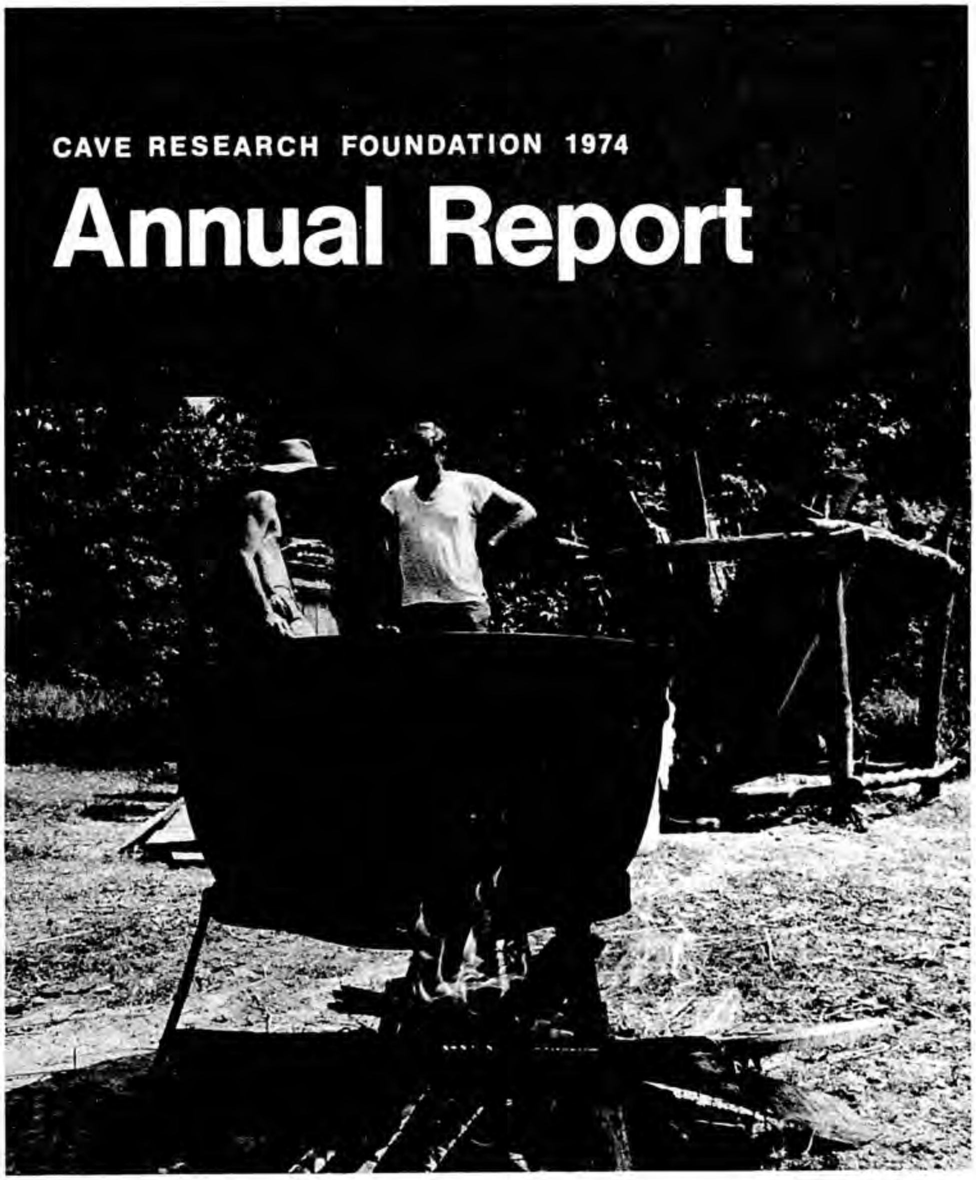
CAVE RESEARCH FOUNDATION 1974

Annual Report



CAVE RESEARCH FOUNDATION

Cave Research Foundation 1974 Annual Report

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Cover: Boiling nitre liquor in the saltpetre extraction process. This historic method was repeated this past year at Mammoth Cave National Park as part of the saltpetre "action history" project. Photo by Pete Lindsley, cover design by Roger Brucker.

ACKNOWLEDGMENTS

Many of the projects outlined in this report have been conducted within the National Park System. The support and encouragement of the Superintendent and staff at Mammoth Cave National Park and at Carlsbad Caverns National Park have contributed greatly to the success of these projects and are gratefully acknowledged.

The work of Mr. Hess and Dr. White on the hydrology of the Central Kentucky area was supported by the Office of Water Resources Research.

Dr. P. J. Watson's archeological researches were supported by grants from the National Geographic Society.

Carol Hill's saltpetre research was supported by a grant from the N.G.S.

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Highlights of 1974

During the summer of 1974, Academic Press released Archeology of the Mammoth Cave Area, edited by Patty Jo Watson. Culminating years of dedicated, inspired research by Dr. Watson, her students and her colleagues, this book is certainly a milestone in the study of North American prehistory.

The Foundation issued three awards to graduate students in 1974. Stephen O. Sears, Pennsylvania State University, was awarded a fellowship for his project: "The inorganic and stable isotope geochemistry of groundwater recharge through unsaturated soils in a carbonate terrane". Kenneth C. Carstens, Washington University, received a grant to support his project: "Surface archeology of the Mammoth Cave National Park area". Glenn D. Campbell, Texas Tech University, was awarded a grant for his project: "Activity rhythm of the Genus Ceuthophilus (Orthoptera)".

Much work is being readied for publication. Dr. W. B. White is presently editing a monograph on the hydrology of the Central Kentucky Karst, to be published in conjunction with the International Hydrologic Decade. A portion of Dr. J. W. Hess' dissertation appeared this year in a water resources publication by Pennsylvania State University. Workers in the Guadalupe Mountain area are preparing a multidisciplinary report on Ogle Cave, to be published in the NSS Bulletin. A map and gazetteer of Lee Cave, located in Mammoth Cave National Park, are being printed. A report of the CRF expedition to Cerros Barra Honda, Costa Rica is nearing completion. A new CRF Personnel Manual is essentially ready for the publisher.

Survey footage continues to be added to almost all the major cave surveys in the Guadalupes, as well as in Edgewood Caverns, a new cave near Albuquerque, New Mexico. In Kentucky, much survey in Proctor Cave and in the lower levels of Mammoth Cave has taken advantage of the recent major discoveries in these caves. A reexamination of the Bedquilt section of Flint Ridge has greatly improved the map of that area and has uncovered evidence of additional cave passages.

During the summer of 1974, a saltpetre expedition at Mammoth Cave National Park combined the historical, chemical, mineralogic, and microbiological aspects of soil nitrates into a very productive session which will channel considerable input into the research and interpretative programs of the Foundation. Also, as this Report shows, the scope and intensity of the cave ecology program has never been greater than it was in 1974.

Roger W. Brucker became the Foundation's fifth president in 1974 replacing Dr. Stanley D. Sides. With a new president and much of its past work coming to press in 1974, the Foundation prepares to pursue newer, more challenging goals involving the study and preservation of karst.

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President's Report

Futures

The goals of the Cave Research Foundation are addressed each year by the Directors and Members. In the fall of 1974 several decisions made should affect the direction of our future efforts. We established an endowment fund. Its purpose is to earn money to underwrite research grants and fellowships. Hopefully such seed money will attract funds from those who desire to make a permanent and continuing contribution to our understanding of karst processes.

A second decision set up a visiting scholars fund. Its purpose is to make available modest support for speleologists who journey great distances to study karst areas in which CRF workers are involved.

A third set of decisions form a policy to step up CRF's interpretive efforts. As one member put it, "We've put a lot of data in the bank. Let's put more of it to work." These decisions should result in more papers and reports, more maps published, some special audio-visual presentations, and more experimentation with innovative interpretation.

In a fourth area we are seeking ways to assure long-term protection of karst features at the edges of national parks. CRF has long recognized the interrelatedness of karst features and processes. Our findings have convinced others that fragile and valuable resources must be saved. We are challenged to show how this protection can take place, beyond presenting the need.

Finally, we face the long-term continuing challenge of operating a wholly volunteer research support organization on a budget. What has been essential ever the years since 1958 was translating our goals -- study, interpretation and education, and conservation of caves -- into results. The glue of togetherness has been individual commitment to out multidisciplinary goals, and a healthy measure of friendship, respect, and good humor. Those who support CRF's goals have always been welcome -- to join the work and share in the fun!

Roger W. Brucker
President

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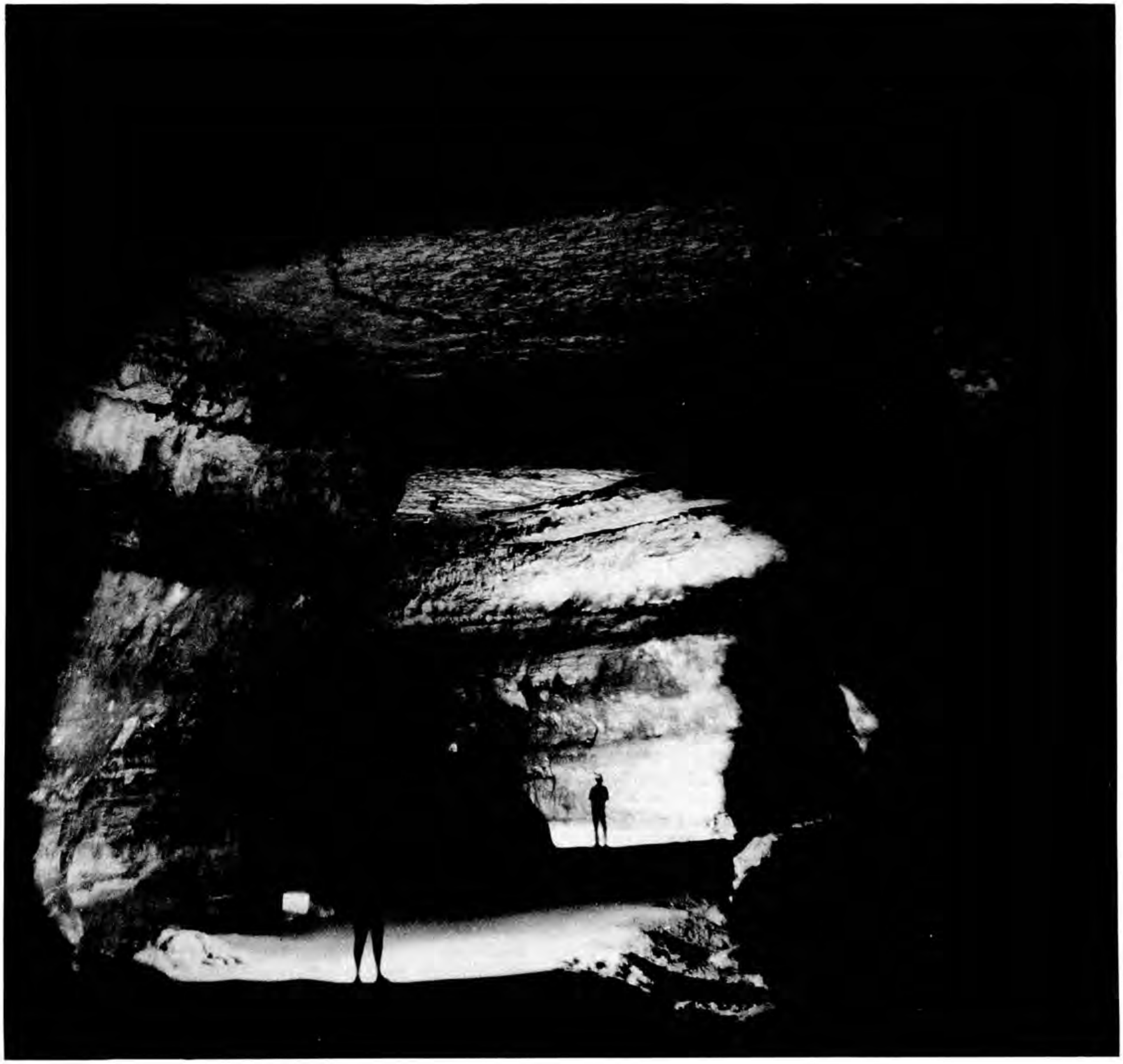
Scientific Programs



Photographing passage cross sections in Main Cave, Mammoth Cave, Kentucky.
Photo by David DesMarais.

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Exploration and Cartography in the Central Kentucky Karst

John P. Wilcox, Patricia P. Crowther, William P. Crowther,

William F. Mann, and Diana O. Daunt

The field program in Mammoth Cave National Park continued highly active through the first part of this year. Toward the end of the year, there was a reduction of effort as steps were taken to reduce the size of expeditions. Underground survey during the twelve-month period ending November first has totalled 17.68 miles, 93.5 percent of it in passages previously unsurveyed by the Foundation. The surveyed length of the Flint Mammoth Cave System has been increased to 167.1 miles.

Though there have not been spectacular discoveries this year, exploration did continue in the lower levels of Mammoth Cave and around the edges of its ridge, in the Bedquilt area of Flint Ridge, and in Proctor Cave. Much progress has been made in surveying the large tourist passages of Mammoth Cave.

A finished version of the Lee Cave map is inked and nearly ready for publication. Manuscript maps of Mammoth Cave are being assembled, starting at the far east end of the cave. A new and much more detailed manuscript map of the Bedquilt area of the Flint Ridge Cave System has been completed.

Exploration and Survey in Flint Ridge

Most of the 1.93 miles of new survey in Flint Ridge this year came from the Bedquilt-Colossal part of the cave. It resulted from an intensive examination of this area by the Crowthers, who worked with a small cartographic crew for nearly a month. Most of their time was devoted to a fuller description of the known parts of the Cave, with emphasis on geologic levels, paleo flows, and passage relationships. They made detailed junction sketches, described passages, traced the geologic column through the cave, and conducted leveling surveys. The results have been a better understanding of the paleo drainage, the much-improved map of the Bedquilt area, and a list of leads to be checked during regular expeditions. Several of these have since been explored and surveyed. Newly-found passages extend to the south and east beyond the previous limits of the cave, with some potential for breakthrough into another arm of Flint Ridge.

Several parties have worked in the upper levels of Unknown Cave. This maze of small canyons continues to yield a modest amount of new survey.

The current surveyed length of the Flint Ridge Cave System is 91.19 miles.

Exploration and Survey in Mammoth Cave

Again this year, the bulk of the field effort has been in Mammoth Cave. This year's survey has been about evenly divided between previously unmapped passages and those on the Nelson and Kämper maps. The cave continues to grow rapidly.

Diana Daunt is leading a major effort toward a pedestal survey of the tourist routes and trunk passages of Mammoth Cave. Working mostly at night, numerous parties have surveyed Kentucky Avenue, Jeanne's Avenue, most of Boone Avenue, Cleaveland Avenue, Pensacola Avenue, and parts of Broadway. Some areas in Pensacola Avenue and Broadway were plane tabled. Kentucky Avenue has numerous side leads. Several of these leads have been surveyed this year, others remain to be done.

Other historic passages that have been mapped include Wilson's Way, Lost Avenue, Harvey's Avenue, and Marianne's Pass. Several lower level passages in the Historic end of the cave remain to be surveyed. The complicated area around Rhoda's Arcade has been surveyed and several previously-unmapped passages have been found there. Side leads and undescended pits remain.

Virgin cave continues to be found in Mystic River and in the east end of the cave. Long, wet crawls have been pushed far under Doyle Valley from each of these areas. Eventually, they may lead to a penetration into Joppa Ridge. In the northwest corner of New Discovery, a muddy hole through breakdown led to an extension of the north fork of the cave, an impressive hall with side passages. One party had been there decades earlier; we have no record of who they may have been.

CRF survey in Mammoth Cave now totals 69.77 miles. The Kämper map shows an additional 6.1 miles of passage not yet surveyed by the Foundation The surveyed length of Mammoth Cave is therefore approximately 75.9 miles.

Exploration and Survey in Joppa Ridge

In Proctor Cave, several parties have descended shafts reached through the trunk system found last year. About a mile of survey has come from the lower levels, and a few leads remain. In general, though, the lower levels have been disappointingly blocked by siphons and fills, so that interconnection with the rest of Joppa Ridge's interior does not appear to be straightforward. Proctor Cave is now 5.52 miles long.

In Lee Cave, a circuitous route through crawlways and breakdown on the east side of the G. Smith Junction Room led to a 15-foot-wide walking passage above the level of the Junction Room ceiling. It trends eastward and has extensive canyon and shaft development in its floor. Exploration has been stopped by technical difficulties three hundred feet in, so the extent of the discovery is not yet known.

Surface Exploration in Mammoth Cave National Park

William L. Wilson

A system has been devised for dividing and enlarging portions of topographic maps to provide workers interested in surface reconnaissance with base maps of convenient scale and area of coverage.

The area of Mammoth Cave National Park and environs has been divided into 1.5 by 1.5 minute quadrangles, each of which will be enlarged to a scale of 1:12,000 (1 inch to 1000 feet) as they are needed for fieldwork. A map of this area and scale will fit on an 8.5 by 11 inch sheet of paper which is convenient for field work and easy to reproduce. Topography is being copied, wherever possible, from the Topographic Map of the Mammoth Cave National Park, Kentucky by R. R. Monbeck et al., 1930, which has been found to represent the land surface much better than the USGS topographic 7.5 minute quadrangles issued in 1965. Ten maps have been prepared for the Doyel and Woolsey Valley areas from Chaumont to Turnhole Bend.

William Wilson and Tom Gracanin initiated field work in Doyel Valley in October, 1974. Reconnaissance in Woolsey Valley is planned for December, 1974 and January, 1975. Maps and descriptions of features observed on each traverse are filed in the CRF Trip Log.

Exploration and Survey in the Guadalupe Mountain Area

James M. Hardy and John J. Corcoran III

The following is a brief summary of CRF surveying operations in the Guadalupe Mountains from December 1973 through October 1974.

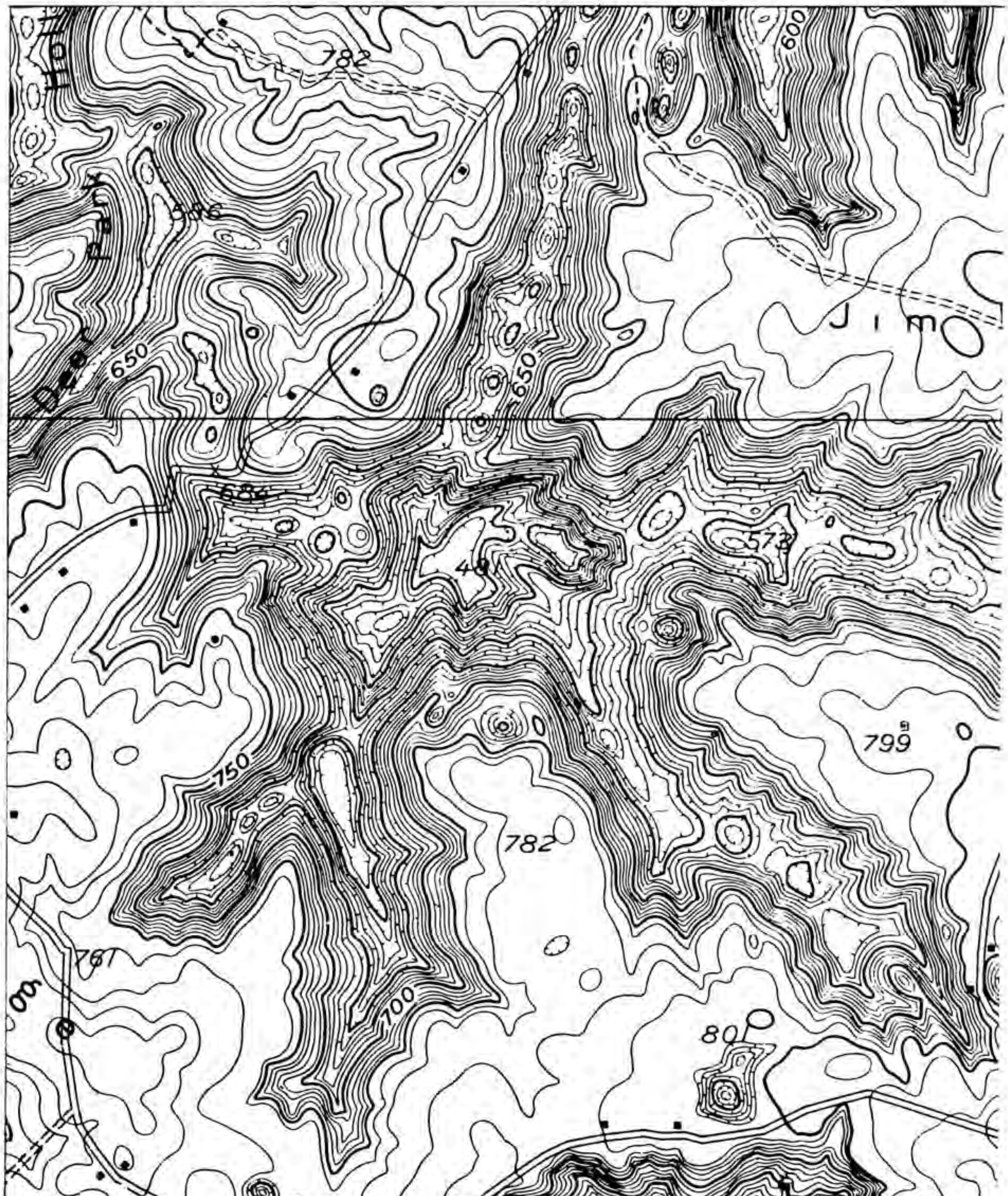
Primary objectives continued to be the control surveys and support surveys of cartographic and geological programs. Survey efforts were primarily in Carlsbad Caverns with additional work in smaller Park caves. Wind Cave and Edgewood Caverns were two non-Park caves receiving

Table 1. Cave and surface survey footages in 1974.

Cave	1974 Survey	Surface Survey	Total Cave Survey to Date
Carlsbad	10,546 ft.	50,698 ft.	106,708 ft.
Spider	212		7,645
Dry	924		18,576
Christmas Tree	598		1,601
Rainbow-Ogle	321		7,771
Wind	2,236		5,000
Edgewood	1,500		8,500

Kentucky - Edmonson Co.
4S-1E/25 Mammoth Cave Quadrangle

Deer Park Hollow Quadrangle
1.5 Minute Series, Topographic



Topography photocopied and enlarged 2.64X by Indiana University AVC Photo Lab, 12-74, from Mammoth Cave National Park, Kentucky, 1933, plane table surveyed by R. R. Monbeck, et al, 1930.

0 1000 2000 FEET

Contour interval is 10 feet

Datum is mean sea level, 1927

N

Figure 1. Deer Park Hollow Quadrangle, Mammoth Cave National Park, Kentucky.

appreciable attention. Total Brunton surveys were 14,937 ft excluding Edgewood Caverns which had an approximate total of 1,500 ft this year. Total control surveys were 88,278 ft on the surface with an extra 1,107 ft in Carlsbad Caverns.

Guadalupe Cartography Drafting Projects — 1974

John J. Corcoran III and James Hardy

The following is a brief summary of the map drafting projects undertaken in 1974 by the western CRF cartography team.

Projects within Carlsbad Caverns National Park

CARLSBAD CAVERNS: Work on the quadrangle maps continued with nine individual maps getting most of the attention. Scattered efforts continued on four other quadrangles. Of the quadrangles nearing completion, four are essentially finished in the Left Hand Tunnel area, one of which is now in manuscript stage awaiting publication. The upper level quadrangle of the New Mexico Room area is now ready for inking, and one quadrangle in Lower Cave is about 75% complete. Future efforts will be concentrated in the Lower Cave, Big Room and New Section areas. Preparation of a North-South vertical profile of Carlsbad Caverns is fairly well underway with completion hoped for around January 1, 1975.

NEW CAVE: Drafting of the main file map is complete. Redrafting of the map for publication is now underway for publication at two scales - 1:600 (1"=50') and 1:6,000 or 1"=500'.

RAINBOW-OGLE CAVE SYSTEM: The base map has been nearly completed. The final version of the working draft is now ready for checking and final drafting pending completion of cross-sections and addition of historical and geological details. Some thought is being given to additional overlay information but no firm plans as yet.

Figure 2. Ogle Cave calcite and water. Photo by Pete Lindsley.

CHIMNEY CAVE: The current map is now under modification to add the survey connection to the new entrance. The map is expected to be finished January 1975.

SPIDER CAVE: Re-drafting for publication has begun.

CHRISTMAS TREE CAVE: Final drafting is to be completed early spring 1975.

WEN CAVE-MIDNIGHT GOAT CAVE: This survey is part of New Cave-Slaughter Canyon-Midnight Canyon Project. Maps have been drafted and will be placed on the New Cave base map after final processing of surface control surveys.

Other Projects

EDGEWOOD CAVERNS: Work continues on the three major quadrangles of this maze cave, with particular emphasis on the Entrance-Drill Hole Quadrangle. Intensive effort is being made to put the maps and their topographic overlays into publishable form. Much new passage has been added to the Pop-up Room Quadrangle. Extensive now areas of the cave are planned for surveying and drafting, along the borders of the Pop-up Room and Canyonlands - Only Bigger Quadrangles.

WIND CAVE: Drafting of the Wind Cave map is now up to date, although only the levels #1 and #2 have been thoroughly surveyed. Much more work is required on levels #3, 4, and 5 to produce a meaningful map of the cave.

DRY CAVE: Preparation of individual level quadrangles has begun, with more work needed in 1975 to produce an overall master base map.

FORT STANTON CAVE: Currently there are seven quadrangles in manuscript form with four others in the final stages of drafting. Further surveys are needed to complete the remaining ten quadrangles although there is some thought about preparing manuscript maps of any quadrangle thought to be 75% complete or more. This would leave only four quadrangles out of 21 that need extensive field work to complete.

Guadalupe Data Processing Program - 1974

Data processing for the Cartography program continued using the current software (i.e. CAVE 16, THEOD, CVPLOT, etc.). The major backlog of work for 1974 has been cleared up and most projects are now up to date with the exception of certain areas in Carlsbad Caverns that were not scheduled for drafting in this year.

Edgewood Caverns

Robert G. Babb II

Edgewood Caverns is a major cave recently opened up in Santa Fe County, New Mexico, about 25 miles east of Albuquerque. The cave was "discovered" by well drillers in the early part of this century when their drill-bit encountered an 8 foot cavity. A corporation formed for the purpose of finding a commercial cave succeeded in drilling an entrance shaft into the cave in the fall of 1973. The only entry into the cave currently is via the drill hole, which is 128 feet deep and 20 to 24 inches in diameter. The cave is in the Madera Limestone (Pennsylvanian age) which is the same formation that caps the Sandia Mountains to the west. The cave is far more extensive than any cave previously found in the Madera. There seems little possibility that a natural entrance will be discovered since the cave passages are overlain by a minimum of 50 feet of bedrock and another 60 feet of alluvium.

The cave passages surveyed so far range in elevation from 6335 to 6415 feet above sea level (195 to 115 feet below the surface) on two major levels and a minor upper level. The water lines seen in the cave (and the cave passages themselves) may correlate with ancient levels of the shallow Pleistocene lake that occupied the floor of the Estancia Valley to the east.

The cave consists of an extremely dense network of solution enlarged joints. A major east-west set intersects a minor north-south set at approximately right angles. The east-west joints are spaced about 12 feet apart. The north-south joint passages are typically from 10 to 40 feet apart, and do not extend across the east-west joints. The average passage width is about four feet, so there are some areas where there is more "cave" than "wall". The east-west passages are

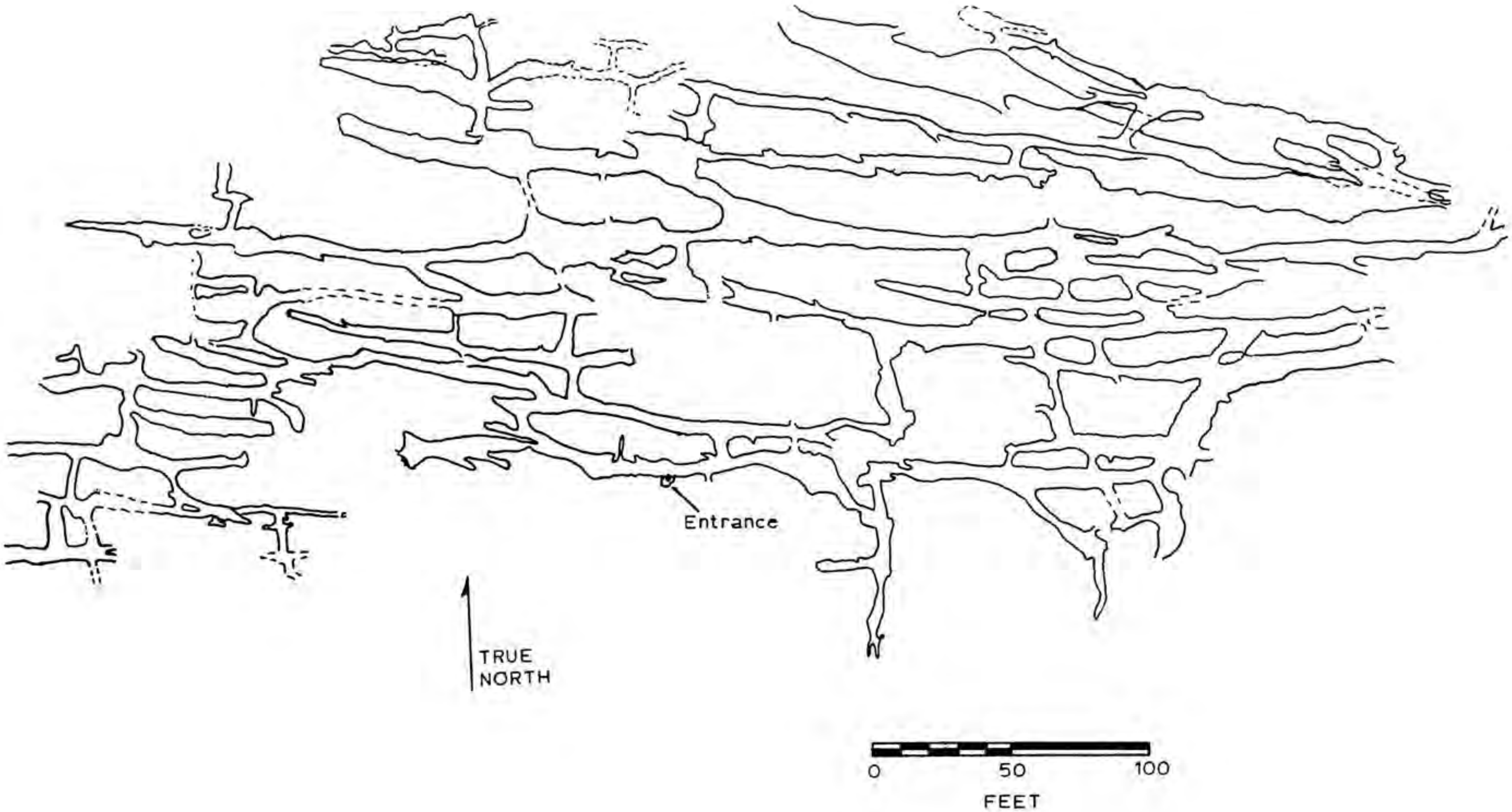


Figure 3. Entrance Quadrangle of Edgewood Caverns, New Mexico.

typically 4 to 30 feet high, and the north-south passages are usually 2 to 8 feet high. The "rooms" in the cave are formed where two east-west joints intersect at an acute angle, or are so close together that the intervening partition has collapsed. The largest room of this type discovered so far is a passage 225 feet long and 6 to 25 feet wide.

No flowstone of any kind has been noted in the cave. However, of interest are extensive deposits of calcite rafts (up to 6 in. thick), dogtooth spar (calcite) crystals, and a wealth of fossils (nautiloids, brachiopods, etc.) partly etched in relief from the walls. The only observed form of life is mold growing on mud shelves throughout the cave.

The Edgewood survey has been carried out with the assistance of Sandia Grotto, the Southwestern Independent Cavers, CRF, and others. Through 15 Sept. 1974, we have mapped 8881 feet (1.68 miles, 2.71 km) using Brunton Compass and steel tape. The potential total passage length is quite large since the 1.68 miles currently mapped covers an area of less than 1/200 of a square mile, and well-drillers have reported encountering cavities over an area of several square miles in the vicinity of the cave.

Reconnaissance of the Barra Honda Karst, Costa Rica

P. Gary Eller, Stephen G. Wells, and Richard B. Zopf

In December 1973 the Cave Research Foundation fielded a month-long expedition involving nine Joint Venturers under the leadership of Richard Zopf to investigate the karst resources of the Barra Honda region, Costa Rica (Fig. 4). The study was undertaken at the request of, and in cooperation with, the recently formed National Park Service of Costa Rica to provide a data base on which to evaluate the suitability of the Barra Honda karst region as a National Park. The study involved cartographic, geologic, biological, and photographic characterization of the Cerros Barra Honda caves, and surface investigation of Cerros Barra Honda and an adjacent hill, Cerros Coralillo.

A series of limestone-capped ridges (ca. 400 m of relief) rise from the lowlands of the Nicoyan Peninsula, Costa Rica (Fig. 5). One of these ridges, Cerros Barra Honda (ca. 2 to 4 km^2 in area) exhibits a synclinal structure with 200 to 300 m of Tertiary limestone (Barra Honda Formation) overlying Cretaceous mudstones and siltstones (Rivas and Sabana Grande Formations). With abundant rainfall during the wet season (150 to 200 cm in the months May through October), the exposed limestones have been intensely karstified to produce what is best described as a poorly developed "cockpit karst". Limestone knobs (mogotes) rise as high as 100 m from the floor of closed depressions (cockpits) and surface drainage is almost entirely absent except during the wettest months. Surface solution features are especially prominent at the near-vertical limestone cliffs forming the perimeter of Cerros Barra Honda, where razor-sharp grikes as large as 2 m wide by 7 m deep are common. The subsurface drainage is primarily directed along the synclinal axis, with a discharge point (.07 m^3/sec, Dec. 1973 dry season) lying down-dip at the limestone-mudstone contact near the east base of Cerros Barra Honda. Discharge for the adjacent hill (Cerros Coralillo), which has a very similar geologic setting, occurs as two large springs (.10 and .13m^3/sec) at the limestone-mudstone contact at the eastern base of Cerros Corallilo.

The Barra Honda caves are generally formed at intersections of joint sets along the synclinal axis. The caves are primarily vertical in nature with the maximum vertical and horizontal extents 118 m and 292 m respectively (Santa Ana-110 cave system). Despite the vertical nature of the caves, however, no single pitch greater than 40 m in depth was found. Most of the nine caves surveyed terminate in nearly hemispherical, phreatically formed rooms (averaging 25 m in diameter) with flat silt floors. The caves are extensively mineralized with calcite formations. These include excellent wall, ceiling, and floor displays and nests of 20 calcite cave pearls up to 3 cm in diameter. Troglobitic life was not observed in the Barra Honda caves, although numerous species of troglophilic forms were found (including fist-sized toads which are abundant at the bottoms of pits, and significant bat populations). An extensive photographic documentation of the caves was obtained.

Perhaps the most outstanding features of the Barra Honda karst region are the large springs at the bases of Cerros Barra Honda and Cerros Coralillo. A spectacular series of rimstone dams (measuring as large as 10 by 3 m laterally, and 2 m in depth) extends as far as 500 m downstream from the discharge points. The travertine deposits also play a major role in local geomorphic changes. Thus in places, the hill has been extended 200 m outward by the massive deposits. In some instances, later erosion and solution have

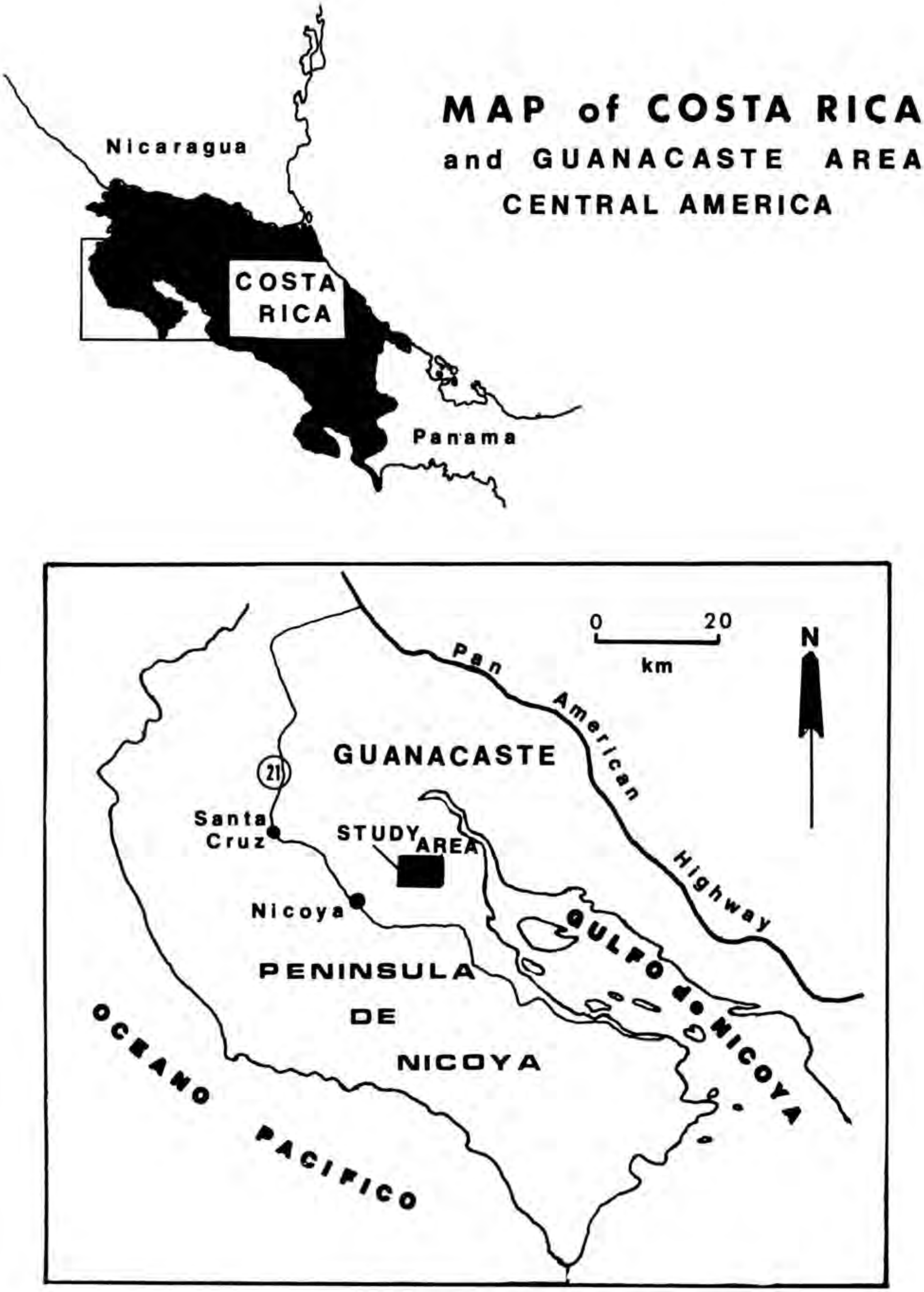


Figure 4. Location map of study area in Nicoyan Peninsula of Costa Rica.

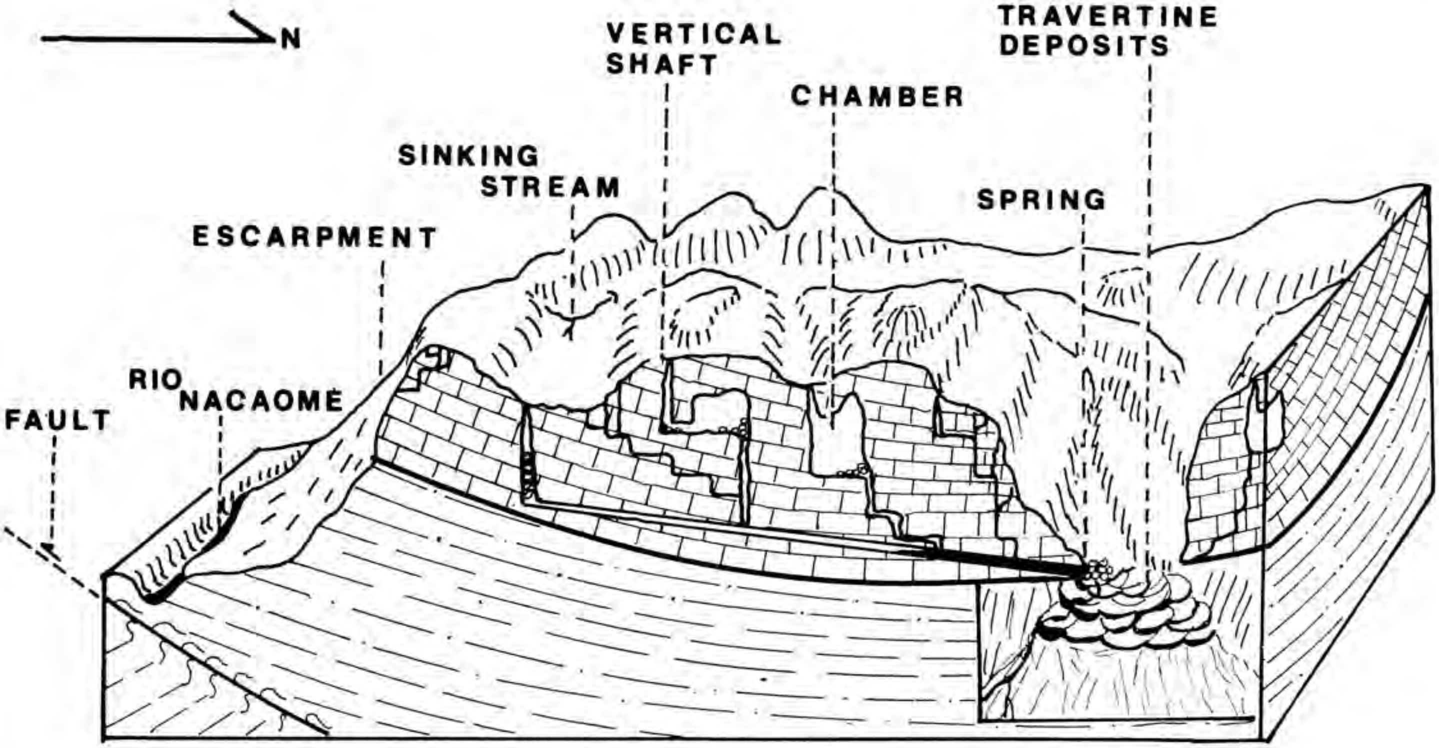


Figure 5. Idealized block diagram of Cerros Barra Honda, showing topographic features and subsurface drainage system.

removed underlying sediments to produce conical hills protected by a veneer of more resistant travertine. The springs are also an important factor in the regional ecology, since they provide a reliable water supply during the arid winter months when essentially no rainfall occurs.

Field observations during this expedition indicated that the potential for significant caves in the uninvestigated nearby limestone ridges is also high.

A 29 page report by Steve Wells on the geology of the Barra Honda karst has been completed and forwarded to the Costa Rica National Park Service. Additional reports in advanced stages of preparation include a full expedition report with detailed maps and descriptions of the Barra Honda caves, and a set of color slides, accompanied by descriptive text, which pictorially describes the karst resources of the region.

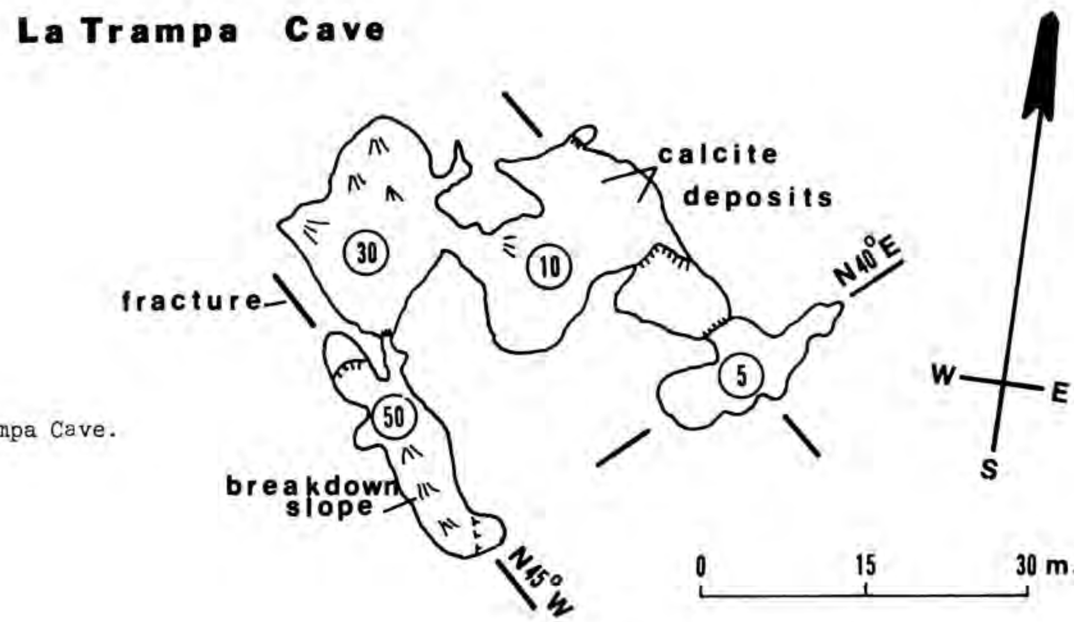


Figure 6. Map of LaTrampa Cave.

Figure 7(a). Defoliated area, known as El Mirador, illustrates the highly solutioned limestones on the southern limb of the Cerros Barra Honda syncline.
(b). Interior, LaTrampa Cave.

Cave Features Within Ozark National Scenic Riverways — A Preliminary Report

David J. DesMarais

The Ozark National Scenic Riverways (ONSR) requested that the Cave Research Foundation (CRF) aid in study and interpretation of the karst resources existing within the ONSR. Of special immediate interest were the following:

1. Caves whose features are of sufficient quality to merit development as visitor attractions;
2. Caves with delicate features which need protection through controlled visitor access; and
3. Caves which present unusual hazards to the Riverways visitors and which should, therefore, be closed.

A substantial percentage of ONSR visitors participate in canoe float trips on the Current River between Akers Ferry and Round Spring. Numerous cave openings in the cliffs along the river are visible to canoeists, openings whose visibility and ease of access may lead to excessive wear of irreplaceable cave features or present unexpected hazards to the visitor. A group from the CRF was to catalog all cave features visible during the summer foliage cover, and to make recommendations regarding these features. A report listing all located caves and the Foundations' recommendations was submitted to ONSR in December 1973.

Of the more than 30 individual cave features investigated between Akers Ferry and Round Spring, only six were not explored to their fullest extent. In addition to the river itself, eight springs were checked for water temperature and specific conductivity (SPC) at 25°C.

Those on the trip felt that three caves investigated merited attention by the Park Service. Wallace Well Cave presents a clear hazard for anyone who enters the cave with a poor light source or who is unaware of the water-filled pit. Access to this cave should be restricted. Secondly, due to its content of bat guano, Bat Cave might infect visitors with the fungus causing histoplasmosis. A warning to this effect should be posted at the cave entrance. Finally, Little Gem (Ebb and Flow) Cave contains numerous fragile speleothems and visitation of this cave is heavy. An accumulation of trash and some damage to the speleothems were noted. Access to Little Gem (Ebb and Flow) Cave should be controlled.

Cave features along other stretches of the Current River within Ozark National Scenic Riverways should be catalogued. Most importantly, people who have done considerable previous work in the area should be contacted for their knowledge and recommendations regarding cave features in the area.

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Water Balance for the Central Kentucky Karst

John W. Hess and William B. White

System Inputs, Outputs, and Losses

By making use of the effective drainage area between the Green River gage at Brownsville and the gage at Munfordville (Fig. 8), it is possible to use long term USGS records to determine water balance. The only major tributary to enter Green River in this reach is the Nolin River, which itself is gaged and whose flow can therefore be deducted. The drainage area of the karst is 989 km^2 (382 mi^2). Green River bisects this catchment into two parts, 245 km^2 north of the river and 744 km^2 south of the river. The water balance is carried out for the entire area to avoid the difficulty of proportioning the two parts, but the spring discharge balance is concerned mainly with the intensely karsted area south of Green River. Relevant data are summarized below in Table 2 .

Long term precipitation data were obtained from 34 years of record taken at Mammoth Cave National Park and nine years of record taken at Bowling Green. The mean average precipitation is 1264 mm (49.77 inches).

Evaporation-transpiration losses were estimated by three methods using the mean annual temperature of the region:

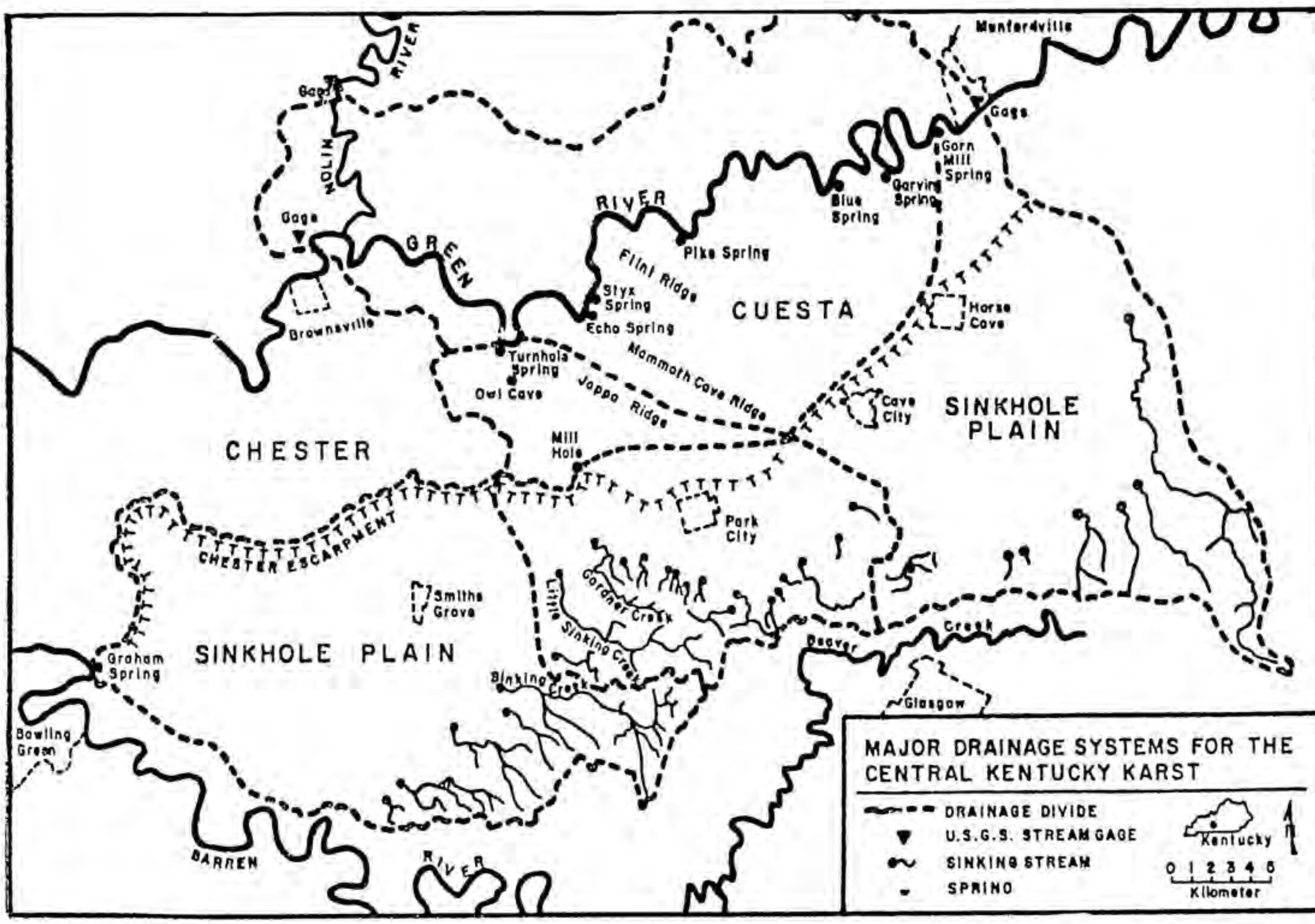

Figure 8. The drainage basin of the Central Kentucky Karst showing sub-basins of interest.

Table 2. Basin Discharge Data

	Area km²	Area Mi²	Mean Annual Discharge ℓ/sec	Mean Annual Discharge CFS	Normalized Mean Runoff ℓ/sec/km²	Normalized Mean Runoff CSM	Years of Record
Green River Basin above Brownsville	7154	2762	115,149	4066	16.1	1.47	40
Green River Basin above Munfordville	4333	1673	72,640	2565	16.8	1.53	45
Nolin River Basin	1831	707	23,222	820	12.7	1.16	23
Central Kentucky Karst	989	382	19,286	681	19.5	1.78	--

Class A pan	39.9 inches	1014 mm
Lake	37.0	940
Thornthwaite Poten.	30.2	767

These can be compared with E-T losses estimated from river records using a simple water balance argument. A total annual runoff was obtained from USGS records at each of the gaging stations and averaged over 40 years of record. These are summarized in Table 3. Evapo-transpiration losses can then be obtained by balancing the runoff against the precipitation and these numbers are also tabulated. The E-T loss for the entire Green River basin calculated at both gaging stations agrees rather well with the estimates from the Thornthwaite potential. Losses from the Nolin River basin are higher and approach those of a lake estimate presumably because of the influence of the Nolin Reservoir. Of greatest interest is the observation that the E-T loss from the karst is lower by some 13 percent than the basin average. It can be argued that rapid infiltration of water into sinkholes is responsible. Normalized runoff is correspondingly higher, although it is, of course, an underground runoff.

Base Flow Estimates

The low flow runoff from the Central Kentucky Karst was obtained by a similar technique. The monthly average runoff at each of the three gaging stations was tabulated for the low flow months over the six years of record 1966 to 1971. The low flow months were September and October. The average monthly flows for September and October at the Nolin and Munfordville gages were deducted from the respective monthly flows at Brownsville and the residual assigned to the low flow runoff from the Central Kentucky Karst. These residuals were averaged over the 12 records (two months for six years) to yield a value of 1440 ℓ/sec (50.9 CFS) over this period. However, Green River is wide and shallow for much of its 64 km course through the Central Kentucky Karst and evaporation losses would be significant. A calculation using the lake formula and the effective area of the river surface yields an additional 140 ℓ/sec (5 CFS) loss. The base flow runoff contributed to Green River from the catchment area of the karst is therefore 1580 ℓ/sec (55.9 CFS) or 1.64 ℓ/sec/km².

Springs and Spring Flows

It is now possible to compare the discharges of the springs with runoff from the entire area and evaluate the contribution of the big conduit springs to the total water balance. The discharges of 81 documented springs along Green River for which a finite flow was observed during the summer months of 1971 and 1972 are listed in Table 4. The total estimated flow of the 37 springs was 2750 ℓ/sec (97 CFS), although this number is not

Table 3. Runoff and Evapo-Transpiration Losses.

Basin	Runoff inches	Runoff mm	Evapo-Transpiration inches	Evapo-Transpiration mm
Green River at Brownsville	19.99	508	29.76	756
Green River at Munfordville	20.82	529	28.94	735
Nolin River Basin	15.75	400	34.02	864
Central Kentucky Karst	24.20	615	25.55	649

too meaningful because springs were observed at different times. The nine largest springs account for 95% of the spring discharge. The two largest springs draining from the south, Gorn Mill Spring and Turnhole Spring together account for 56% of the total spring discharge and an even larger fraction of the drainage from the area south of Green River.

Table 4. Inventory of Springs in the Central Kentucky Karst (Hess et al., 1974).

Number	Name	Discharge (ℓ/sec)	Percent of Total
1		0.3	
3	Gorn Mill Spring	963.0	35%
4		1.4	
6		0.03	
9		0.3	
10		1.4	
13		0.3	
14	Garvin Spring	85.0	3%
15		0.1	
19		2.8	
20		0.03	
21	Blue Spring South	56.0	2%
27	Blue Spring North	453.0	16%
28		14.0	
29		0.3	
32		1.4	
33		0.03	
34	Mile 205.7 Spring	42.0	
37	Dennison Ferry Spring	2.8	
38		0.3	
39	Pike Spring	227.0	8%
41	Big Spring	71.0	3%
42		1.4	
43		1.4	
44		0.03	

Table 4. Continued.

Number	Name	Discharge (ℓ/sec)	Percent of Total
47		28.0	
48		0.03	
49	Ugly Creek Spring	7.1	
52	Floating Mill Spring	0.3	
54	Styx River Spring	2.8	
55	Echo River Spring	56.0	2%
64	Turnhole Spring	566.0	21%
73	Sal Hallow Spring	1.4	
74	Buffalo Creek Spring	142.0	5%
76		1.4	
80		1.4	
81	Houchins Ferry Spring	14.0	

The six large springs that enter Green River from the south were measured at various times during the summer of 1973 in a search for low flow conditions, a difficult task in an exceptionally wet year. The set of measurements finally accepted was obtained in September, already established as one of the low flow months in this region. They are listed in Table 5. Mill Hole, listed in the table, is a karst fenster on the Turnhole Spring drainage (Fig. 8). It provides a measurement point on an upstream part of this spring drainage net. The total discharge from the spring group during low flow was 952 ℓ/sec (33.6 CFS) compared with 1388 ℓ/sec for this same group of springs in Table 5. If the total discharge of all springs is adjusted by the ratio 952/1388 = 0.68, an estimated low flow discharge of 1870 ℓ/sec (66 CFS) is obtained equivalent to 1.86 ℓ/sec/km^2 (0.17 CSM). Considering the rough nature of the spot measurements, this number is in good agreement with the 1.64 ℓ/sec/km^2 (0.15 CSM) obtained from a longer term averaging of river records.

If we accept the values in Table 5 as true base flow discharges, and use the base flow runoff calculated from the river records, an estimate of the catchment areas that feed the big springs can be made. The sum of the drainage areas so calculated is 820 km^2 (316 mi^2), which is 110% of the measured catchment of 744 km^2 (287 mi^2) south of Green River. There is an additional error of about 5% that arises from having ignored the contributions of the small springs. The most obvious source of this overestimate of drainage area is that the flows listed

Table 5. Base Flow and Catchment Areas for Major Springs

Spring	Base Flow ℓ/sec	CFS	Calc. Area km²	Mi²	Measured Area km²	Mi²
Gorn Mill Spring	731	25.8	445	172	313	121
Garvin Spring	42.5	1.5		10		
Blue Spring S.	59.5	2.1	134	14	163	63
Pike Spring	68.0	2.4		16		
Echo River Spring	51.5	1.8		12		
Turnhole	396	14*	241	93	246	95
Mill Hole	269	9.5	163	63	186	72

* Based on estimated discharge corrected to low flow conditions.

in Table 5 are not true base flows. Since long period records on the individual springs are not available, this point cannot be checked.

The main objective of this set of measurements and calculations, however, seems quite unequivocal. To within experimental error, all runoff from the karst is discharged through the springs, and most of that is through a few large springs. The two regional springs actually account for more than 80% of the discharge. Therefore it can be concluded that the bulk of the ground water in this mature karst is being carried by the conduit systems. The diffuse component, which one can argue must be present, is lost in the experimental uncertainties.

Reference

J. W. Hess, S. G. Wells, and T. A. Brucker (1974) A survey of springs along the Green and Barren Rivers, Central Kentucky Karst. NSS Bull., 36(3), pp. 1-7.

Evolutionary Trends of Ground Water Geochemistry in the Central Kentucky Karst

John W. Hess and William B. White

Carbonate Water Types

The routing of water through a carbonate aquifer system is shown schematically in Fig. 9. The ultimate source of water is precipitation. Some of it falls on surface catchments and recharges surface sinking streams that become part of the underground drainage. Some precipitation infiltrates the land surface directly and becomes soil water. Part of the precipitation recharges perched aquifers above the basal carbonate aquifer. Discharge from these perched aquifers sinks into the underlying carbonates via vertical shafts and seepage.

Within the aquifer itself some of the main flow connections are indicated by arrows. Obviously these are not exclusive classes and the categories are parts of a continuum of flow paths. Soil water may move downward through small joints and primary porosity and is observed as small seeps and drips in open cave passages. As the vertical pathways become more open, the water moves more rapidly and may be aerated. This is important because vertical seeps will retain their high carbon dioxide concentrations gained from the soil zone, while vertical flows in larger pathways may lose their carbon dioxide.

Interconnections near the top of the saturated zone are fairly complex and hard to represent. Water moving in open channels or in pipe-full conduit flow are labeled "conduit system." Some conduit water discharged directly into springs and some fraction of this water also makes its way into phreatic storage. Shaft drains are small

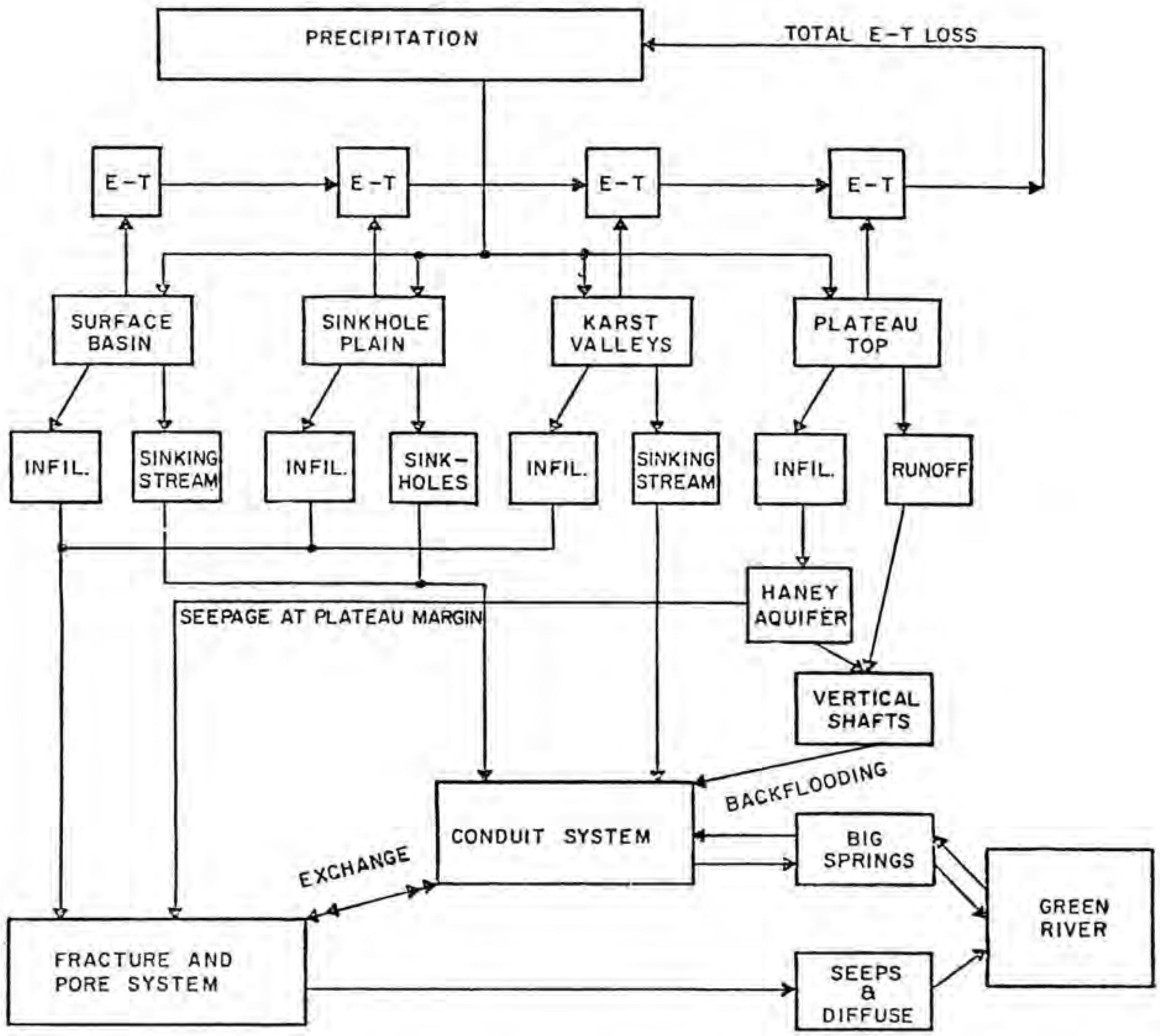

Figure 9. Model for groundwater flow in the Central Kentucky Karst aquifer.

conduit-like passages which may drain into large streams or emerge directly at the surface as a small spring. Little is known about the interconnections near the top of the saturated zone; particularly poorly understood is the manner in which groundwater is exhausted through diffuse percolating discharge.

Evolutionary Trends

The concept of the karst water type implies a systematic change in the chemistry of the water as it moves through the aquifer. These evolutionary changes are examined in this section.

Three parameters characterizing karst waters are the saturation index with respect to calcite, the carbon dioxide partial pressure, and hardness. The short term variations are smoothed, but the seasonal variations are retained by averaging the data over all sampling locations of the same type in two seasonal groups: the summer months, July, August, and September and the winter months January, February, and March.

The evolutionary trends are shown for both winter and summer data in Figs. 10 & 11. The behavior of the regional and local drainage systems is very distinctly different. The winter and summer data for these two types of systems tend to be of similar pattern but offset in numerical values.

Consider first the hardness-P_{CO_2} relations (Fig. 10). The vertical (local) system begins with the Haney springs which are characterized by low hardness and moderate carbon dioxide content. These waters drain through vertical shafts and the cave system to emerge at the local springs. There is apparently little loss or gain of CO_2 along this route and the waters emerge from the springs with more dissolved $CaCO_3$ but at about the same CO_2 partial pressure. In summer, the initial CO_2 content is higher, reflecting the seasonal trend established earlier, but the evolutionary path is the same. The regional system begins with the sinking streams which

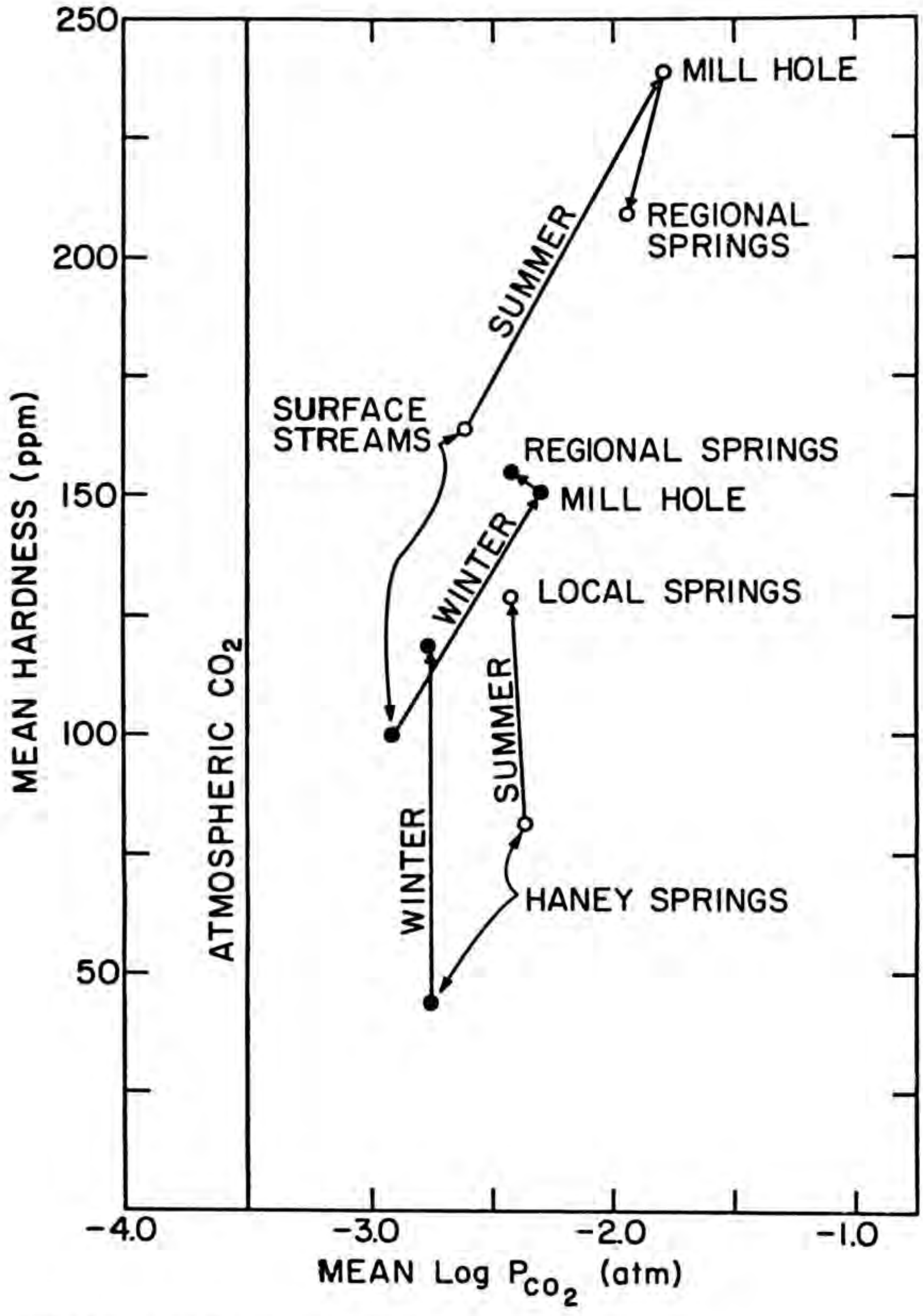

Figure 10. Plot of mean log P_{CO_2} versus mean hardness.

contain almost as much $CaCO_3$ and CO_2 as do the local springs. This water passes under the Sinkhole Plain to one of the two large regional springs. On the Turnhole drainage line, the flow can be observed at an intermediate point, Mill Hole, where the flow is already aggregated into a single conduit, just before it passes beneath the Chester Escarpment. Both hardness and P_{CO_2} have greatly increased, presumably because of the addition of infiltration water from the Sinkhole Plain. There is a decrease in both hardness and CO_2 when the water is measured at the regional spring (sampled at Owl Cave on the Turnhole drainage line). This decrease can be explained by dilution of the Sinkhole Plain water by injection of less concentrated water from the Plateau.

A similar pattern appears if the CO_2 pressure and the saturation index are compared (Fig. 11). Again the vertical component of the flow simply becomes more saturated as it moves toward the local springs. An additional link in the flow path is provided by analytical data from the vertical shafts reported by Brucker et al. (1972) which were available for the summer period only. The PCO_2-SIc point for the shafts falls directly on the line between the Haney springs and the local springs. The hardness of the vertical shaft waters was essentially identical to that of the local springs so it did not appear as a separate point in Fig. 10 .

The surface streams tend to be supersaturated in the summer and undersaturated in the winter but beyond this difference, the regional flow system trends to a common level of undersaturation very quickly. The effect of mixing water from the

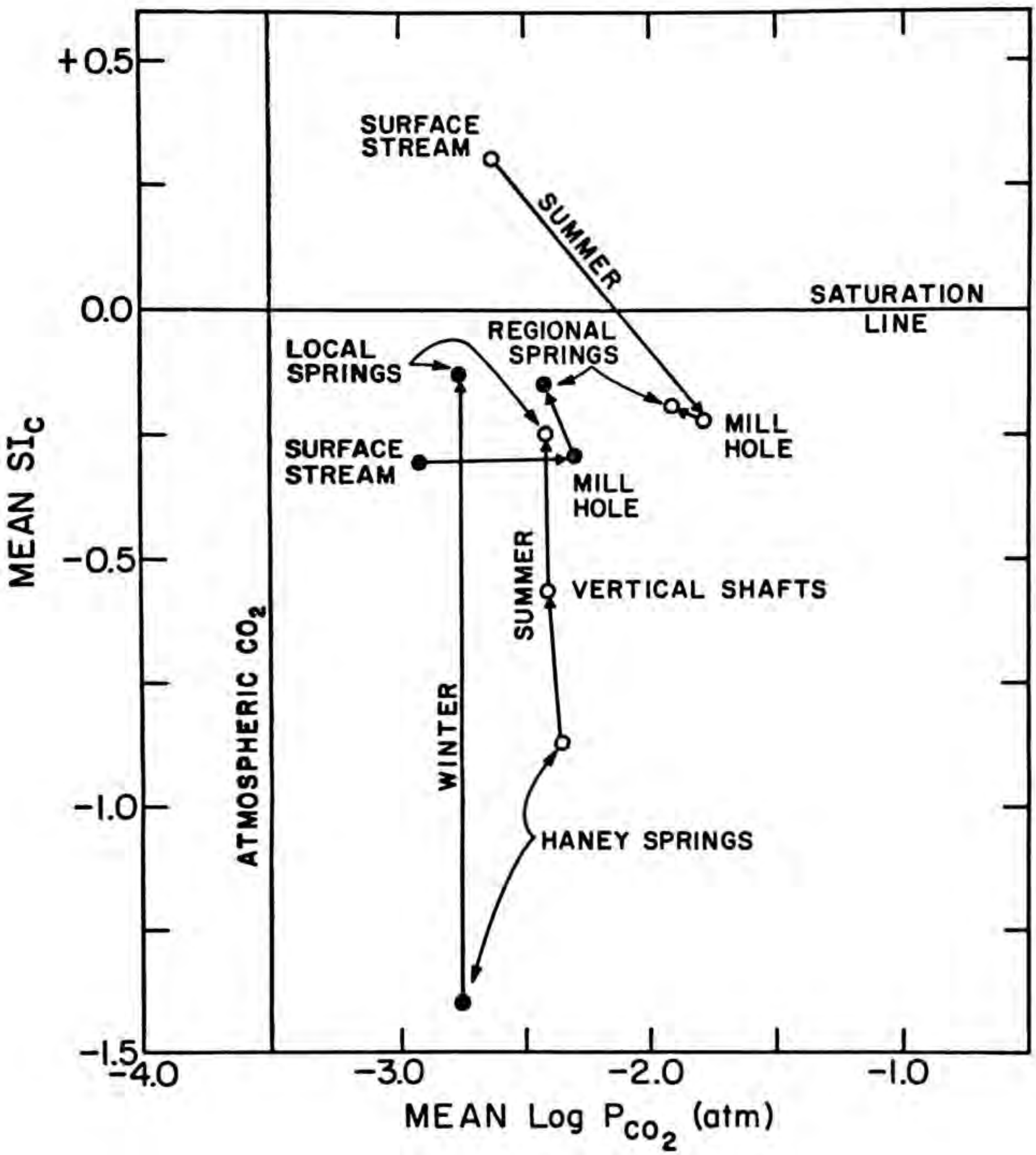

Figure 11. Plot of mean log P_{CO_2} versus mean saturation index.

Plateau appears mainly in a decrease in the CO_2 partial pressure below the values observed at Mill Hole. In general, the level of undersaturation of all springs in both seasons is the same within the statistical fluctuations of the measurements.

The pattern described is a bit distorted by averaging both regional springs together in keeping with the definition of water type. Only the Turnhole spring receives water from the Plateau, whereas Graham Spring receives water only from the Sinkhole Plain. If these two regional springs are plotted separately, the data from Graham spring fall close to the points for Mill Hole as would be expected for water sampled at the margin of the Sinkhole Plain, and the points for Turnhole alone are close to those labeled "regional springs" in the figures.

The main conclusions concerning evolutionary trends of the groundwater can be summarized:

(i) The distinction between the local and the regional springs, drawn originally on geologic grounds, is also manifested in the water chemistry.

(ii) The thick soils of the Sinkhole Plain are shown to be the most important source of CO_2 in the groundwater system. The thin soils and forest cover of the Plateau are a less important source.

(iii) All waters trend toward a common level of undersaturation. Both vadose and base level (shallow phreatic) waters appear to be undersaturated most of the time.

The results on the regional flow system are in good agreement with those obtained earlier by Thrailkill. We concur with his conclusion that the CO_2 pressure increases in the direction of groundwater flow, at least as far as the edge of the escarpment, and that soil infiltration water is the source of this CO_2.

Reference

Roger W. Brucker, John W. Hess, and William B. White (1972) Role of vertical shafts in the movement of ground water in carbonate aquifers. Ground Water, 10, 6.

Analysis of Storm Response Events

John W. Hess and William B. White

The Turnhole Spring system is a regional drain whose catchment is shown in Fig. 12. It was instrumented for continuous recording of temperature and specific electrical conductance, Spc, at Owl Cave. A rain gage network was established to measure storm inputs. The records for the period July through November 1972 are shown in Fig. 13. The average daily precipitation is shown as a bar graph at the top of the figure. Specific conductance, temperature and river stage values are for 12:00 noon each day.

In order to probe the interior workings of the aquifer, sharp input pulses of water are needed. These are best provided by intense storms of short duration followed by periods of little or no rain through the recovery period. It can be seen from Fig. 13 that only three events, labelled A through C, occurred within the five month period. In fact, only eight such events occurred within the entire year and a half period of observation. Detailed examples of two storm events were given in the 1973 CRF Annual Report.

Relaxation of the Aquifer

The recovery time of the Spc and temperature hydrographs after a storm event is on the order of two to three weeks for the Turnhole drainage. Since the Spc is a measure of the hardness and the hardness has been shown to correlate weakly with discharge, then the Spc can be a rough measure of the discharge. Even if the recovery is off by a large percentage, the data still indicate that the through-put time for the total storm input is very rapid. This observation indicates the presence of a very open system with conduit flow and very little long term storage above the stage as determined by the Green River.

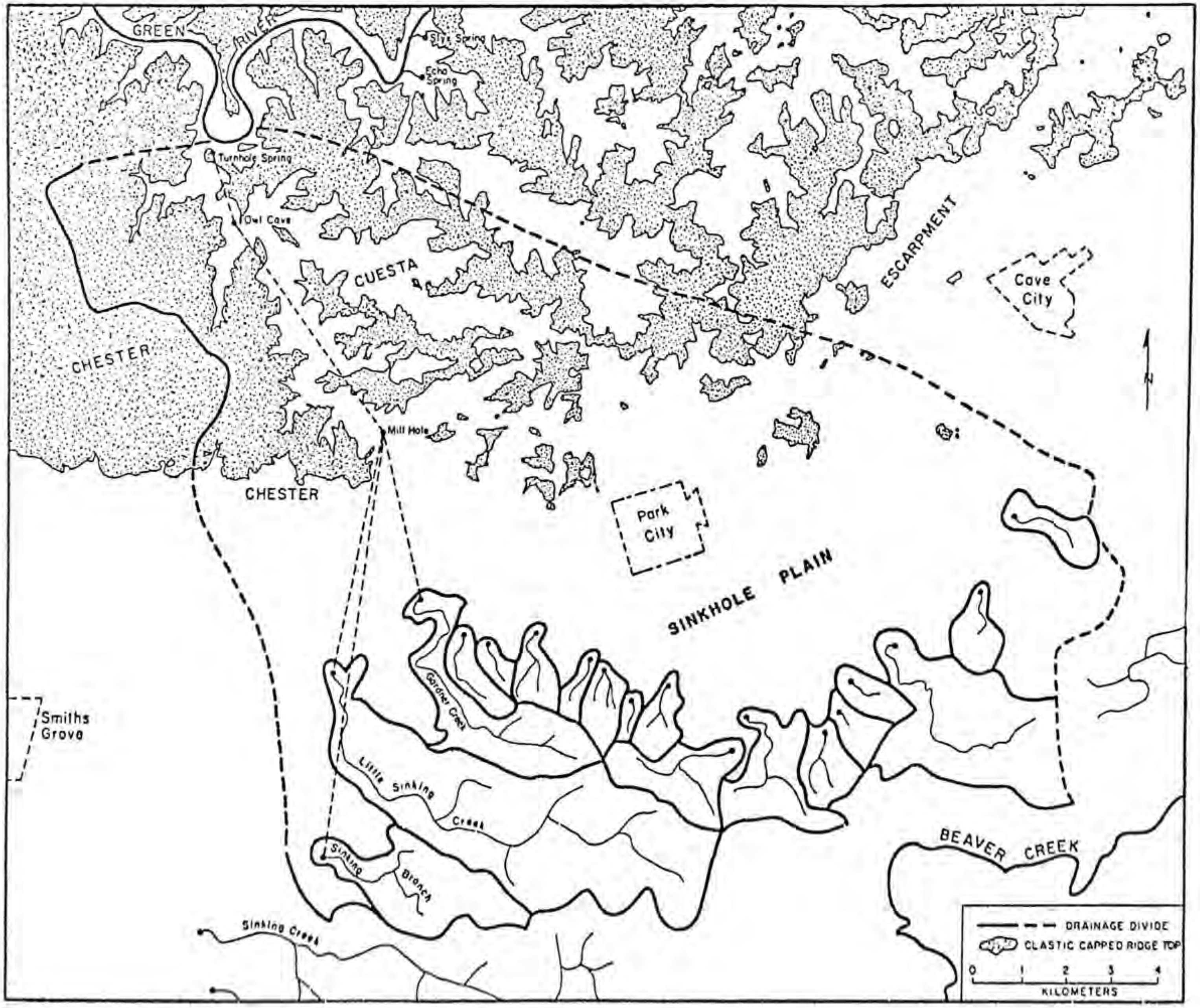

Figure 12. The Turnhole Spring drainage basin.

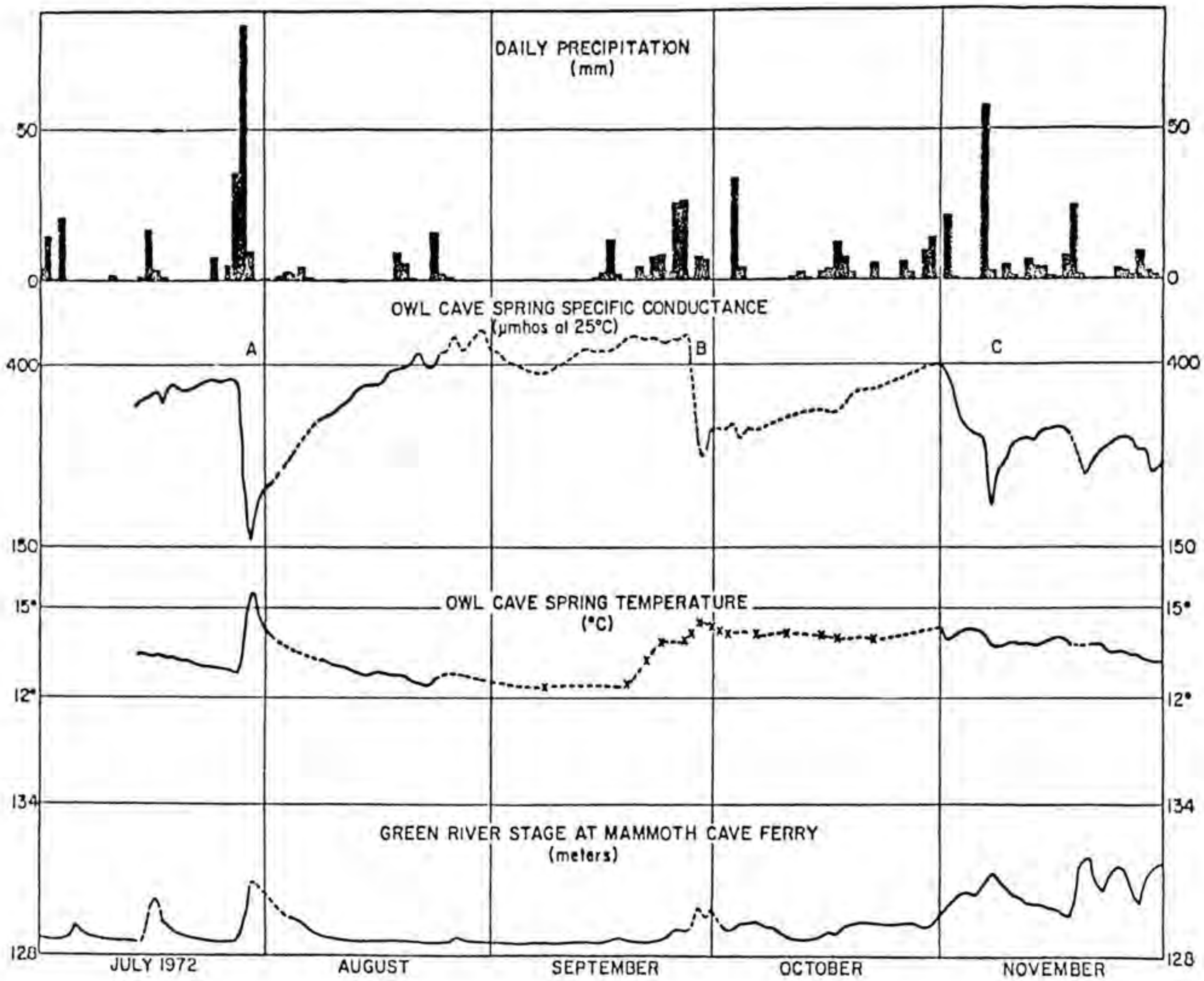

Figure 13. Annual continuous records for Owl Cave, July-November, 1972.

Karst Drainage Patterns North of the Green River in the Central Kentucky Karst

Joseph W. Saunders

Little is known about present or past karst drainage patterns north of the Green River. Much of the region draining southward to the Green River consists of clastic-capped ridges. It differs from the region south of the river because it has a more confined catchment area and the drainage flows generally in opposition to the bedrock dip. In addition, this area contains perennial surface streams tributary to the Green River. Numerous sinking streams are present north of the river, and thus drainage is divided between surface and subsurface routes. The first major contribution to our knowledge of subsurface drainage patterns of this area was that of Hess, Wells, and Brucker (1974), which provided information on the discharges and locations of 29 springs on the north side of the river. With this information, it was possible to start tracing the subterranean flow of the region. In early September 1974, under intermediate flow conditions, ten pounds of fluorescein was placed in Sinking Creek, two miles east of the town of Cub Run. The traps were first checked eight days later, and the dye was detected in traps set at the Blue Hole North resurgence, three miles due south of the site where the Sinking Creek stream sinks. The Blue Hole North appears to be the largest spring on the north side of the Green River (Hess, Wells, and Brucker; 1974). Sinking Creek presently sinks into alluvium at a horizon in the Girkin Limestone about elevation 600 feet, and resurges from the lower Ste. Genevieve Limestone on the Green River at approximate elevation of 430 feet. Sinking Creek has an apparent surface drainage area of four square miles. The tracing of Sinking Creek to the Blue Hole North on the Green River has geomorphic significance because it indicates that Sinking Creek, which topographically appears to be the former headwaters of the nearby Nolin River tributary Cane Run, has been pirated by the Green River. Other sinking streams in the area will be traced with dye in an attempt to delineate the drainage basin of the Blue Hole North.

In Buckner Spring Cave four miles east of Munfordville, a more direct picture of a karst drainage system on the north side of the river has been obtained. The cave survey to date totals 2.1 miles, 1.9 of which carries a major base level stream, 0.5-1.0 cfs in low flow. The main passage maintains an average width of fifteen feet, with heights between two and twenty feet. Tributaries enter at grade, are numerous and small, and rarely can be followed more than a hundred feet. The predominant sediment is sand; the main stream is skirting a large sandstone-capped ridge. Present observations suggest a rather simple history of the cave. Buckner Spring Cave is developed in the lower St. Louis Limestone, apparently perched on the underlying Salem about thirty feet above the Green River.

Further exploration and survey in Buckner Spring Cave are planned.

<u>Reference</u>

J. W. Hess, S. G. Wells, and T. A. Brucker (1974) A survey of springs along the Green and Barren Rivers, Central Kentucky Karst. <u>NSS</u> <u>Bull</u>., <u>36</u>(3), pp. 1-7.

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Pleistocene Paleoclimates as Recorded in Central Kentucky Speleothems

Russell S. Harmon

During 1974 age dating and stable isotope analysis of stalagmite 72041 (Davis Hall) was completed and resulted in the first ^{18}O content vs. time profile for a speleothem from the continental interior of North America. Analyses of modern soda-straw stalactites and associated drip waters were completed and allowed a climatic interpretation to be placed on the ^{18}O record for sample 72041. Two other deposits, samples 74008 and 74009 (Great Onyx) are presently under study.

The purpose of this study was to investigate late Pleistocene paleoclimates of continental North America as recorded in the speleothem record. In detail, oxygen-18 and deuterium/hydrogen analyses of calcite speleothems and entrapped fluid inclusions provide a means of determining the climate, and in some cases, the absolute temperature at which the speleothem was deposited. Thus by determining the age of a speleothem and running an axial stable isotope profile for the specimen, a paleoclimate curve can be constructed.

Ages for speleothems analyzed to date along with pertinent radiochemical data are given in Table 6. The central Kentucky area is unique in the ten karst areas studied to date in that only there and in the Nahanni Region of northern Canada has speleothem material of such antiquity been consistently preserved. In all other areas speleothems older than 200,000 years B.P. are rare, whereas in central Kentucky it is rare to find material younger than 300,000 years.

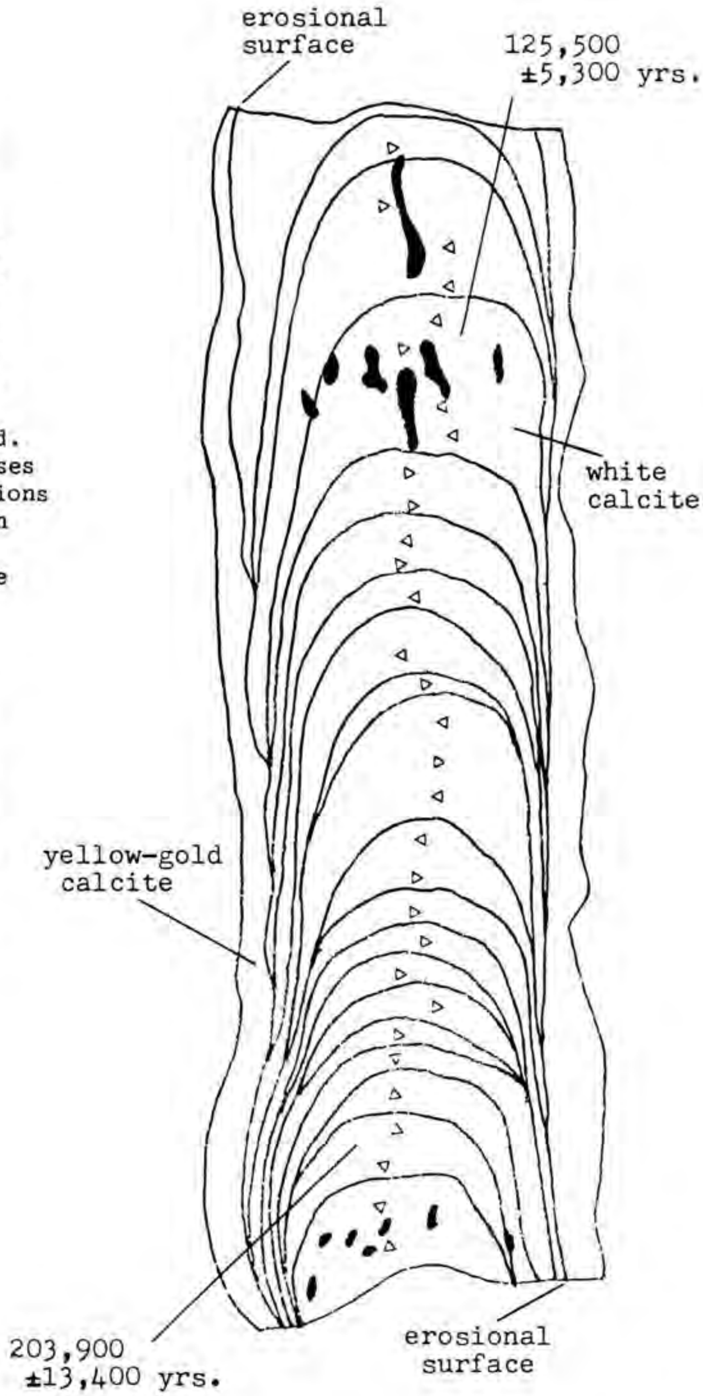


Figure 14. Schematic diagram (full size) of stalagmite sample 72041 from Davis Hall of the Flint Ridge-Mammoth Cave System, Central Kentucky.

Table 6. Speleothem Age Data

Sample #	U conc. (ppm)	Activity Ratios $^{230}Th/^{234}U$	$^{234}U/^{238}U$	$^{230}Th/^{232}Th$	Age (years B.P.)
72041:13	1.5	.697 ± .016	1.16 ± .03	37	125,500 ± 5300
72041:5	0.57	.866 ± .012	1.17 ± .14	44	203,900 ± 3400
74009:1	53.1	.904 ± .016	1.05 ± .03	254	247,200 ± 5400
72036:4	0.28	1.14 ± .10	.976 ± .12	75	>300,000
72037:1	0.25	1.05 ± .08	.992 ± .05	19	>300,000
72035:1	1.13	1.02 ± .039	1.149 ± .026	50	>300,000

The oxygen isotopic composition of a series of points along the axis of speleothem 72041 (Fig. 14) has been made. The results are plotted against age compared with the modern dripstone deposits in Fig. 15. The ^{18}O profile is in good agreement with other speleothem results over the same time period, but the absolute amplitude of the ^{18}O variation is less than for other areas presumably due to the remoteness of central Kentucky to the major North American ice sheets during the Pleistocene. The well recognized 100,000 and 180,000-200,000 years B.P. periods are prominent in the 72041 record as is the extended cold period 130,000-170,000 years B.P. (Illinoian glacial period).

Several fluid inclusions extracted from the calcite stalagmite have been analyzed for their D/H ratios in order to determine the ^{18}O composition of the water from which the specimen was precipitated. This allows for a calculation of absolute temperature of deposition to be made, based upon experimental determination of the calcite-water fractionation factor as a function of temperature. Stable isotope ratios and calculated temperatures for sample 72041 are given in Table 7. It is seen that temperatures during the Illinoian glaciation were consistently 10°C lower than present, and that the adjacent, warmer interglacial periods had temperatures a few degrees Centigrade less than at present. This adds additional support to present speculation that the present interglacial period in which we are living is unusually warm and is unequalled in the Pleistocene.

Additional samples will be analyzed during the next year as the project nears completion and it is hoped that a final report will be completed within the next twelve months.

Table 7. Calculated Paleotemperatures for Kentucky Speleothem 72041

Sample #	Dist. above base (cm)	Age (yrs. B.P.)	$\delta^{18}O_c$ *	$\delta^{18}O_n$ *	T (°C)
fossil stalagmite 72041					
FIS-13	2.2	188,000	25.30	-6.14	10.7
FIS-4 & 5	5.0	179,000	25.58	-7.28	5.1
FIS-9 & 10	7.8	168,000	24.57	-6.88	10.6
FIS-11 & 12	10.2	160,000	26.18	-7.40	2.4
FIS-7	16.5	137,000	25.55	-8.32	1.1
FIS-14	22.0	117,000	25.24	-6.51	9.5
FIS-3 & 6	23.8	110,000	24.99	-6.99	8.9
FIS-2	26.8	100,000	25.55	-6.78	7.2
modern stalactites					
SS-10	----	0	25.13	-5.84	13.8 +

* per mil values expressed relative to standard mean ocean water (SMOW).

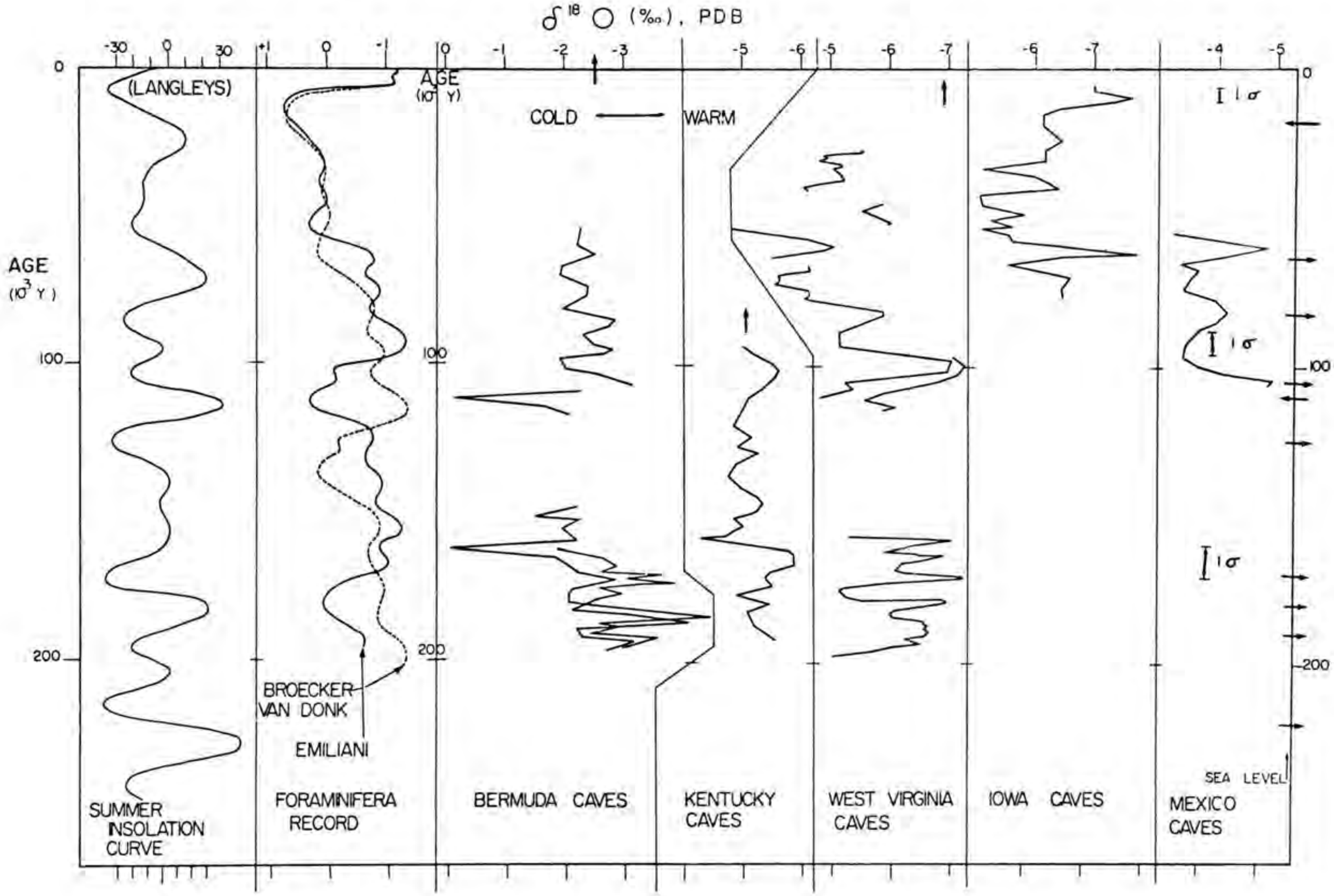


Figure 15. ^{18}O *vs.* age profiles for speleothem samples from five North American karst areas. The foraminiferal ^{18}O and insolation records are shown for comparison. Arrows on abscissa indicate ^{18}O for modern deposits and arrows on the ordinate indicate relative sea level positions for that particular time.

Saltpetre Conversion and the Origin of Nitrates in Caves

Carol A. Hill, P. Gary Eller, Carl B. Fliermans, and Peter M. Hauer

With the assistance of a National Geographic Society grant, an interdisciplinary attack was mounted on the long-standing mystery of the origin of nitrates in caves and the production of saltpetre from cave soils. Anticipated to be of four to five years duration, the saltpetre project will study the chemistry, history, microbiology, historical archeology and mineralogy of cave nitrates, and how these relate to the interpretive program at Mammoth Cave National Park.

The research commenced over the July 4th expedition with the action history experiment. The purpose of this experiment was to duplicate the historical process of making saltpetre crystals from saltpetre dirt (as was done in the War of 1812 at Mammoth Cave). The nitrate that exists in cave soils may be nitrocalcite, $Ca(NO_3)_2 . 4H_2O$. Nitrocalcite is hygroscopic, that is, it absorbs moisture from the air. For this reason nitrocalcite had to be converted to niter (KNO_3, otherwise known as saltpetre) before using it in gunpowder. The saltpetre conversion experiment was successfully carried to completion during the July 4th week. The origin of cave nitrate study was begun concurrently with the action history experiment. The purpose of this investigation will be to study how cave nitrates relate to 1) different types of guano (bat, rat, beetle, cricket) and microorganismal activity on these guanos, and 2) surface drainage and amount of nitrates in overlying bedrock. We also plan to investigate the regeneration rates and the mineralogy of cave nitrates.

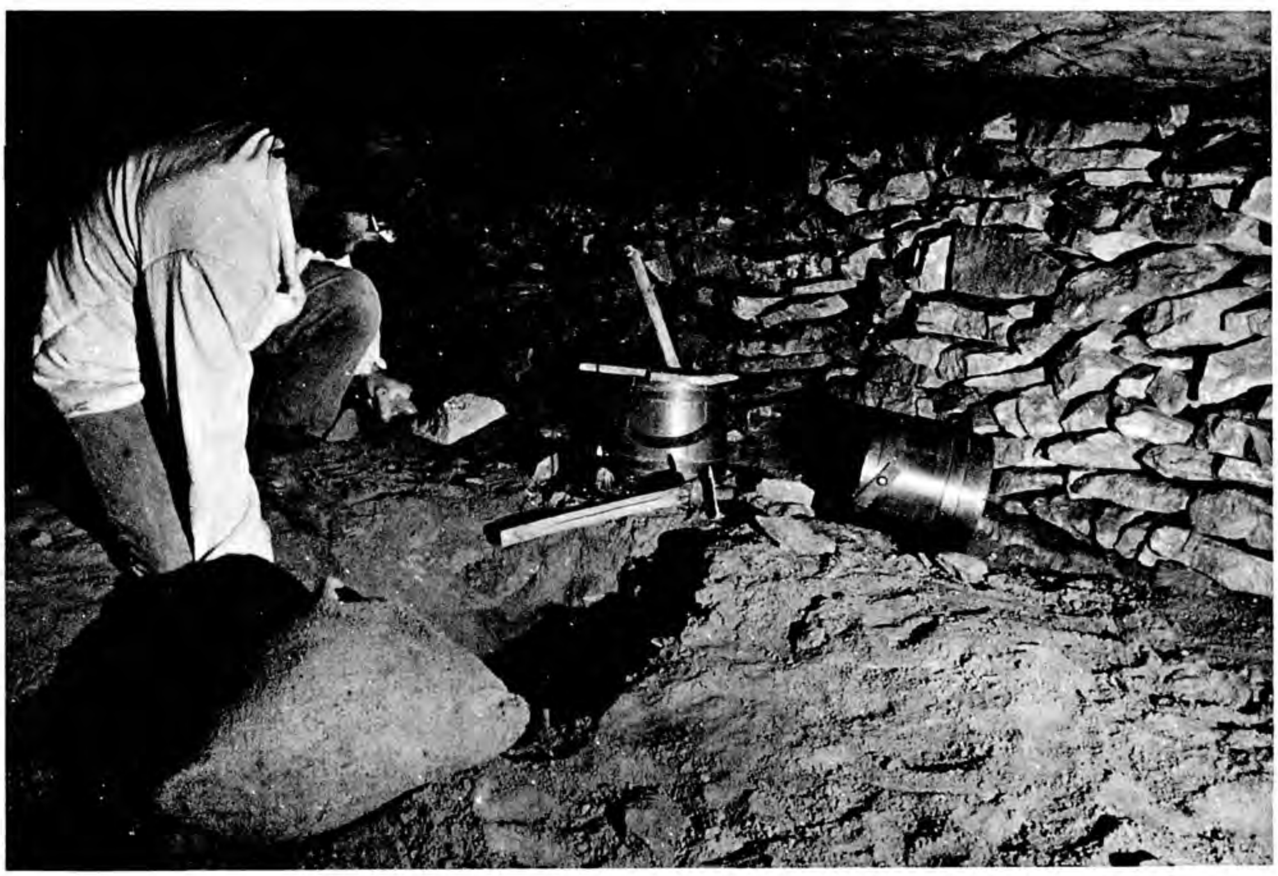
Replication of Artifacts

A complete small scale replication was made of the saltpetre manufacturing process used commonly in caves of the Southeastern United States during the 18th and 19th centuries. A saltpetre leaching vat, or "hopper" was constructed with antique hand tools. The bottom drain trough to the hopper was constructed of white oak. It was cut to length with a hand axe, hewed out with a broad hatchet and footadze, and then finished with a chisel and mallet. The shorter catch trough, which received the nitre liquor from the drain trough, was also cut of white oak and was hewn using the same tools as before. The framework of the saltpetre vat was cut from a variety of available wood including yellow locust and birch. The corner posts were axed to length and the tops trimmed to pegs with a small broad hatchet and finished with a pocket knife. The peg holes were drilled with an antique wood auger. A wooden mallet was used to pound the framework into place. The vat was lined along the sides with slabs of white oak. The vat was finally lined with wheat straw and loaded with saltpetre dirt. The loaded vat seemed quite stable. The straw, combined with the wet saltpetre dirt, sealed the sideboards so that there was very little leakage along the sides of the vat. No nails of any kind were needed in the construction of the vat.

Saltpetre Conversion

Field work during the year established that nitrates are distributed in the sediments of Mammoth Cave and that large local variations of nitrate concentrations (between 0-2%) occur. A laboratory bench run with a 500 g sample (analyzing at 2.4% nitrate) from Kingston Saltpetre Cave (Bartow Co., Ga.) yielded 8 g of high purity saltpetre and reconfirmed the practicality of the conversion process. A field run at Lobelia Saltpetre Cave (Pocahontas Co., West Virginia) served to identify difficulties which can occur in the replicated saltpetre conversion process. For the Mammoth Cave action history experiment, a site in Audubon Avenue, Mammoth Cave was selected which gave a strong nitrate test (0.55% nitrate). Approximately one bushel (103 kg.) of nitre earth was dug using an antique mattock and hewn saltpetre paddles and was carried from the cave in gunny sacks. Period costume (homespun shirts) and authentic lighting (lard oil lamps) were used during the mining operation. The nitre earth was placed in the leaching vat (lined with straw to prevent leakage) and water (25 gal) was allowed to percolate slowly through the nitre earth; the leach water was recycled through the vat for further concentration of nitrates. Concentrated potash lye liquor (5.4% potassium), prepared by leaching oak and hickory hardwood ashes, was added to the leach water until further addition produced no further turbidity. This particular step, the only chemical transformation in the saltpetre conversion process, serves two functions: the precipitation of undesired calcium and magnesium as insoluble hydroxides, and the addition of potassium ions to give (ultimately) the non-hygroscopic KNO_3. The gelatinous precipitates were removed by straining through cheesecloth, and the liquor was concentrated in an iron kettle over an open fire. At a volume of about one liter, the first product separated as tabular crystals of arcanite (K_2SO_4). At 600 ml a thin surface layer of "grease and foam" (which old published accounts mention) was successfully removed by adsorption onto turnip chunks. Concentration to 300 ml gave a mixture of arcanite crystals and schoenite ($K_2SO_4 . MgSO_4 . 6H_2O$) crystals. At 100 ml additional arcanite and needle crystals of niter (KNO_3) formed. Further concentration yielded almost exclusively niter crystals. Crystalline products were identified by physical and chemical properties, by elemental analysis and by x-ray powder diffraction patterns. Quantities obtained were: schoenite (116 g), arcanite (12 g) and niter (44 g). The once-leached nitre

Figure 16. (a) Construction of saltpetre vat.
(b) Removing niter earth from Mammoth Cave.



earth was again leached with 25 gal of fresh water and the above conversion and evaporation process was repeated. Again, only three crystalline forms were observed: schoenite (22 g), arcanite (30 g) and niter (54 g). The saltpetre was readily refined by fractional crystallization from water to give white needles of approximately 85% purity (based on potassium analysis). The total quantity of saltpetre obtained (98 g, or 11% recovery of the total nitrate in the nitre earth) indicates the leaching process is very inefficient and certainly does not approach the 2-6 lbs per bushel sometimes claimed in the old literature. The poor yield, however, could reflect our inexperience with the leaching and conversion process.

The sulfate minerals which crystallized undoubtedly derive from dissolution and conversion of soluble sulfate minerals commonly present in the Mammoth Cave sediments (primarily gypsum, epsomite and mirabilite). The solubility curves in Fig. 17 vividly illustrate the reason that fractional crystallization serves so well to isolate pure saltpetre. The solubility curves of most common impurities are relatively flat with respect to temperature, whereas the solubility of saltpetre increases markedly with temperature. In contrast to old accounts of the crystallization process, no sea salt (KCl and NaCl) crystals were observed.

Once the vat was constructed and the nitre earth collected, the saltpetre conversion was easily performed on a small scale (such as was done over the July expedition) by one individual in two days.

Microbial Studies

Sediment samples were collected from various parts of Mammoth Cave for the microbial studies. Biomass tests were made at the Audubon Avenue test site before, during and after leaching. All sediments were positive for both Nitrobacter and Nitrosomonas bacteria. All samples contained Nitrobacter agilis rather than Nitrobacter winogradskyi (the predominant microorganism of surface soils). Both direct FITC and indirect plating techniques demonstrate that the total bacterial populations in the cave were low (10^5 bacteria per gram of sediment) compared to total populations

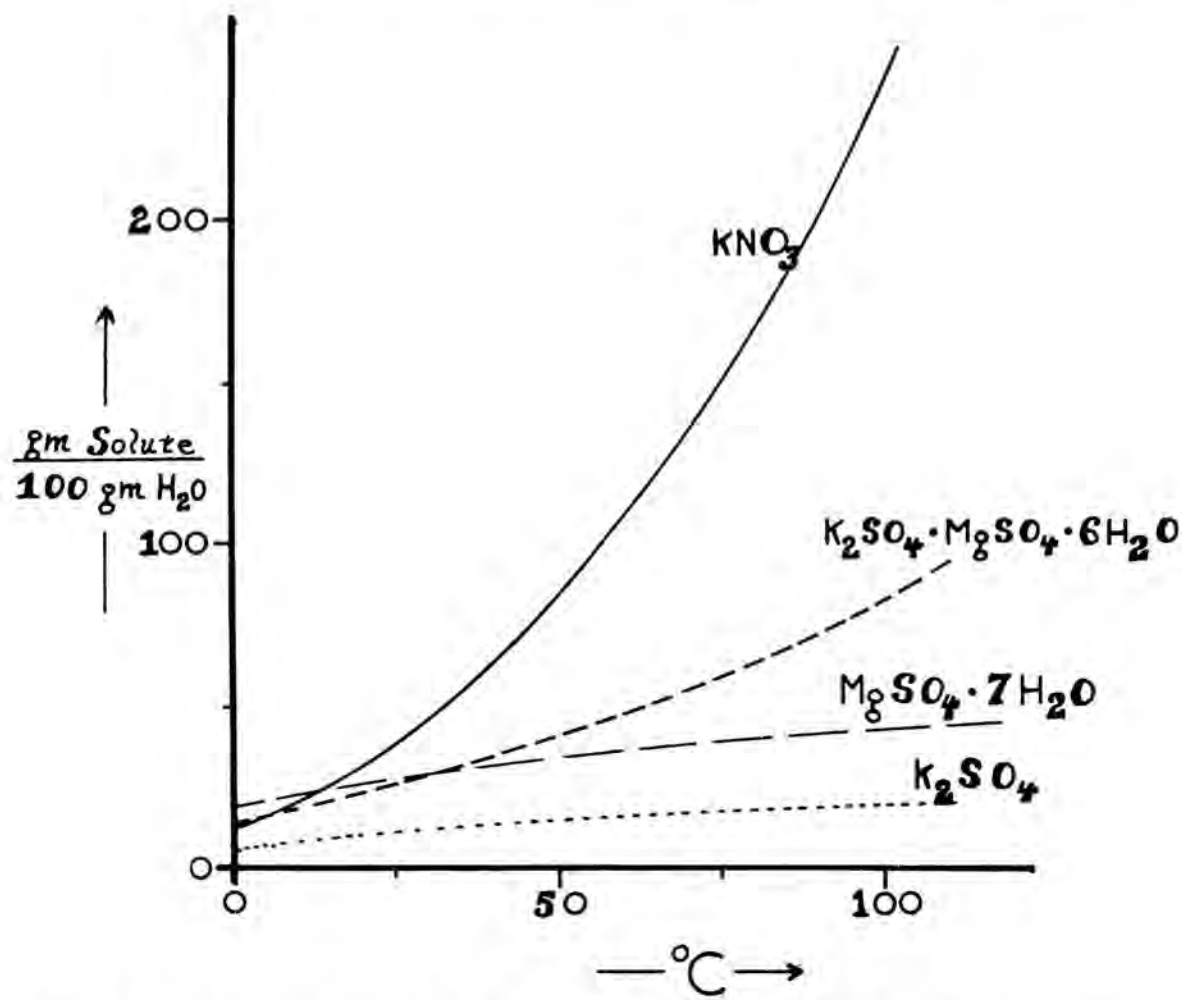


Figure 17. Solubility curves for niter (KNO_3), schoenite ($K_2SO_4 \cdot MgSO_4 \cdot 6H_2O$), epsomite ($MgSO_4 \cdot 7H_2O$) and arcanite ($K_2SO_4$).

Figure 18. (a) Removing liquor from saltpetre vat.
(b) An authentic 1812 vintage Mammoth Cave boiling kettle, near Brownsville, Ky.

in agricultural soils or soils above Mammoth Cave (10^7-10^8 per gram). During the leaching experiments 85-90% of the total heterotrophic population was leached while only 10-15% of the Nitrobacter population was removed. This fractionation could mean that during leaching many of the competitive heterotrophic bacteria are removed while Nitrobacter remains. Thus, the regeneration of nitrates may be facilitated both by removal of inhibitory levels of nitrate and by removal of competing heterotrophic bacteria. Activity measurements on the total bacterial population by monitoring CO_2 evolution demonstrated that nutrients rather than moisture limit the activity of the bacteria. This is most unusual in that under normal conditions (e.g. agricultural soils) the limiting factor for activity is moisture. This observation further demonstrates that cave ecosystems are unique and extreme in that certain parameters such as nutrients, light, moisture etc. are limiting. The regeneration, if any, of nitrates in the leached earth (returned to the original digging site in Audubon Avenue) will be monitored by respiration techniques.

History and Archeology

The following important historical and archeological discoveries were made by the saltpetre research team:

1. An authentic 1812 vintage Mammoth Cave boiling kettle (weighing some 900 lbs.) was found in a corn field near Brownsville, Ky.
2. Previously undocumented remains of saltpetre vats were identified in two other caves within Mammoth Cave National Park.
3. The foundations of the original boiler chimneys were located at the entrance to Mammoth Cave.
4. Cartographic and eyewitness descriptions of the relic mother liquor pumps in the Rotunda indicate that the liquor probably was pumped out using slave labor rather than by a gravity-flow system.

Photography

All stages of the "action history" experiment were photographically recorded by Pete Lindsley. We now have an excellent file of photographs documenting all facets of the action history experiment, associated chemical and microbiological experiments, saltpetre artifacts in Mammoth Cave, boiling kettles, local historical personalities and subjects of geographical interest on the sinkhole plain, Chester escarpment and the Green River.

Characterization of Karst Soils by Reflectance Spectroscopy

William B. White

The present investigation utilizes the light reflecting properties in both the visible and near-infrared regions of the spectrum to compare underground and surface soils and to provide some clues to source areas. Karst areas are noted for their bright red soils as contrasted with the brown soils on most other rocks. What this investigation accomplishes is a quantification of the color of the soil and further extends the "color" beyond the range perceived by the human eye.

Surface soils were collected from the B-horizon where the soil profile was exposed in roadcuts. One traverse was made across the Sinkhole Plain along Route 90 from Glasgow to Cave City and from Cave City along Route 70 up onto the Chester Cuesta to Mammoth Cave National Park. Residual soils were collected from road cuts north of Green River and several samples of bright red sand were collected from weathered outcrops of the Pottsville (Caseyville) sandstone. Red residual soils were collected from the Sinkhole Plain and fluvial soils were collected from the floodplains of two of the larger sinking creeks (Sinking Creek and Little Sinking Creek), from the mouths of Echo River Spring and Pike Spring, from the bottom of Cedar Sink and from the Green River floodplain. In all 24 surface soils were analyzed.

Samples of cave sediments were collected at various times from 1961 to 1973 in the course of other investigations of the cave system. From a total collection of some 70 soils, 24 were selected for spectroscopic investigation. These were chosen from major passages in the cave system and usually several samples from the same passage were included.

The reflectance of a selected group of soils in the visible region of the spectrum is shown in Fig. 19. Since the soils are highly absorbing, particularly in the blue region of the spectrum, the curves are plotted as absorbance (A) rather than percent transmission $A = -\log T$. Each spectrum is a monotonic curve showing high reflectivity in the red and poor reflectivity in the blue. The spectrum of the karst soil slopes upward very steeply indicating that the sample is reflecting mainly red light which, of course, is just what one observes in the color. The curves for the upland soils and the floodplain soils are each less steep, resulting in some reflectivity in the yellow and green regions of the spectrum and giving an overall brown and yellow color respectively. The cave soils from the upper levels have much the same appearance as the spectra of the upland soils and the baselevel cave soil spectra much resemble the spectra of the floodplain soils. The curves are not quite featureless. There is a distinct shoulder or plateau at about 450 nm. This feature, like the 900 nm band observed in the near infrared, is re-

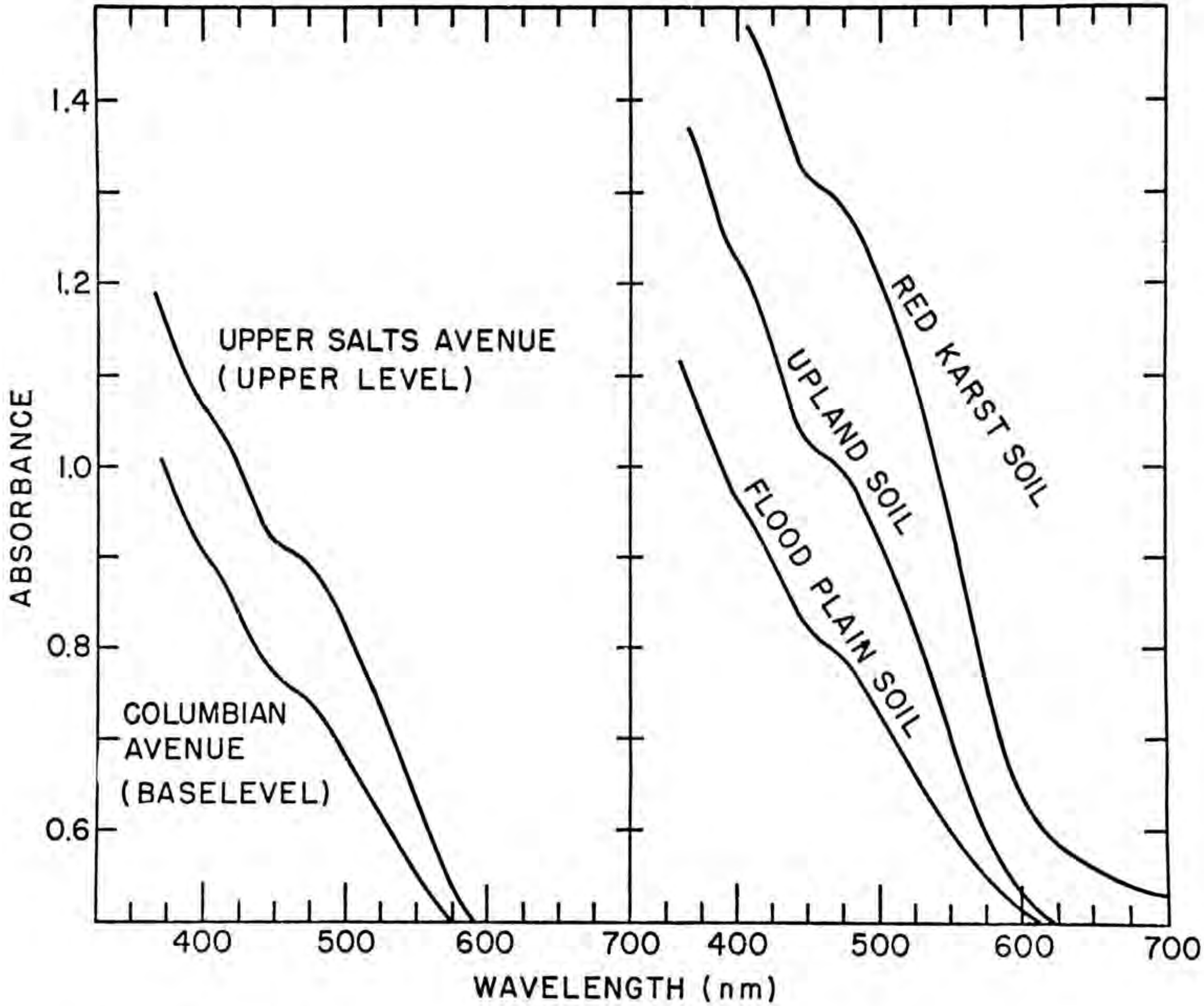


Figure 19. Curves depicting wavelength versus absorbance for selected Central Kentucky Karst soils.

lated to the presence of ferric iron.

The visible spectra were analyzed by comparing the absorbance at several wavelengths. Selected were 450 nm (blue), 525 nm (green), and 600 nm (red). Plots of different combinations of these measures against each other produced a quite definite separation of the soils. Most definite was the plot of the blue/red ratio against the green/red ratio shown in Figs. 20 and 21. Since the wavelength separation of the measurements is constant, these ratios are essentially measures of the overall slope of the line against the slope of the blue end of the line. If the visible spectra had consisted of straight lines, measures of the slope on two different intervals would have produced the same number and the resulting plot would have been a straight line with a 45° slope. Since the spectra exhibit a distinct curvature, the green to red segment has a different average slope from the blue to red segment.

The surface soils are rather neatly separated into three sequences. The red limestone residual soils fall along one straight line segment on which also plots two bright red weathered sands from the Caseyville formation. The brown soils fall on a second sequence offset from the red soil sequence. The brown soils from the eastern margin of the sinkhole plain are not distinguished from the residual soils from the Plateau. Considering the diversity of soil types, however, the regularity of the plot is surprising. The fluvial soils, spring mouth soils and river floodplain

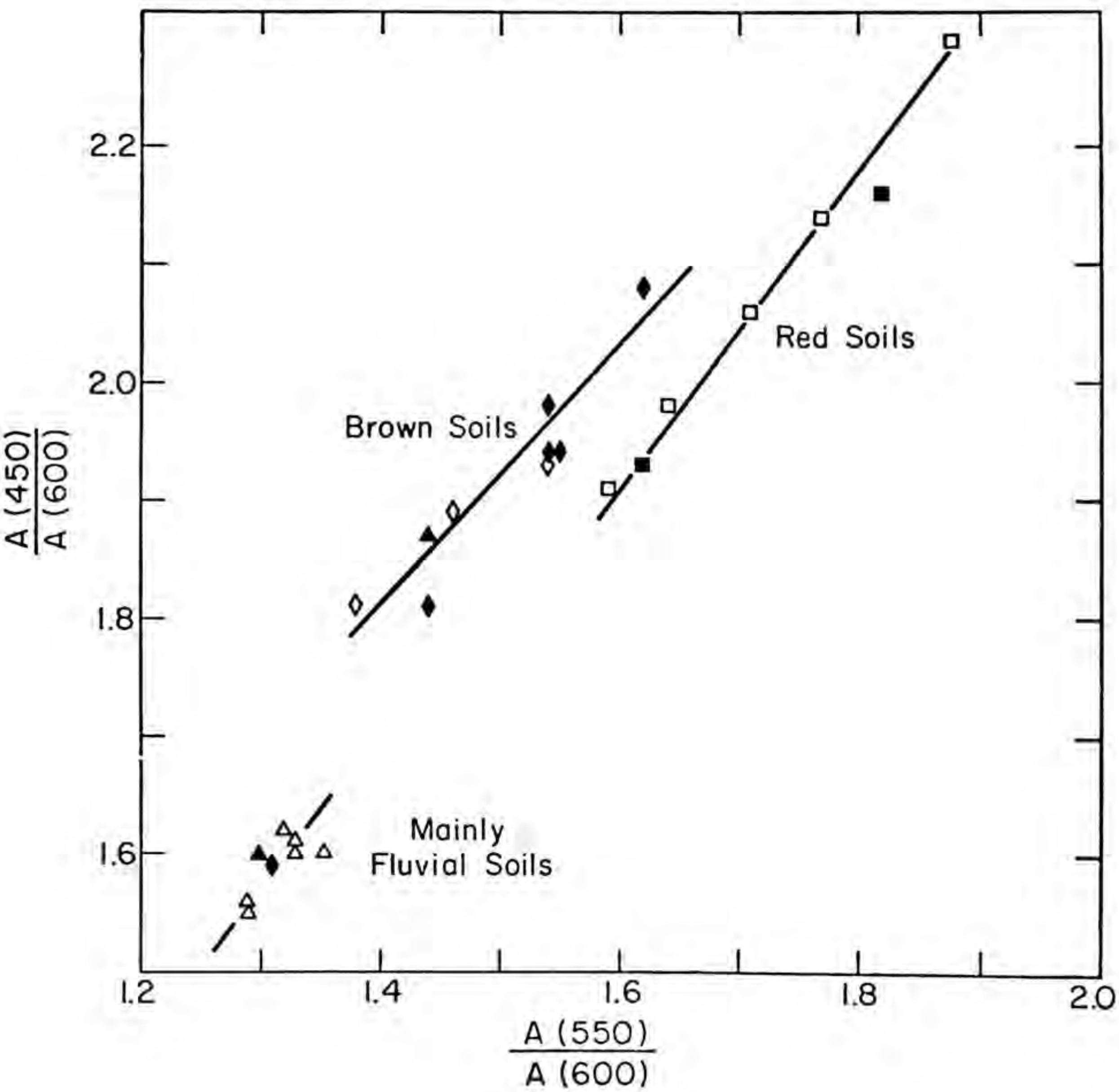


Figure 20. Plot of characteristic ratios calculated from soil absorbances at 450, 550, and 600 nm.

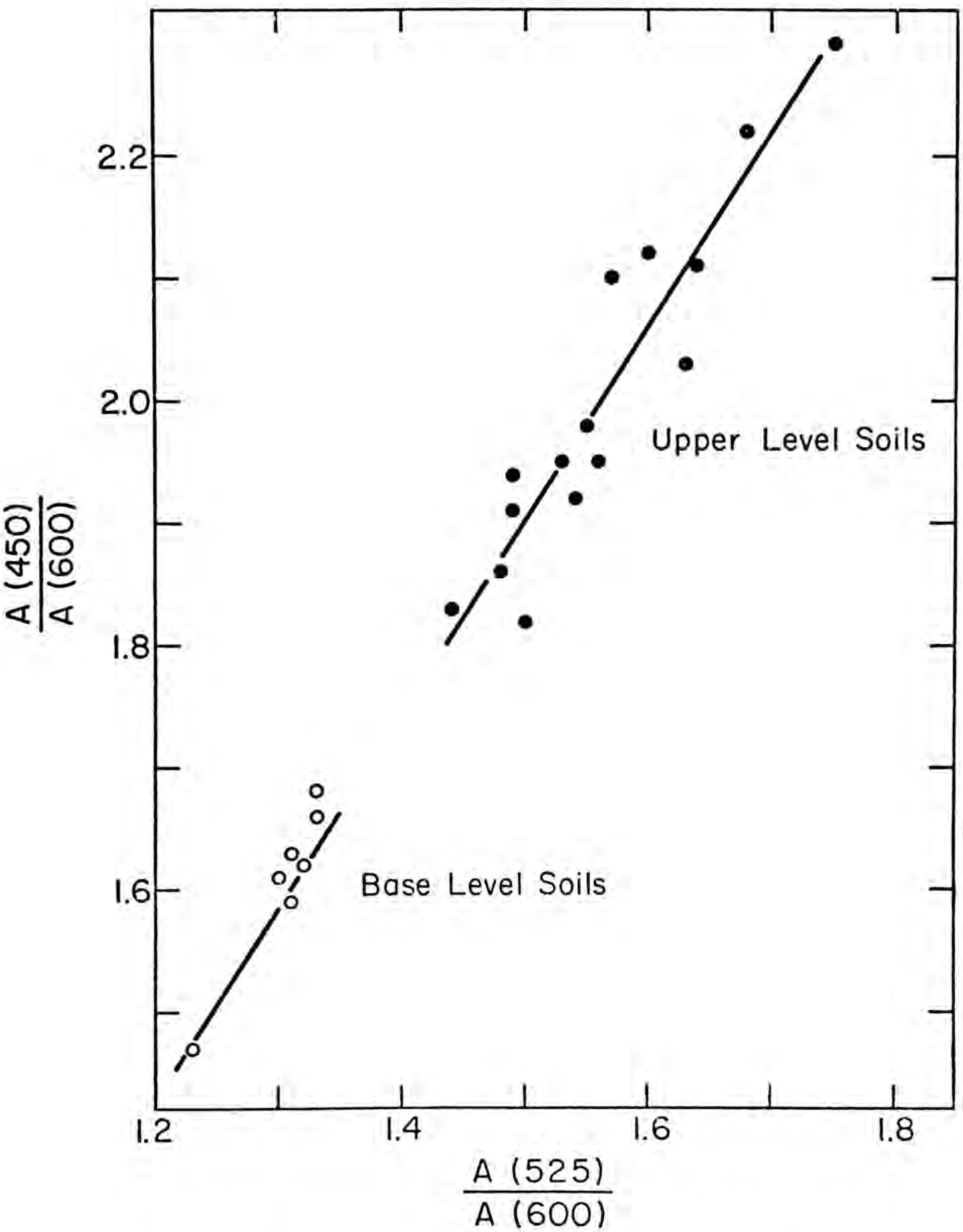


Figure 21. Plot of characteristic ratios calculated from soil absorbances at 450, 525, and 600 nm.

soils fall into a tight group in the lower corner of the diagram. There are two anomalies. One plateau soil plotted with the fluvial group. It was a residual soil from the Big Clifty formation and was essentially a yellow sand that looked much like the fluvial soils. Of the two sinking creek floodplain soils, one fell with the brown residual soils and one fell with the fluvial group. Since the physical appearance of these two soils is nearly identical, it is difficult to explain the anomaly.

The cave soils fall onto a single trend line, but in two quite distinct groups. Again the upper level soils clearly group separately from the base-level soils. There is no elevation relation along the line of upper level soils. Two samples from Turner Avenue, for example, plotted at nearly opposite ends of the line.

If the two comparisons are superimposed, it is found that the baselevel soils from the cave system in each case fall directly over the plots of fluvial soils. Likewise, the upper level soils have the same characteristics as the brown plateau soils. No sediments were found in the cave that have a spectral reflectance like the red limestone residual soils.

Geology and Geomorphology of Crystal Cave

Arthur N. Palmer and Margaret V. Palmer

Nearing completion during 1974, the Crystal Cave project was extended beyond its titular boundaries into other parts of Mammoth Cave National Park. The stratigraphic section from Crystal Cave was extrapolated by observation through the main passages of the Flint-Mammoth Cave System and other nearby caves, and to road cuts in and around the National Park. Detailed hand leveling, the mainstay of the Crystal project, was conducted only in areas of special significance or interest. Although facies changes and variations in stratal thickness complicated the correlation, the major rock units of the Girkin and Ste. Genevieve Formations could be identified with little difficulty throughout the Central Kentucky Karst. A generalized geologic column is in preparation.

By identifying the geologic units exposed in passages throughout the Park it was possible to determine the approximate altitude of each passage with the aid of the structural contours shown on the USGS geologic maps of the area, although in places a correction factor was required to compensate for variations in formation thickness. The sequence of passage development in the Flint Mammoth System was interpreted from this information. In doing so, it was recognized that absolute altitudes are not as useful for correlation of truncated passage segments as are the stratigraphic horizons exposed in their walls, owing to the high degree of concordance between the cave passages and the geologic structure in all but local areas. A full interpretation of the sequence of passage development will appear in the forthcoming book on the hydrology of the Central Kentucky Karst edited by William White. Listed below, however, are some of the more interesting observations:

1. The oldest passage in the entire Flint Mammoth System is Collins Avenue in Crystal Cave, which is also the highest stratigraphically, only 10-15 feet beneath the base of the Big Clifty Sandstone.

2. The solutional levels of the "Vestibule", Dismal Valley, and other sections of Upper Salts are located more than 60 feet below the sandstone cap-rock and represent a much later episode of cave formation than that of Collins Avenue.

3. The main passages of Great Onyx Cave do not correlate with nearby Pohl Avenue in the Flint Ridge System, but instead correlate both stratigraphically and in projected elevation with Upper Salts (as does Dyer Avenue in Crystal Cave, which is perhaps a precursor of Great Onyx).

4. The oldest, and stratigraphically highest, observed passages in Mammoth Cave (Blue Spring Branch - Gothic Avenue - Broadway - Audubon Avenue) are situated within the basal 30 feet of the Girkin Limestone.

5. The oldest strata encountered in the Flint Mammoth System are in Mammoth Cave, which extends at least 40 feet into the St. Louis Limestone.

Results of the project are to be published in the near future. The interpretation of structural and stratigraphic control of cave passages will appear in a geological journal, and a guide to the geology of the park is being prepared for publication under the auspices of the Cave Research Foundation.

Gravity Survey at Carlsbad Caverns

John McLean

The gravity survey at Carlsbad Caverns now includes more than 300 stations. Several of these have been occupied two or three times in an attempt to minimize drift errors. Bench marks up to a half mile from the surveyed area have been occupied to provide data on the regional gravity gradient. Several stations in the Mystery Room of Carlsbad were occupied to provide additional data on the density of the overlying limestone. Field work in the near future will be limited to reoccupying a few missed and questionable stations and to establishing the value of the free-air gravity gradient in the area.

A preliminary analysis of the observed gravity gradient in the elevator shaft indicates that the limestone density is about 2.5 gm/cc. This is in poor agreement with six samples of Capitan Limestone taken from the spoil pile in the Underground Lunchroom. These samples had a mean density of 2.625 gm/cc with a standard deviation of only .028 gm/cc. Compensating for the known cave using the point-element technique and using a measured free-air gradient value may bring the calculated value into better agreement with the sample values.

Plans for 1975 include writing a series of utility programs to correct the station gravity values for terrain effects using the line-integral method and to calculate the near-surface density using the Nettleton method.

Speleogenesis in the Guadalupe Mountains

David H. Jagnow

The purpose of this study is to further document the geologic factors influencing speleogenesis in the Capitan Reef complex of New Mexico and Texas. The study is primarily focused on caves other than Carlsbad Caverns, with a secondary purpose of further refining earlier observations in Carlsbad Caverns. The study area is confined to approximately 200 square miles of rugged mountains and canyon along the northeast prong of the Guadalupe Mountains in southeast New Mexico and adjacent west Texas. Elevations within this area extend from 3500 feet at the mouth of Dark Canyon to 8751 feet at Guadalupe Peak, the highest point in Texas.

To date, the study includes geologic investigation of 52 caves, with the 1974 field work being concentrated in Ogle Cave and Rainbow Cave. The work accomplished this year included primarily drafting of structural cross sections and cave maps, petrographic analyses, and continued literature research and writing.

One of the most important conclusions is that sulfuric acid (in addition to carbonic acid) played a major role in the solution of these caves. The source for the sulfuric acid is in the overlying Yates Formation, where massive concentrations of limonite and abundant limonite pseudomorphs after pyrite document what was originally great volumes of iron pyrite. The final stages of solution by sulfuric acid resulted in thick beds (up to 30 feet) of finely laminated (varved?) gypsum being deposited in most Guadalupe caves. Recent vadose diagenesis of these gypsum beds has resulted in recrystallization and/or complete removal by solution of much of the gypsum.

Detailed cross section surveying in the Left Hand Tunnel of Carlsbad Caverns documents a slight tilting of former water level markers (lines of popcorn), with an apparent dip of $\frac{1}{4}^{\circ}$E. This indicates partial uplift of the Guadalupe Mountains following solution of this level of Carlsbad Caverns. Structural dip in this immediate area is approximately 1°E. Future surveying of these popcorn lines should better define the true dip of previous base levels, and will undoubtedly project into adjacent caves (Spider Cave, Chimney Cave, Wind Cave).

This project summarizes the lithologic, hydrologic, and structural controls in speleogenesis in the Guadalupe Mountains. The study is near completion, and will be published as an MS thesis during the spring of 1975.

Control of Species Diversity in Terrestrial Cave Communities

Thomas L. Poulson

Effects of Food Rigor and Predictability

The experimental studies outlined in the CRF 1973 Annual Report (pp 52-54) were approved by the National Science Foundation in the spring of 1974, with funding to be initiated in December of 1974. The first series of experiments was initiated last July.

To reiterate briefly, the multiple hypotheses being tested center around the idea that high food predictability and low food rigor selectively favor simple communities because such a pattern and rate of food input favors species that have abilities to exclude (interference) or outcompete (exploitation) the species of complex subcommunities. The hypotheses being tested derive from field observations of natural experiments as described on p. 54 of last year's annual report.

Starting in July, 20 replicated experimental series were initiated in areas close to entrances, where there are many facultative cave species and obligate species, and in areas farther from entrances where obligate species predominate and there are fewer kinds of food input and thus fewer subcommunities. The cave areas are Great Onyx, Austin entrance area of Flint Ridge, Little Beauty on Joppa Ridge, and Hanson's Cave on the sinkhole plain. An experimental series consists of 5 pitfall traps each with a different treatment: a control with 5 adjacent rocks; 5 piles at 30 g each of monthly renewed standard horse manure (lowest rigor=highest available calories per time) and 5 rocks; 5 piles of unrenewed horse manure (to allow microsuccession) and 5 rocks; 5 piles of dead beech tree leaves renewed monthly and 5 rocks; and 5 piles of dead beech tree leaves unrenewed to allow microsuccession (highest rigor =lowest available calories per time) and 5 rocks. Visual counts under rocks and food piles and trap contents (visual and microscopic) are taken at 1, 2, 4, 12, and 24 hours, at 2, 4, 8, 15, and 30 days, and at 2, 3, 4, 5, 6, 8, 10, and 12 months. After the initial intensive month of study this entailed 3 days per month by 4-6 biologists working in the caves 12 hours/day. To control for the limited dispersion possible for an experimental series in entrance areas, where the 5 treatments were only 1 meter apart in a cluster (:·:), half of the replicate series in deeper cave areas were clustered and half dispersed with intertreatment distances of about 5 meters and interseries distances of 10 meters.

Coincident with following the food manipulation experiments, data are being gathered on three aspects of each species' biology to rank the species on an r^+ to r^- selected continuum (see column 3, p. 51 of the 1973 Annual Report for some of the aspects). The first aspect is foraging pattern including such items as kinetics of arrival at food, bias for food types compared to control, consistency of finding each pile when a food treatment is found, and rates of movement and turning which generate a mean free path. The second and third aspects are life history and bioenergetics which may be interrelated through the idea of caloric life span, e.g. live fast=die fast and vice versa. Life history includes age at first reproduction which is related to generation time, fecundity, size of eggs which is related to size of smallest individuals seen, and frequency of reproduction. Bioenergetics includes growth and metabolic rates, foraging cost, and relative energy allocation to growth, maintenance, and reproduction.

The results to date show that low food rigor somehow favors simple communities with a high dominance of one to two r^+ selected species. For example, near entrances these include, in order of appearance and dominance, the sciarid fly Sciara, the sphaerocerid fly Leptocera, the catopid beetle Ptomaphagus, and the staphylinid beetle Quedius. In the same areas the highest food rigor attracts, with slower kinetics, a more diverse array of species with no dominants. The r^+ selected species just mentioned are present but no more common than the r^- selected species which include such species as, from the r^+ to r^- end of the spectrum, the springtails Arrhopalites and Onychiurus, the bristletail Plusiocampa, the millipede Scoterpes, the carabid beetle Pseudanophthalmus (including larvae), and usually one other predator from the three rarer cave specialists which include the phalangid, Phalangodes, spider Anthrobia, and the pseudoscorpion Kleptochtonius.

The data are just being analyzed but other interesting trends are: 1) an increase in diversity between piles of food and rocks with time over the entire experimental series and perhaps with microsuccession; 2) that the specialized obligate cave predators, the ultimate r^- selected species, arrive at the most rigorous food when the prey numbers and biomass are declining; 3) that there appears to be seasonal reproduction of some of the more r^+ selected species despite continued availability of fresh food; and 4) that cross gradients of species immigration exist even far back into the cave whereas the microsite effects near entrances persist in spite of the expected evening effect of food addition.

As usual this year's observations have generated new hypotheses and suggested new approaches for the following year. These include: 1) the possibility that some r^+ selected species exclude other species will be tested using enclosures with additions of known densities of the species in question; 2) the possibility that the organisms do not rely on decomposition by native microflora since the sequence of phyco-asco-basidio-mycete flora on the leaves and horse manure were different for each food type but the same in all areas of the cave irrespective of the rate of microsuccession; 3) the possibility that some r^- species arrive late just because of slow dispersal will be checked by adding them to fresh food in exclosures both with early colonists present and with no other organisms; and, 4) the possibility that the island-area effect of food addition differs with the same amount concentrated vs. dispersed is being checked in the Natural Bridge Area.

Comparative foraging and Physiological Ecology of the Crickets (Gryllacrididae, Rhaphidophorinae) Ceuthophilus and Hadenoecus subterraneus

This work represents the Master's thesis research of Ellen Levy (foraging behavior) and Ai Chu Wu (physiological ecology, especially bioenergetics). Ms. Levy will complete her work soon; Ms. Wu is starting.

Levy is testing the proposition that Hadenoecus is a scavenger whereas Ceuthophilus is a more generalized omnivore. The lines of evidence being used include morphology, sense organs, gut contents, and behavior with emphasis on the latter. The longer legs and antennae in Hadenoecus suggests a "scavenger on stilts" strategy which is adaptive in getting the animal and its long antennae off the ground and out of the quiet boundary layer into air that carries scents of possible food. Ceuthophilus, in contrast, has short legs and moves along over leaf litter beating its shorter antennae and maxillary palps on the ground. Contents of digestive tracts and bait trapping show that these different behaviors are associated with different foraging success. The large distensible crop in Hadenoecus is an adaptation to securing rare and widely dispersed food items and the rarity of identifiable gut contents are consistent with this. Ceuthophilus has a small crop and muscular gizzard and plant parts are almost always identifiable. A lower percentage of guts full or with continuous food boluses in Hadenoecus would be consistent with its feeding by scavenging on rare and unpredictable food items. Bait trapping outside of caves in summer, where both species forage, show that Ceuthophilus shows little discrimination between baits whereas Hadenoecus, especially the large individuals, shows a bias in the following order of decreasing calories available per gram of food: peanut butter $>$ limburger cheese $>$ rotting meat $>$ fermenting fruit $\gg$ horse manure $>$ fermenting leaf litter $\gg$ fresh crushed leaves $\geq$ control.

Wu is working out techniques for determining metabolic costs at different absolute humidities. So far the techniques used are weight loss and times to become quiescent and recovery times with CO_2 anesthetization. For animals of the same body weight, Hadenoecus has the higher metabolic rate.

Studies of Simple Cave Communities: Predation Strategies of Two Co-occurring Carabid Beetles

(Ph. D. Dissertation Abstract. University of Notre Dame. August, 1974)

Thomas C. Kane

Heterogeneity or lack of uniformity is an important component of most ecological systems. The present study assesses the importance of heterogeneity and species diversity on the ecology of two carabid beetle species, Neaphaenops tellkampfii and Pseudanophthalmus menetriesii. Heterogeneity of food resources appears to be of primary importance in considerations of between habitat diversity in these systems. Effects due to abundance of food and heterogeneity of substrate also affect between habitat diversity, but are less significant influences than resource heterogeneity. Physical rigor is not important in considerations of between habitat diversity, although it has been shown to affect within habitat diversity.

The population dynamics of the predaceous carabid beetle Neaphaenops tellkampfii are consistent with a spreading of the risk or multiple factor model. Neaphaenops establishes semi-isolated populations in many qualitatively different types of habitats. Fecundity varies directly with degree of heterogeneity whereas variability in fecundity varies inversely with heterogeneity of habitat. Preliminary results indicate that between year fluctuations in

population size are smaller in heterogeneous than in homogeneous habitats.

The foraging strategies of Neaphaenops and a second carabid species, Pseudanophthalmus menetriesii, are greatly influenced by the temporal and spatial pattern of their respective preferred food resources. Neaphaenops prefers the eggs and nymphs of Hadenoecus subterraneus (Orthoptera : Gryllacrididae) which are abundant only in spring and summer. Habitats in which these items occur are poor in alternate prey items. As a result, Neaphaenops is forced to switch diet and habitat in fall and winter when eggs and nymphs of Hadenoecus are rare.

P. menetriesii prefers microarthropods associated with organic material. These items are patchy in space but evenly distributed over time. As a result, P. menetriesii shows more restricted diet and habitat utilization than Neaphaenops. The observed foraging behavior of both Neaphaenops and P. menetriesii is shown to be consistent with the predictions of theoretical models of optimal feeding strategies.

Resource Partitioning in Five Species of Carabid Beetles

Thomas C. Kane, Terry Van Zant, and Thomas L. Poulson

An important question currently facing ecologists concerns the manner of control of diversity and stability in natural communities. Several processes have been suggested as controlling mechanisms of stability and diversity and principle among these have been predation and competition. Predation appears to be important in systems where the predator preys on a species which is a superior competitor and, by lowering the numbers of this prey, permits coexistence of one or more of its competitors. A second way in which predation has been shown to enhance species diversity has been reported by Estes and Palmisano. In an arctic marine system they found that predation on sea urchins by sea otters permitted the establishment of kelp beds and fauna associated with them, resulting in a much more diverse community.

Whereas predation often acts to increase species diversity, interspecific competition generally acts to place a limit on the number of species that can stably coexist. Schoener has proposed an approach to the study of competition and its impact on a community through the investigation of resource partitioning among multispecies complexes. Using this method, one recognizes the multi-dimensional character of the niche. It becomes important then to ascertain which niche dimensions are important in permitting or preventing coexistence of several closely related competing species. Further, the investigator can order the several species along the axes of these dimensions and determine the distance between species required to permit coexistence.

The present study proposes to investigate resource partitioning in five species of carabid beetles which are important components of the terrestrial cave community in the Central Kentucky Karst region. Caves are valuable model systems for such studies in that they are simple, allowing accurate census in the field, and further, since most species are invertebrates, they lend themselves to more detailed study in the laboratory. In addition, the limestone in central Kentucky is extensive and continuous. This has two advantages. First, the entire system has access to the same potential species pool and therefore differences in species composition from site to site reflect ecological rather than historical differences (Poulson and White). Second, there are many caves in the area which may differ in several measurable parameters. As a result these caves may be treated as natural experiments in which the manipulations have already been made.

All of the carabid beetle species under consideration are obligate cave dwellers (i.e. troglobites). The complex is composed of the monotypic genus Neaphaenops tellkampfii and four species of the closely related genus Pseudanophthalmus. A number of morphological and behavioral differences noted between the five species are potentially important in understanding the pattern of resource partitioning and form the basis of this study. These differences include differences in body size (Barr), differences in substrate preference (Kane and Poulson; Kane; McKinney), differences in degree of aggressive behavior (McKinney), and differences in timing of adult recruitment (Kane; McKinney).

The differences reported for these species suggest four potential niche dimensions along which resource partitioning may occur. Body size differences often reflect differences in size of preferred prey item or differences in size range of prey items taken (Brooks and Dodson; Price). Differences in substrate preference suggest separation along habitat dimensions, either on a large scale (i.e. macrohabitat) or on a finer scale within a macrohabitat (i.e. microhabitat). Presence or absence of aggressive behavior suggests differences in the use of interference competition. Finally, differences in timing of adult recruitment may suggest qualitative differences in prey species preferences.

Population and Behavioral Studies of a Troglobitic Isopod, *Asellus jordoni*, in a Groundwater Environment

James H. Keith

From May, 1973 through January, 1974, a population of the isopod Asellus jordoni was studied in a groundwater seep in the basement of Jordan Hall on the Indiana University campus, Bloomington, Indiana. The seep was divided at the halfway point by a wire screen with a mesh opening of 0.75 mm. Weekly visits were made and the following was noted:

1) Population size above and below the screen.
2) Size of each isopod.
3) Substrate on which each was found.
4) Number and size of amphipods when present.
5) Velocity of seep.
6) Temperature of seep.
7) Presence, number and sizes of copulating pairs.

The findings can be briefly summarized:

1) The average isopod size was smaller below the net than above (5.5 mm vs. 8.7 mm).
2) Upstream movement appeared to be as important to the colonization of each area as was down stream drift.
3) The population fluctuated markedly on both sides of the net, but the fluctuations were synchronized.
4) The fluctuations increased in amplitude and peaked in October. At this time, copulating pairs of isopods were observed. After October, the fluctuations decreased.
5) Amphipods were never numerous in the seep, comprising only 10% of the total animal count at maximum.

The presence of the fluctuations proved to be of the most interest. The fact that they were synchronized indicates that some form of olfactory regulation of population size probably exists among this species of isopods, at least. Further experiments are being done to discover whether such a mechanism does exist and its impact on the isopods and their population size.

Ecology of the *Neaphaenops - Hadonoecus* Predator - Prey Systems

Russell M. Norton

The chief goal of this project during 1974 has been to demonstrate the selective basis for the long-short ovipositor polymorphism in populations of the cave cricket, Hadenoecus. The long and short ovipositor morphs occur in Hadenoecus populations which live in the respective presence or absence of Neaphaenops, a cave beetle predacious chiefly on the eggs and nymphs of Hadenoecus. Experiments placing Hadenoecus eggs at the long and short oviposition depths have failed to show any differential predation. This was not wholly unexpected since Neaphaenops digging behavior is presumably coevolved with the longer Hadenoecus ovipositors. Since unexpected, it will be impossible to study beetle digging behavior which is not coevolved for predation on the more deeply oviposited Hadenoecus eggs. The next step will be to compare the digging depth of Neaphaenops with Darlingtonea, its eastern Kentucky ecological equivalent. Since Darlingtonea is essentially the same size as Neaphaenops and since the more robust eastern Kentucky Hadenoecus species has a longer ovipositor than the western Kentucky species, the hypothesis is that Darlingtonea will dig to a deeper depth than Neaphaenops. The result should strengthen the demonstration that beetle digging behavior is coevolved with ovipositor morphology, since any egg oviposited at a deeper depth must have a (slightly) higher probability of not being predated. This next phase of research will be conducted outside MCNP and demonstrates the relevance of cave research outside the region to faunal studies within the Park itself.

Activity Rhythm of the Cave Cricket, *Ceuthophilus conicaudus* Hubbell

Glenn D. Campbell

During 1974 the initial phase (a Masters thesis) of my research on the activity rhythms of cave crickets in two caves of Carlsbad Caverns National Park (Water Tank Cave, Spider Cave) was completed. The following is a brief summary of the results obtained in my thesis research.

The thesis describes and analyzes the movements of a population of the cave cricket Ceuthophilus conicaudus Hubbell inhabiting Spider Cave (Carlsbad Caverns National Park) in southern Eddy County, New Mexico. Field data were obtained during July and August 1974 to ascertain both the specific activity exhibited by this population and the environmental conditions of the hypogean and epigean environments that might have directed or influenced the activity. Laboratory data supplemented the description of the activity as to its nature under constant and varying conditions.

Stations were established within Spider Cave at the entrance, along the entrance crawl tunnel, and along the inner walk tunnel of the cave at varying intervals. Air temperature, relative humidity, rate of air movement in the cave, direction of air flow, barometric pressure, light intensity, and various surface weather conditions were continuously taken during the study period. Cricket movement was monitored at the entrance by an electronic counter that accurately estimated the number of crickets leaving the cave each hour of the night. A periodic nature of the emergence was evident, with movement out of the cave beginning each night at about 2000 hours (MST), furthermore, a period of nocturnal activity, and a long period of diurnal inactivity was observed. There were significant differences between the total number of crickets leaving the cave during the hours of the day. An average of the 10 nights showed that 91% of the crickets left the cave between 2000 and midnight.

The number of crickets leaving the cave on any given night was found to vary significantly. There was a range from the high of 1195 crickets leaving the cave the night of July 7th to a low of 110 leaving the night of July 3rd. Climatic conditions of the surface and cave environments were investigated with regard to their influence on the size of this nightly cricket movement. Multiple factor analysis and regression techniques were used to determine the relative importance of these climatic conditions. The multiple regression analysis explained a total of 63% of the variation of the number of crickets emerging nightly. Of this percentage, the surface temperature and humidity accounted for most of the variation (45%). A component not included in the factor and regression analysis was moonlight. Observations of moon phase and cloud cover gave a fairly accurate picture of relative moonlight intensity. Moonlight was found to be closely correlated with cricket appearance with more crickets leaving the cave when there was little moonlight. This avoidance of light is conceivably a mechanism to evade predation.

Analysis of environmental conditions at the time of the appearance of the first cricket each night suggested the factor that might trigger emergence. Light intensity variation between the nights was quite low, leading one to suspect a key role played by this factor in initiating cricket appearance to the outside. At approximately the same time each night, 2000, as the light intensity quickly diminished, the first crickets emerged from the cave.

Cricket movement was also monitored within the cave by an activity sensing device designed for detecting movement across two metal strips. Each day two nocturnal periods of movement, 2200 to 0200 and 0500 to 0900, were evident, with a corresponding lack of movement during the "daylight" hours, 0900 to 2100.

Individual movements, population levels, and distribution of crickets within the cave were further investigated from August 20th to the 23rd by the use of a color-coded marking system. Crickets in different areas of the cave were marked with different colors. Morning and evening censuses involved searching the crawl tunnel and main walk tunnel. The total number of mature C. conicaudus was noted and special attention was given to the color and exact location of all marked crickets. Periodic observations of individually marked crickets indicated a three-day movement from the walk tunnel to the entrance. Movement within the cave occurred only during the night hours.

A study of the other species of crickets, C. carlsbadensis and C. longipes, is planned along with a population study of all the crickets in Water Tank Cave. The specific cavernicolus status (troglobite or troglophile?) of C. longipes, will be investigated in the field and in the lab.

Survey of the Cave Fauna of Carlsbad Caverns and Guadalupe Mountains National Parks

W. Calvin Welbourn

Work in 1974 was again concentrated in Slaughter Canyon of Carlsbad Caverns National Park. Five caves (four in Slaughter Canyon) were biologically investigated. One, Ogle Cave, was intensively studied in preparation for a series of papers to be published next year.

The investigation of Ogle Cave included placing fifteen baited, pitfall traps. These traps were set at both ends of the cave for 24 hours and then removed, and the specimens in each trap were separated and counted. Samples of the substrate at several trap sites, were collected for extraction by berlese funnel. The invertebrate groups represented in Ogle Cave include: Nematoda, Pseudoscorpionida, Diplopoda, Acarina and Araneae. The insects are represented by Diplura, Collembola, Orthoptera, Hemiptera, Coleoptera, Diptera and Siphonaptera with most specimens identified.

Work in the future will be concentrated in the western part of Carlsbad Caverns National Park, and Guadalupe Mountains National Park will get more attention. More work with berlese funnel on the surface and in the caves is planned, and a long term project dealing with guanophiles in Carlsbad Caverns is planned.

Survey of New Mexico Cave Fauna

W. Calvin Welbourn

In 1974 thirteen caves, all in Eddy County, were investigated, bringing the total to 24 different caves investigated outside Carlsbad Caverns National Park in the last two years. Five caves in the Lincoln National Forest were investigated under a permit issued by the Guadalupe District Ranger.

Many specimens are being identified and, pending identification, there may be some significant additions to the New Mexico cave fauna. The isopod, Breckenridgia, was found in four new caves this year. It is probable that this isopod will prove to be common in many Guadalupe Caves.

Future work will continue in the Guadalupe Mountains, but more work needs to be done in the caves of the central, northern, and western part of New Mexico.

Climatic and Biotic Studies of a Terrestrial Cave Ecosystem in Indiana

James H. Keith

From May, 1973 until August, 1974, Murray Spring Cave near Paoli, Indiana was the object of a community-ecosystem level study. Research carried out in this cave was meant to answer the following questions:

1) How do the following parameters vary by season and by depth within the cave: flooding, water temperature, general air temperature and relative humidity, substrate air temperature and relative humidity, substrate temperature, substrate moisture and substrate organic content?
2) What animals live in the cave, at what times are they abundant, what types of habitat do they prefer and how do their numbers vary?
3) In what manner do the climatic parameters interact to produce the observed cave environment?
4) In what manner do the component populations interact?
5) What is the role of climatic rigor and predictability, energy inputs, competition and predation in determining the habitat choice and densities of the component populations?

6) What is the role of climatic rigor and predictability, energy inputs, competition and predation in determining the local diversity and trophic complexity within the cave?

To date, only the climatic data have been completely analyzed. These data are summarized below:

1) Flooding:
   a) It is highly seasonal, occurring from late fall-early winter through late spring-early summer. Late summer and early fall are essentially flood-free periods.
   b) Stream level fluctuations vary seasonally in their response to rainfall. This seems to be due mainly to the amount of water present in the soil. In the summer and fall, there is very little variation in stream level in response to rainfall. The correlation between rainfall and stream level fluctuation increases in winter and reaches a maximum in spring. (Note: stream level fluctuation refers to all changes in water level, both flooding and relatively minor changes in the depth of the stream).

2) Substrate moisture and organic content:
   a) Substrate moisture does not vary significantly by season. There is, however, a highly significant spatial variation (determined by ANOVA, 5% confidence level). This indicates that cave morphology exerts a strong influence on substrate moisture by controlling deposition and therefore substrate texture. This, in turn, determines the amount of moisture the substrate can hold. Areas of high substrate moisture occur in those areas of the cave just before passage constrictions, where the water slows and the deposition of silt and clay is increased. The lack of seasonal variation means that the moisture capacity of the substrate is probably fixed and that moisture levels are probably maintained by soil moisture and/or the cave stream.
   b) Substrate organic content varies both spatially and temporally. The spatial pattern coincides almost precisely with substrate moisture ($r=.93$; $p<.01$), indicating the relationship between substrate deposition and moisture. Temporally, there is a single "pulse" of organic material introduced into the cave in April, 1974. This was followed the next month by a large drop in organic content. The April increase is attributable to high water runoff, which carries a large amount of debris into the cave. Reasons for the May drop are unknown, but it is likely that two events are occurring at this time:
      (1) Litter decomposition rates are increasing.
      (2) Runoff is decreasing due to water uptake by plants.

      These two factors together may account for the May drop in substrate organic content.

3) Relative humidity:
   a) These were taken both at the substrate level and at the mid-passage level. Spatially, there was found to be an increasing gradient in relative humidity from the entrance of the cave toward the rear. Beyond the 100 m point in the cave, the relative humidity was at or near 100% all year.
   b) Temporally, the cave varies with the lowest relative humidities occurring in the summer and fall. This occurs chiefly within the first 100 m of the cave and reflects the fact that the substrate in this area is unable to charge the air with moisture during the dry season. In the winter, when the substrate is constantly moist, the air in the front area of the cave is 100% saturated even though there is a strong inward flow of cold air.
   c) Relative humidity is controlled by slightly different means at the two levels measured. At the substrate level there is a smooth drop in relative humidity that lasts until August. It then rises smoothly and peaks in January. This is again likely to be a response to levels of soil moisture. The passage relative humidity likewise drops until August, but stays low until November, when it suddenly rises and equals substrate relative humidity. This rise corresponds to the onset of late fall flooding. It appears that there is very little interchange between passage and substrate level air. On the other hand, the relative humidity of substrate level air seems to depend strongly on substrate and soil moisture.

4) Water temperature:
   a) These varied entirely by season, reaching a peak in July and a depression in January. There was no significant difference in temperatures taken at four points in the cave.

5) Substrate temperatures:
   a) These were found to vary in the same way as the water temperatures. However, the total range of the substrate variation was only about half that of the water.
   b) There was no statistically significant spatial variation but it was found that the substrate in the first 50 m of the cave was cooler than the rest of the cave. Because Murray Spring Cave has a descend-

ing entrance, it probably acts as a cold air trap. A flowstone plug 50 m in from the entrance probably serves to limit this effect.

c) Substrate temperatures were taken at three levels (surface, 10 cm deep and in cracks) but these did not differ significantly.

6) Air temperatures:

a) These averaged 1°C. higher than substrate and water temperatures. Spatially, the air temperatures did not vary significantly. However, once again, there was a depression in air temperature near the entrance. This depression extended for 80 m into the cave. Air flow was probably responsible for the extension of the temperature depression past the flowstone plug.

b) Temporally, the air temperatures follow the water and substrate temperatures until January. Instead of rising after January, however, the temperature continued to fall through April. This is attributed, again, to the trapping and retention of cold air by the descending cave entrance. Inward movement of cold air after January would then serve to lower the cave air temperature further.

7) Air movement:

a) Seasonally, there was outward movement of air from May through October, 1973, inward movement from November, 1973 until May, 1974 and outward movement through the end of the study- July, 1974. Air movement correlated well with the inside-outside temperature differential: flowing outward when the outside air was warmer and inward when the outside air was cooler. This correlation broke down in May, 1974, however, when the outside air was warmer than the cave air. Air continued to flow inward during this month. This may have been due to a "plug" of stagnant air at the entrance which may have taken a month to warm and move out of the cave.

b) There was a significant spatial variation in air movement within the cave, which is somewhat surprising. The present data strongly suggest the presence of convection cells established within the larger segments of cave passage at certain times of the year. These cells are transient and seem to be set up for only a few days at a time. There seems to be no observable temporal pattern to the establishment of these cells.

Along with other data, these results will be used to characterize the habitats of various portions of the cave. Responses at a community level to habitat change will then be examined.

Archeology in Central Kentucky

Patty Jo Watson

The biggest archeological news for this year is the publication of our latest report (P. Watson, ed. Archeology of the Mammoth Cave Area, Academic Press). It appeared in July, 1974.

Chronological Summary of Fieldwork in Mammoth Cave National Park, 1974

K. Carstens, J. Levy, and P. J. Watson carried out surface reconnaissance in the vicinity of Good Spring Church, Cade, Three Springs Pumphouse, and around the Turnhole Bend "peninsula". No indication of occupation sites was found in the first two places (the Good Spring Church locality was reported to us by the North Shore Task Force via Jim Quinlan; the Cade locality was suggested by Superintendent Kulesza as being an area where chert had been found in plowed fields, and we did find two small flakes). There are several shelters in the ravine below Three Springs Pumphouse; three of these were designated as sites by Schwartz some twenty years ago. We located these and noted that one (MC-21 in Schwartz's system) has a considerable amount of chert and a few sherds on the surface.

In the Turnhole Bend area, we relocated MC-11 ("Bat Cave" - gated) and MC-16 (Nelson's Shelter), and briefly examined a small cave in the third ravine north of Boardcut Island (east side of the river). We also checked a small shelter just west of the road where it climbs up over the bluff from Mammoth Cave Ferry.

The second installment of field work occurred in our Spring Break period in March. K. Carstens and D. Patch made a canoe trip from Mammoth Cave Ferry to Houchen's Ferry on March 17 to look for rock shelters in the bluffs along the river. They located several likely looking outcrops which we later checked on foot, but none of which seemed to be sheltering a site. Meanwhile a mapping crew visited the Morgantown/Logansport area (forty miles west of the Park) and made a contour map of one of the shell-mounds on the Green River there (site Bt-11, the Haynes mound, now owned by William Rueff of Morgantown).

The rest of the week was spent: 1) looking for rock shelters or other sites along First Creek; 2) examining a badly dug-up shelter at the junction of Second Creek and the Nolin River; 3) excavating in Salts Creek Vestibule (Trench K); 4) recording aboriginal debris in Upper Salts (P1 to P20) and in Upper Mammoth (Flint Dome and Flint Alley); 5) attempting to locate chert outcrops in Eaton Valley (unsuccessful) and in the hollow that runs south of the old Chestnut Hill school (chert nodules found in stream bed).

We recorded aboriginal debris in Wilson's Way of Mammoth Cave (only the first sixteen stations from Gratz Avenue: W1 to W16; there are 27 more stations) which is very time-consuming because Wilson's Way is so small. We located some promising shelters in Blue Spring Hollow, and rechecked a few at the lower end of First Creek Hollow.

We spent some time in Logansport making arrangements for the summer's work at the shell-mound sites (Bt-5 and Oh-13). Our group also recorded debris in Upper Salts (from P40 to P35).

Our group worked the Shellmound Archeological Project excavations at Bt-5 and Oh-13 near Logansport and Rochester, Kentucky, respectively.

We recorded aboriginal debris in cairns area of Upper Salts (H survey) and from P35 to P31. We also continued excavation in the Salts Vestibule (Trench K), and recorded in Upper Mammoth (Wright's Rotunda area).

K. Carstens, D. Patch, and G. Behrend mapped Three Springs Pumphouse Shelter (MC-29), while the rest of the crew excavated in Salts Vestibule Trench K and recorded debris in cutarounds near K-31 (P63/64 area) of Upper Salts. We also set up the flotation system Sunday morning at Dennison's Ferry and floated several bags of low-priority fill from Bt-5, Square C 13. Saturday night, L. Robbins examined Lost John, cleaned the fungus off him, and removed some tissue from inside, enough - we hope - for a radiocarbon date. She also got some samples of fecal material from inside his lower intestine.

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

Stanley D. Sides

In 1971, an active field program was initiated in an attempt to systematically record names and dates written in the caves of Flint Ridge. During the 165 years of documented exploration of the Flint Ridge Cave System, many stories of fact, rumors, and purposefully false anecodotes have arisen. In an attempt to place these into historic perspective, this project was begun.

In 1974, a total of eight trips was made into caves in Mammoth Cave National Park in the process of recording names of historic interest. Upper Salts has now been completely searched, the results will be compiled and published. Several names have been found in Lower Salts which contribute to our understanding of the exploration of this area in the early 1950's. The historic section of Floyd Collins Crystal Cave has been searched, and one trip was made Left of the Trap.

A recently found 1927 newspaper article by Russell T. Neville confirms that Edmund Turner surveyed known passages of Salts Cave. Cave Research Foundation, as well as William T. Austin and Jack Lehrberger, surveyed the cave in the 1950's. Survey markers in the area of the Pike Chapman entrance indicate a fourth survey was done. This was not likely performed during Hazen's attempt at commercialization of the cave in 1897, or during the development of the Blue Grass Country Club (1922-1928).

The Turner Survey is important because Floyd Collins and Turner explored and surveyed the cave extensively in 1912. Their names are recorded randomly in the cave, with no increased incidence in any one section of Upper Salts. It is known that they did not enter Lower Salts. Rumors exist that they discovered passages which they later hid. Turner reportedly discovered Great Onyx Cave from Salts Cave by passages not now known (see "Notes on Edmund Turner", JOURNAL OF SPELEAN HISTORY 1:12, 1968).

In 1975, the names survey will continue in Floyd Collins Crystal Cave and Colossal Cave. The history of Floyd Collins' exploration in area caves will receive special emphasis. The daughter of Edmund Turner cannot be found, so it is doubtful that more can be learned about this pioneer of cave exploration in Flint Ridge.

Historical Geography of the Underground Landscape, Mammoth Cave National Park

Duane DePaepe

The cultural manifestations of the extensive cavern system of Mammoth Cave span the spatial and time factors of pre-agricultural Indian groups up through the contemporary era of the National Park. Here, the unique landscape of the Human Geographer is the restricted environment of the underground where the microcosm of 3000 years in the history of man can be trapped and analyzed much like the biologist contemplates the closed ecosystem in the simple underground ecology of a cave.

There is much uncertainty as to the first historic contacts with the integrated underground system. Research efforts to date suggest that the surface regional terminology of "Barrens" was not a negative term as might be suggested, but is descriptive of positive features of a grass landscape that would have made it more attractive at an early date for agricultural purposes. In addition, the navigable feature of the Green River from the Ohio River further suggests early historic contact with the caverns in Mammoth Cave National Park despite the lack of extensive documentation of the caves until after 1800.

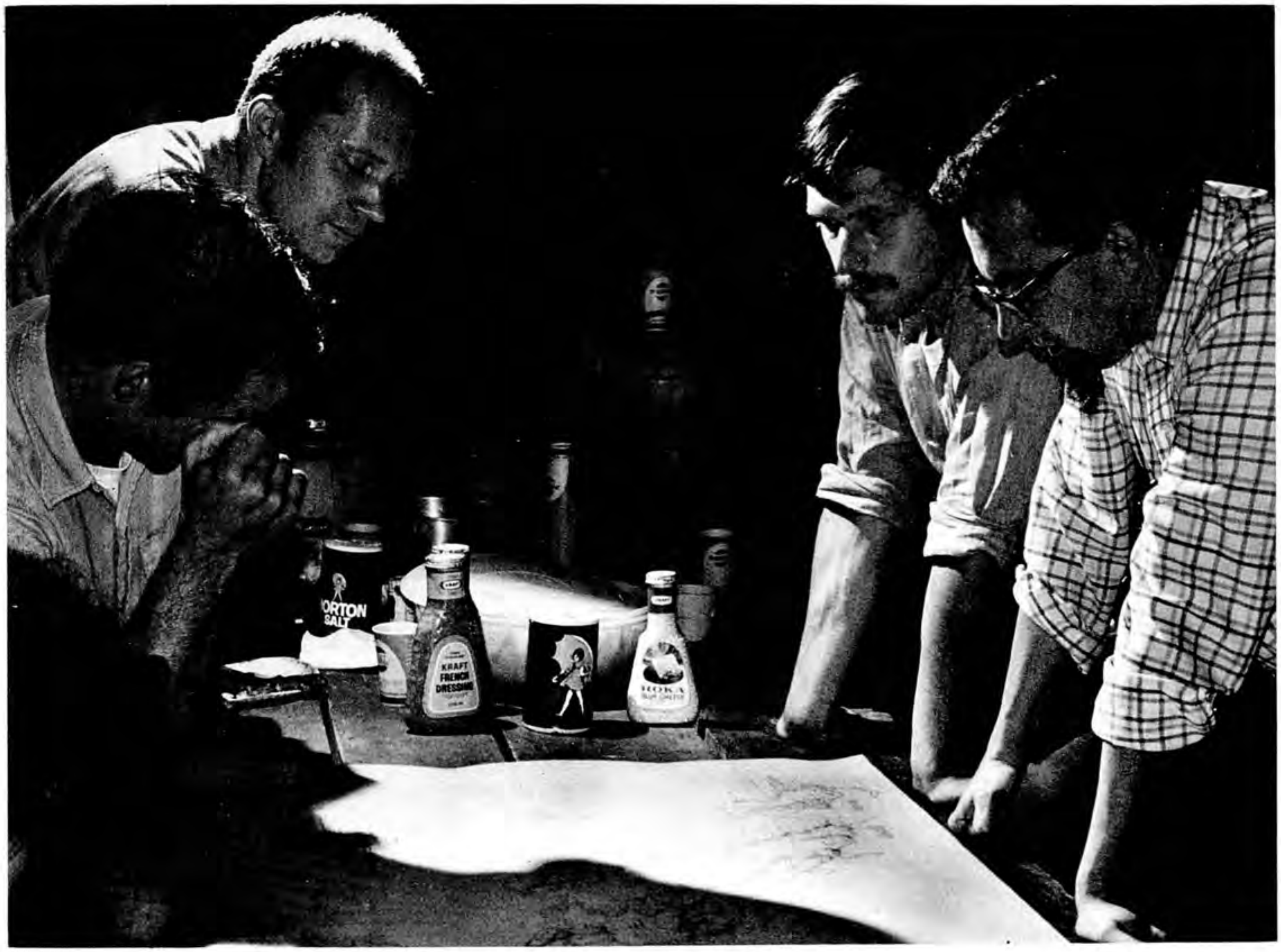
Prehistoric Indian use of the cave system, for the primary purpose of extraction of crystalline sulfate minerals, is evidenced by considerable quantities of perishable artifacts and blackened surfaces of walls and ceilings from combustion products. The first historic use of Mammoth Cave was economic in the activity of nitrate mining during the period of the War of

1812. The slave labor utilized became the nucleus of the guide service in the later era of tourism. During the 1840's Mammoth Cave was briefly used for tuberculosis sanatorium experiments and although the project ended in failure it is still considered one of the milestones in medical history.

Three factors account for Mammoth Cave's sustained early interest to visitors; the dimensional underground scenery, prehistoric Indian remains and later, the discovery of newly identified troglobitic animals. Regional transportation in the form of stage lines, steamboats and the railroad permitted world-wide visitors access to the cave. After 1900, cave touring became a dominant economic factor in an otherwise marginal agricultural environment. During peak years of commercialization at least twenty caves in the area were developed for visitors. Most of these ventures ended eventually in failure but Mammoth Cave was assured continuance because of its dominant fame and its status as a national park in 1941.

Today, the national park assumes a major role in the regional economy. Man's activity in Mammoth Cave over the centuries has been primarily economic, often extractive and especially at present, has affected the surrounding regional landscape. Environmental impact because of urbanization, population pressure and developed transportation networks mandate protection, preservation and area planning if the cavern and landscape are to maintain their educational and recreative function.

Management and Publications



Examining cave maps at the Flint Ridge Field Station, Mammoth Cave, Kentucky.
Photo by Roger Brucker.

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Management

Directors and Committees

Directors

Several changes in the Directorate were made during the past year.

Dr. Stanley D. Sides resigned this fall as President after a very fruitful term in office. The Board elected Roger W. Brucker as the new President of the Foundation. Dr. Denver P. Burns resigned as Secretary, Acting Treasurer, and Director. Dr. P. Gary Eller has assumed the office of Secretary, and Dennis E. Drum has been elected to the Board as Director and Treasurer. Dr. William P. Bishop resigned as Director, and R. Pete Lindsley has been elected to the Board to fill his place.

The present members of the Board of Directors are:

Roger W. Brucker, President
P. Gary Eller, Secretary
Dennis E. Drum, Treasurer
Joseph K. Davidson
David J. DesMarais
R. Pete Lindsley
John P. Freeman
Stanley D. Sides
John P. Wilcox

Officers and Management Personnel

For general management of the Foundation:

Newsletter Editor	Mary E. Drum
Publications Officer	Ernst H. Kastning
Historian	Stanley D. Sides

For the Central Kentucky Area:

Manager	Steve G. Wells
Cartography	William P. Crowther Patricia P. Crowther
Exploration and Survey	John P. Wilcox
Field Station	Gordon L. Smith Frank E. Campbell Richard B. Zopf
Log Keeper	L. Greer Price
Personnel Officer	William F. Mann
Safety Officer	Norbert M. Welch

For the Guadalupe Escarpment Area:

Manager	R. Pete Lindsley
Cartography	John J. Corcoran III James M. Hardy
Field Station	Elbert Bassham
Food Supplies Coordinator	Karen Welbourn
Log Keeper	Len Jelinek
Personnel	Rondal R. Bridgemon, Jr.
Finances	Dorothy M. Corcoran
Science Coordinator	David H. Jagnow

Operating Committees

Many of the functions of the Foundation are managed through operating committees, usually chaired by a Director. The present list of committees, their function, and their membership follows.

RESEARCH COMMITTEE: Functions to coordinate all sponsored research within the Foundation, to initiate new projects, to review proposals and fellowship applications, and to coordinate back-up support from personnel and the field stations. By definition, all persons conducting research projects under Foundation sponsorship are members of the Research Committee.

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

R. Pete Lindsley, Chairman
Roger W. Brucker
P. Gary Eller
John P. Freeman

EXPLORATION AND CARTOGRAPHY: Covers the whole range of concerns in survey and mapping in all areas. This committee sets survey techniques and standards, oversees the maintance and cataloging of log books, devises data reduction procedures, and arranges for the publication of cave maps. Present membership is

John P. Wilcox, Chairman
John J. Corcoran III
Patricia P. Crowther
William R. Crowther
Diana O. Daunt
James M. Hardy
L. Greer Price
Richard B. Zopf

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

Dennis E. Drum, Chairman
Jacqueline F. Austin
Roger W. Brucker
Dorothy M. Corcoran
Gordon L. Smith
Philip M. Smith

John W. Hess, Jr.
Horton H. Hobbs III
Bethany Jean Grover
David H. Jagnow
Charles E. Mohr

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 at Mammoth Cave National Park and the preparation of interpretative materials and trail guides for Park use. Present membership is

Thomas L. Poulson, Chairman

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

Joseph K. Davidson, Chairman
William P. Bishop
David J. DesMarais
Stanley D. Sides
Philip M. Smith
Richard A. Watson

Field Operations

Field Operations in the Central Kentucky Area

Three major observations of the 1974 field season at Mammoth Cave National Park are outlined below:

1. During the operation year of 1973-74 at MCNP, twenty-one expeditions were led by fifteen different leaders. Ten of the expeditions were regularly scheduled with cartography as the basic objective; eleven expeditions had special objectives including biology, geology, archaeology, and maintenance. Five JVs were introduced into the 'art' of expedition leading during this field season. The total number of expedition days for 1973-74 was 126, an amazing increase of 48 expedition days over the 1972-73 period.

2. A maintenance program was put into effect during the 1974 season, and was aimed at improving the field facilities at Flint Ridge. A list of priority repairs, operations, and needed materials was compiled. Two expeditions were scheduled with maintenance and repairs as the major objectives. Restoration was initiated on the Collins House, toilet facilities, bunkhouse, Ticket Office, and Austin House. This program will remain as a continuing effort for the next few field seasons.

3. In addition to the eight special objective expeditions, several scientific projects were conducted during scheduled expeditions: surface study of karst valleys, Saltpetre Project, dye tracing of caves in Joppa Ridge, etc. Special topic seminars were used in place of the traditional interpretive sessions, and these were given by researchers active in the MCNP during this summer.

Field Operations in the Guadalupe Escarpment Area

The number of expeditions for 1974 was reduced slightly from previous years in support of the fuel shortage; the regular amount of expeditions is planned for 1975. Six expeditions were held in 1974, primarily on the major holidays. Emphasis of the expeditions and other trips made by researchers has been in the areas of cartography, biology and geology. Glenn Campbell, who received a grant from CRF, has been working on a study of the cave cricket population in Spider Cave and Water Tank Cave. Calvin Welbourn has been making an exhausting study of the biology in several Slaughter Canyon Caves, Carlsbad Caverns National Park. David Jagnow and Carol Hill have concentrated their geology studies on the same Slaughter Canyon Caves. Much of the Slaughter Canyon study has been in connection with a special project at Ogle/Rainbow Caves, and this data is expected to be published during 1975. The cartography effort has strongly supported the Ogle Cave project as well as other projects. Caves that have seen recent work, either in the form of actual survey or in the form of map drafting, include New Cave, Rainbow Cave, Ogle Cave, Chimney Cave, Spider Cave, Christmas Tree Cave, Wen Cave, Midnight Goat Cave and, of course Carlsbad Caverns. Emphasis in Carlsbad Caverns has been in the Left Hand Tunnel, Lower Cave and the Big Room. Two caves outside of the Park that have received cartographic emphasis are Wind Cave (Bureau of Land Management) and Edgewood Caverns (private).

Maintenance of the CRF buildings #6 and #7 at Carlsbad Caverns National Park during 1974 included a massive clean-up inside the buildings and a new paint job for the majority of the interior. The shower facility in #6 was reworked and repair was attempted on some small roof leaks.

Building #6 is used as the main headquarters during field expeditions and #7 is used as expedition sleeping quarters. In addition, #7 was used during the year by several visiting researchers. Both buildings now have kitchen facilities including a stove, sink and refrigerator.

Personnel

Overall the number of CRF Joint Venturers has increased somewhat over the past year and now stands at 321.

Number of JVs as of November, 1973	294
Attrition	-25
Continuing JVs	269
New JVs -- Kentucky Area	46
New JVs -- Guadalupe Area	6
Number of JVs as of November, 1974	321

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Publications

Books

Patty Jo Watson, ed., Archeology of the Mammoth Cave Area, Academic Press, New York, 1974.

Articles and Theses

Articles

John P. Freeman, Gordon L. Smith, Thomas L. Poulson, Patty Jo Watson and William B. White (1973) Lee Cave, Mammoth Cave National Park, Kentucky. Bull. Nat. Speleol. Soc., 35(4), 109-125.

J. W. Hess, S. G. Wells, and T. A. Brucker (1974) A survey of springs along the Green and Barren Rivers, Central Kentucky Karst. NSS Bull., 36(3), pp. 1-7.

J. W. Hess and W. B. White (1974) Hydrograph analysis of carbonate aquifers. Institute for Research on Land and Water Resources, The Pennsylvania State University, Research Publication No. 83, 63 p.

T. C. Kane and T. L. Poulson (1973) Field experiments in simple cave communities: predation strategies of two co-occurring carabid beetles. Am. Zool., 13, 1328.

Franz-Dieter Miotke (1974) Carbon dioxide and the soil atmosphere. Abhandlung zur Karst - und Höhlenkunde, Series A, Vol. 9, 49 pp.

Margaret V. Palmer and Arthur N. Palmer (1975) Landform development in the Mitchell Plain of southern Indiana: origin of a partially karsted plain. Zeitschrift f. Geomorphologie, v. 19, no. 1, p. 1-39.

William B. White and James J. Van Gundy (1974) Reconnaissance Geology of Timpanogos Cave, Wasatch County, Utah. NSS Bull., 36(1), 5-17.

Theses

Glenn D. Campbell (1974) Activity rhythm of the cave cricket, Ceuthophilus conicaudus Hubbell, M.S. in Zoology, Texas Tech. University.

J. W. Hess (1974) Hydrochemical investigations of the Central Kentucky Karst Aquifer system, Ph.D. Thesis, The Pennsylvania State University, 218 p.

T. C. Kane (1974) Studies of simple cave communities: predation strategies of two co-occurring carabid beetles. Ph.D. Dissertation. University of Notre Dame, 125 pp.

Papers at Professional Meetings

1974 American Geophysical Union Annual Meeting (Washington, D.C., April, 1974)
John W. Hess, Jr. and William B. White,
"Water balance in the karst aquifer of south central Kentucky."

American Society of Zoologists Meeting (Houston, Texas, December, 1973).
Thomas C. Kane,
"Field experiments in simple cave communities: predation strategies of two co-occurring carabid beetles".

1974 Geological Society of America (Miami Beach, Florida, November, 1974).
John W. Hess and William B. White,
"Groundwater geochemistry in the central Kentucky karst aquifer."

23rd Annual Meeting of the Southeastern Section of the Geological Society of America (Atlanta, Georgia, April, 1974)
Steve G. Wells,
"Geomorphology of the sinkhole plain in the central Kentucky karst."

5th International Congress of Speleology (Stuttgart, 1969)
William B. White,
"The Appalachian karst: an overview."

Fourth Conference on Karst Geology and Hydrology (Morgantown, West Virginia, May, 1974)
G. H. Deike III,
"Geometry of cavern passages."

J. W. Saunders,
"Paleohydrology of Crump Spring Cave, Central Kentucky Karst."

Steve G. Wells,
"Morphology in the sinkhole plain of the Central Kentucky Karst."

National Speleological Society Convention (Decorah, Iowa, August, 1974)
David J. Des Marais,
"Underground stream piracy in the Garrison Chapel karst valley, Monroe County, Indiana."

Russell S. Harmon,
"Submerged stalagmites as indicators of former low sea level stand in Bermuda."

Ernst H. Kastning,
"Caves of Fantasy."

Harold Meloy,
"Wandering Willie walks to Mammoth Cave."

Kay F. Reinartz,
"The cave wars and the courts: the case of Edwards et al. vs. Lee."

William B. White,
"Characterization of karst soils by near infrared spectroscopy."

Talks

Roger W. Brucker
"The longest cave" Yellow Springs Lions Club, February, 1974.
Miami Valley Radio Association, April, 1974.
Fairborn School Science Class, October, 1974.

W. Crowther
"Surveying the longest cave" National Park Service Cave Interpretation Seminar, Mammoth Cave National Park, July, 1974.

J. P. Freeman
"The longest cave" Genesee Valley Chapter, Adirondack Mountain Club, Rochester, New York, February, 1974.
Northeast Regional Organization, National Speleological Society, Manchester, Vermont, June 8, 1974.

John W. Hess
"Water balance in the Central Kentucky Karst and hydrograph analysis of carbonate aquifers," Carbonate Seminar Group, Pennsylvania State University, April, 1974.

David Jagnow
"The discovery and exploration of Coldwater Cave, Iowa" 1974 NSS Convention banquet speech and slide lecture, Decorah, Iowa, August, 1974.

Thomas Kane
"Predation strategies of two co-occurring carabid beetles." Department of Biological Sciences, University of Illinois at Chicago Circle, January 1974.

"Predation strategies of two co-occurring carabid beetles." Department of Biological Sciences, University of Cincinnati, April, 1974.

John McLean
"Microclimate" National Park Service Southwest Regional Natural Science Conference, Santa Fe, New Mexico, November, 1974.

H. Meloy
"Mammoth Cave History" National Park Service Cave Interpretation Seminar, Mammoth Cave National Park, July 1974.

A. N. Palmer
"Geology and Geomorphology Studies in the Flint Mammoth System" National Park Service Cave Interpretation Seminar, Mammoth Cave National Park, July, 1974.

Stanley D. Sides
"X-Radiation and Cave Research" Department of Radiation Medicine Seminar, University of Kentucky School of Medicine, Lexington, Kentucky, November, 1974.

"Cave Research by Private Research Organizations in National Parks," National Park Service Cave Interpretation Seminar, Mammoth Cave National Park, April, 1974.

W. Calvin Welbourn

"Research Activities of the Cave Research Foundation at Carlsbad Caverns and Guadalupe Mountains National Parks" National Park Service Southwest Region Natural Science Conference, Santa Fe, New Mexico, November, 1974.

William B. White

"Cave conservation and the caver overpopulation problem," Nittany Grotto.

"Cave geology," Pittsburgh,Grotto.

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