducted December 12 and 13, 1976, at the Proposed Location for Recreation Pavilion, Volleyball Court and Seasonal Quarters, Maintenance Area, Mammoth Cave National Park.

——— (1977). "Cultural Resources Assessment of Proposed Small Parking Lot in Residential Area, Mammoth Cave National Park." Cave Research Foundation manuscript report submitted to the Superintendent, Mammoth Cave National Park, July, 1977.

1977 Fellowship and Grants Awarded

The 1977 CRF Fellowship was awarded to Mr. Ernst Kastning, Jr. of the Department of Geological Sciences, University of Texas—Austin for his PhD dissertation research: "Geomorphology and Hydrogeology of the Edwards Plateau Karst, Central Texas." This study will be the first comprehensive investigation of a major karst area in the southwestern United States.

Research grants were awarded to:

- —Mr. Edward Lisowski of the Department of Entomology, University of Illinois—Urbana-Champaign for his thesis research: "Ecological Genetics of Cave and Spring Populations of Isopods from Western Kentucky, and Southern Illinois and Indiana."
- —Mr. Kenneth Cole of the Department of Geosciences, University of Arizona for his PhD research: "Fossil Packrat Deposits in the Horseshoe Mesa of the Grand Canyon, Arizona."

In 1977, an In-house Grant was given to Mr. Duane De Paepe of South Bend, Indiana, for his research: "Economic Geography of the Mammoth Cave National Park Regional Saltpetre Industry." The CRF In-house Grant will be made available from time to time when researchers who are associated with CRF and are not working on degree-related research need financial support.

The CRF support for research this year has been significant. The Cave Research Foundation continues to be the leader in supporting karst-related dissertation and thesis research. Additionally, CRF has finally established an internally sponsored research program to aid worthy, non-degree studies (a goal established in 1973).

Management Structure

DIRECTORS

W. Calvin Welbourn, President
Roger E. McClure, Treasurer
Steve G. Wells, Chief Scientist
Charles F. Hildebolt, Operations Manager for the Central Kentucky Area
Roger W. Brucker
Rondal R. Bridgemon, Secretary
R. Pete Lindsley, New Projects Operations Manager
Elbert F. Bassham, Operations Manager for the Guadalupe Escarpment Area
Patty Jo Watson

OFFICERS AND MANAGEMENT PERSONNEL

Guadalupe Escarpment Area Management Personnel:

Manager	Elbert F. Bassham
Personnel	John S. McLean
Cartography	Robert H. Buecher
Field Station	Ron Kerbo
Finance and Supply Coordinator	Karen Welbourn
Log Keeper and Survey Book Coordinator	Robert G. Babb, II
Safety	Don P. Morris

Central Kentucky Area Management Personnel:

Manager	Charles F. Hildebolt
Cartography	Richard B. Zopf
Field Station	Robert O. Eggers, Roger L. McMillan
Log Keeper	Jennifer A. Anderson
Personnel	Walter A. Lipton
Safety	Lewis Dickinson, M.D.
Vertical Supplies	Donald E. Coons
Supplies	Tomislav M. Gracanin

Lilburn Cave Project Management Personnel:

Manager	Stan Ulfeldt
Cartography	Ellis Hedlund
Personnel	Luther Perry
Safety	Howard Hurtt

Operating Committees

Administration Committee: Sets goals, identifies problems, and evaluates progress in the operation of the Foundation. Present membership is:

R. Pete Lindsley, Chairman
Rondal R. Bridgemon
Roger W. Brucker
Patty Jo Watson
W. Calvin Welbourn
Steve G. Wells

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

Roger E. McClure, Chairman
Roger W. Brucker
Charles E. Hildebolt
Stanley D. Sides
Gordon L. Smith
W. Calvin Welbourn
Karen H. Welbourn

Interpretation and Information: Deals with the dispersal of information in a form suitable for the public. The output of the committee has mainly taken the form of training sessions for guides and naturalists and the preparation of interpretive materials and trail guides for Park use. Present membership is:

Thomas L. Poulson, Chairman
John W. Hess, Jr.
Carol H. Hill
William B. White
W. Calvin Welbourn
Steve G. Wells

Conservation: Is the Foundation's liaison with all aspects of the conservation movement, including Wilderness Hearings, and maintaining contact with conservation organizations. Present membership is:

Roger W. Brucker, Chairman
William P. Bishop
Rondal R. Bridgemon
Joseph K. Davidson
John P. Freeman
Stanley D. Sides
Philip M. Smith
Richard A. Watson

Initiatives: Is a special committee charged with stimulating thought about "provacative and risk" future directions. Present membership is:

Stanley D. Sides, Chairman
Elbert Bassham
Philip M. Smith
Stan Ulfeldt
Richard A. Watson
Steve G. Wells

Field Operations

AREA	Number of Expeditions	Number of Field Days	Frequency of JV Attendance
Mammoth Cave National Park	32	90	453
Guadalupe Escarpment Carlsbad Caverns National Park Bureau of Land Management Lincoln National Forest	10	16	116
Buffalo National River	7	26	37
Big Bend National Park	2	5	10
Grand Canyon National Park Horseshoe Mesa	5	7	26

Contributors To This Report

Dr. Elbert F. Bassham
Box 437
Presidio, TX 79845

Mr. Roger W. Brucker
445 W. South College St.
Yellow Springs, OH 45387

Mr. Robert H. Buecher
2208 Sparkman
Tucson, AZ 85716

Mr. Kenneth L. Cole
Dept. of Geosciences
University of Arizona
Tucson, AZ 85721

Mr. Duane DePaepe
1130 East Wayne, South
South Bend, IN 46615

Dr. David J. DesMarais
Chemical Evolution Branch
AMES Research Center
Moffett Field, CA 94035

Dr. P. Gary Eller
P.O. Box 47
Los Alamos, NM 87544

Dr. Russell S. Harmon
Dept. of Geology
Michigan State University
East Lansing, MI 48824

Mr. Peter Hauer
(Deceased)

Dr. Horton H. Hobbs, III
Dept. of Biology
Wittenberg University
Springfield, OH 45501

Dr. Thomas C. Kane
Dept. of Biological Sciences
Brodie Science Complex
University of Cincinnati
Cincinnati, OH 45221

Mr. Ernst H. Kastning
Dept. of Geological Sciences
University of Texas-Austin
Austin, TX 78712

Ms. Karen L. Lindsley
5507 Boca Raton
Dallas, TX 75230

Mr. R. Pete Lindsley
5507 Boca Raton
Dallas, TX 75230

Ms. Gail McCoy
1324 Randol Ave.
San Jose, CA 95126

Mr. Harold Meloy
P.O. Box 454
Shelbyville, IN 46176

Dr. Robert K. Murray
Dept. of History
816 Liberal Arts
Penn State University
University Park, PA 16802

Mr. Duane R. Packer
Woodward-Clyde Consultants
Three Embarcadero Center
San Francisco, CA 94111

Dr. Arthur N. Palmer
Dept. of Earth Sciences
State University College
Oneonta, NY 13820

Ms. Margaret V. Palmer
Dept. of Earth Sciences
State University College
Oneonta, NY 13820

Dr. Thomas L. Poulson
Dept. of Biological Sciences
Box 4348
University of Illinois-Chicago Circle
Chicago, IL 60680

Dr. J. Michael Queen, Jr.
Dept. of Geological Sciences
University of California
Santa Baraba, CA 93106

Mr. Edward N. Lisowski
Dept. of Entomology
University of Illinois-Urbana-Champaign
Champaign, IL 61820

Mr. Bruce W. Rogers
U.S. Geological Survey
Br. W. Environmental Geology
345 Middlefield Road
Menlo Park, CA 94025

Dr. Stanley D. Sides, M.D.
2014 Beth Drive
Cape Girardeau, MO 63701

Dr. John C. Tinsley
U.S. Geological Survey
Br. W. Environmental Geology
345 Middlefield Road
Menlo Park, CA 94025

Mr. Stanley R. Ulfeldt
780 West Grand Ave
Oakland, CA 94612

Dr. Patty Jo Watson
Dept. of Anthropology
Washington University
St. Louis, MO 63130

Mr. W. Calvin Welbourn
306 Sandia Road, N.W.
Albuquerque, NM 87107

Dr. Steve G. Wells
Dept. of Geology
University of New Mexico
Albuquerque, NM 87131

Ms. Patricia P. Wilcox
Box 46
Cool Spring, PA 15730

Ms. Kathleen M. Williams
26 South 12th St.
San Jose, CA 95112

Mr. Richard B. Zopf
331 Jacoby St.
Yellow Springs, OH 45387