Cave Research Foundation 1969-1973

CAVE RESEARCH FOUNDATION

THE CAVE RESEARCH FOUNDATION

1969 - 1973

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by

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INTRODUCTION

THE CAVE RESEARCH FOUNDATION: 1969 - 1973 constitutes Volume Two of materials directed toward the history of the Cave Research Foundation. It contains the Cave Research Foundation annual reports from 1969 through 1973. The first volume in this series, THE CAVE RESEARCH FOUNDATION: ORIGINS AND THE FIRST TWELVE YEARS: 1957 - 1968, contains the annual reports from 1957 through 1968 plus numerous other early documents and papers relating to the Cave Research Foundation. The third volume in the series containing the annual reports from 1974 through 1978 is being published at the same time as the present volume. Individual copies of the annual reports from 1979 through 1984 are available from the Cave Research Foundation.

The Cave Research Foundation was incorporated as a non-profit foundation in 1957 in Kentucky, U. S. A. Its primary purpose is to support and promote research, interpretation, and conservation concerning caves and karst. Contributions to the Cave Research Foundation are tax-deductable.

Further information about the Cave Research Foundation can be obtained by writing to:

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ELEVENTH ANNUAL REPORT

of the

CAVE RESEARCH FOUNDATION

For the year ending

December 31, 1969

Cave Research Foundation
464 M Street, SW
Washington, D.C. 20024

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Acknowledgements

Many of the projects outlined in this report have been conducted in Mammoth Cave National Park. The continuing support and encouragement of the Superintendent and staff of the Park has contributed greatly to the success of these projects and is gratefully acknowledged.

The archaeological research in Salts Cave has been supported by a grant from the National Geographical Society. This support is gratefully acknowledged.

INTRODUCTION

Archaeology was on the forefront of Flint Ridge Research in 1969. New research on the prehistoric uses of Salts Cave on an examination of the Salts Cave mummy, and on a search for surface indian village sites was sponsored by the National Geographic Society. A number of major field expeditions under the direction of Dr. Patty Jo Watson have worked in Salts Cave since April.

A most important event in 1969 was the discovery of Lee Cave on Joppa Ridge. The entrance was discovered on Thanksgiving, 1968 and the major exploration took place in the winter and spring of 1969. The main portion of the cave is a 7000 foot fragment of trunk passage whose dimensions range up to 100 feet wide by 50 feet high. Lee Cave is the first large fragment of trunk passage, other than the short segment represented by Owl Cave in Cedar Sink, to be found in Joppa Ridge.

The Cave Research Foundation fellowship for 1969 went to Mr. Thomas E. Wolfe, Dept. of Geography, McMaster University to support his PhD dissertation on sedimentation processes along the Allegheny Front in West Virginia.

The Foundation's role in graduate and undergraduate education continues to expand. Four theses in which the Foundation had some part appeared during 1969. R. Carwile and E. Hawkinson completed their B.S. thesis project on the sediments of Columbian Avenue in January. David C. Culver completed a Ph.D. dissertation on the dynamics of cave stream communities in the West Virginia karst late in 1969. Alan P Covich likewise completed his Ph.D. research on the sediments of a limestone lake in Yucatan. Finally, the Salts Cave archaeological project has produced its first thesis--the M.S. work of Charles Redman on the stratigraphic sequences of the Salts Cave vestibule. In addition dessertation projects are underway by Paul Goldberg on sediments in Israeli caves, by T.E. Wolfe, mentioned above, and by John W. Hess on a new project on the hydrology of the Central Kentucky Karst.

Other experiments in education were conducted during the year, one of which was the initiation of the practice of holding evening seminars at the base camp during the principle summer field expeditions. In this way the volunteers working on the cartographic program were also made aware of the activities in the various scientific programs.

In April Dr. Franz-Dieter Miotke of the Geographical Institute of the University of Hannover, Germany toured the Central Kentucky Karst with J.F. Quinlan and E.R. Pohl. There was a reconaissance investigation of terraces along Green River and several trips were taken into Mammoth Cave and Flint Ridge. Dr. Miotke has extensively studied alpine karsts in northern Spain and, as part of an 8 month fellowship in American, he visited many karst areas and studied two, in Texas and Puerto Rico, in detail.

THE SCIENTIFIC PROGRAMS

THE CARTOGRAPHY PROGRAM

MACA-N-9 The Cartographic Description of the Caves of Mammoth Cave National Park (Dr. Denver P. Burns, CRF)

The cartographic program continued a planned expansion of field work and examined several methods of data handling during the past year. The field portion of the cartographic program included continuing survey work in the Flint Ridge Cave System, surveying portions of Mammoth Cave, and the discovery and initial exploration and survey of Lee Cave, a major cave in Joppa Ridge. Advances in data handling included the computation of survey station coordinates to supplement our present plotting system and investigating the value of using computer controlled plotting machines.

Flint Ridge: The longest surveyed cave system in the world is the Flint Ridge Cave System. Its length as of November 1, 1969 was 75.04 miles.

Figures for survey work done in the Flint Ridge Cave System last year are:

Passages surveyed for the first time totaled 6.36 miles in length

Passages resurveyed (to replace stations) 2.00 miles in length.

Several areas of the Flint Ridge Cave System yielded large amounts of survey or important connections between previous surveys. These areas were:

a) north end of Colossal River where two tributaries of Colossal River were surveyed. One tributary drains from the southwest near the Twin Domes and takes drainage from Twin Domes and Serpentine Canyon, the other drains upper levels of the Colossal-Salts Link and flows in an opposite direction of a major stream about 200 feet north of the head of the tributary. Downstream Colossal River was surveyed to a point where the deep water requires wet suits for comfort.

b) a survey connection was made between Lower and Upper Salts via a hole in Dismal Valley.

c) Miller Trail yielded 1600 feet of survey and several leads give the area much potential for more cave.

d) surveys were run through newly penetrated passages between Hosken Trail and Penck Trail. The route passes under the upper reach of Floating Mill Hollow via complex pit and drain systems.

e) several passages were discovered and surveyed off Foundation Hall including one walking passage 1300 feet long and an extensive canyon system.

f) Engle Way yielded more than 3000 feet of survey including a large loop that extended to the southeast well under the caprock.

g) a maze of passages in the Albright Junction area were surveyed.

h) a canyon and crawl passage more than 1600 feet long was surveyed in a loop at the south end of Roebuck Trail.

Joppa Ridge: Surface reconnaissance of Joppa Ridge was rewarded last year with the rediscovery of the Lee Cave Entrance. Cave Research Foundation survey teams penetrated beyond T. E. Lee's early and historic discovery to reach the first known segment of large trunk drainage passage in Joppa Ridge. The main passage extends more than a mile with several types of sulfate minerals, large thick beds of sediments, and prehistoric Indian torches, cairns, feces, and a grape bark tie. Side passages with several leads bring the current surveyed length to 2.22 miles. Numerous leads promise much more cave in Joppa Ridge extending from Lee Cave.

Mammoth Cave: The Ganter Avenue area received the brunt of survey activity in Mammoth Cave. All of the passages between the Wooden Bowl Room and Edith Avenue as shown on the Kaemper Map have been surveyed together with new passages. The surveys are tied into Walker survey benchmarks in the Wooden Bowl Room and Wright's Rotunda. The length of Cave Research Foundation surveys in Mammoth Cave is 4.28 miles.

Data Handling: Plotting errors are now eliminated before they can cause trouble by computing the coordinates for each survey station and comparing the coordinates of the plotted position against the correct coordinates. The coordinates are based on the initial survey station since a parkwide coordinate system will not be available until the entrance locations are precisely fixed. Tests are being conducted to determine the usefulness of computer-guided plotting machines so that we can bypass the tedious and demanding job of plotting survey lines.

Mr. Burnell Ehman, CRF Director, represented the Foundation at the 1969 International Congress of Speleology session on the world's longest and deepest caves. The Flint Ridge Cave System retained its position as the longest surveyed cave in the world with Holloch in Switzerland the second largest.

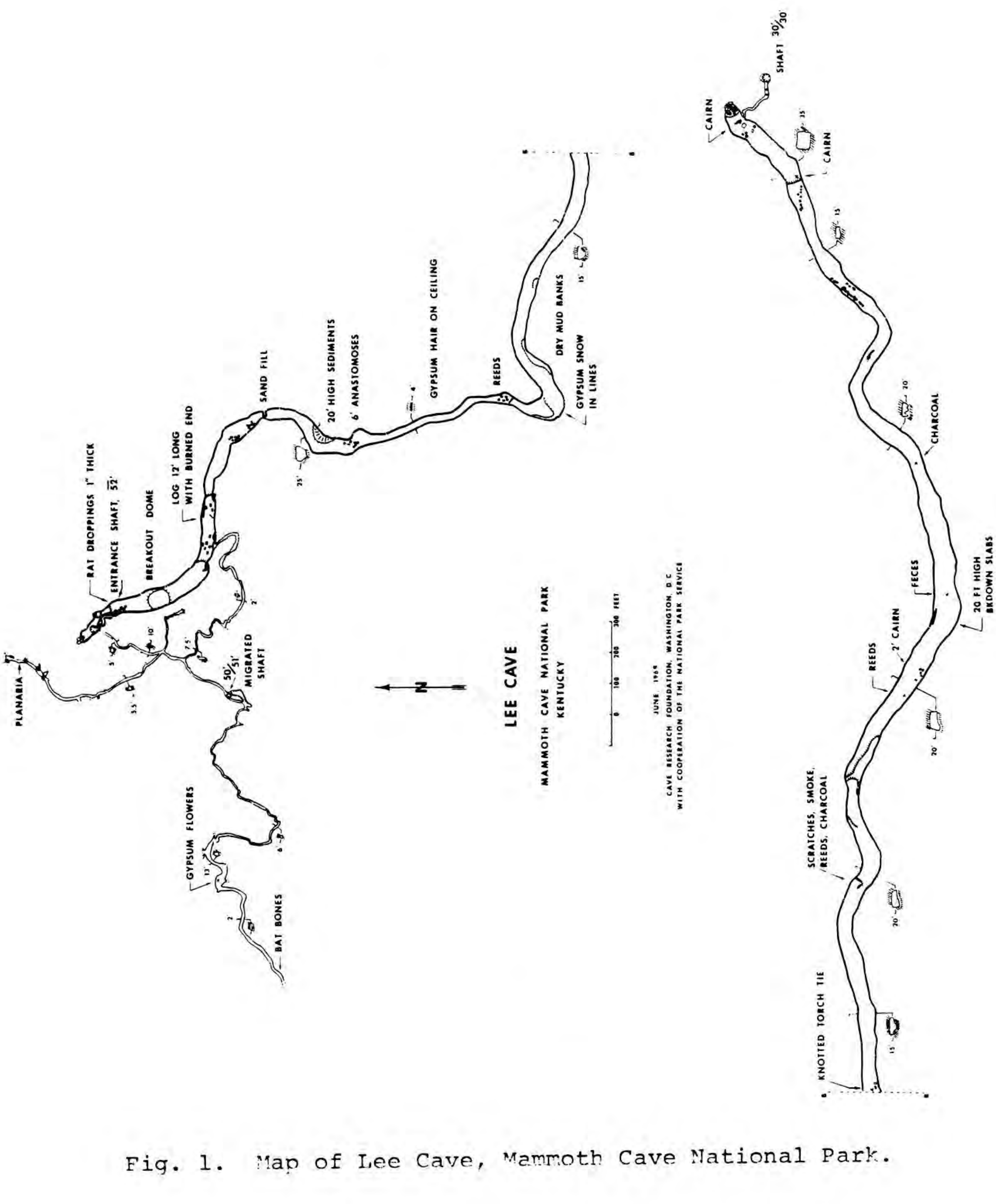

Fig. 1. Map of Lee Cave, Mammoth Cave National Park.

THE HYDROLOGY PROGRAM

MACA-N-11 Paleohydrology of Mammoth Cave and the Flint Ridge Cave System (G.H. Deike, Western Illinois University and William B. White, CRF and The Pennsylvania State University)

This project is completed except for writing the final report. Some further progress on the manuscript was made. During July, additional data on the scallop patterns of Mallott Avenue, Smith Avenue, and Bögli Avenue were collected.

MACA-N-12 Hydrology of the Central Kentucky Karst. (W.B. White, R.W. Brucker, J.W. Hess, and R.A. Watson, CRF)

This is a long term on-going project concerned with the overall interpretation of the karst region. Presently active facets deal with the development of vertical shafts and with quantitative hydrology and water balance in the drainage basins of the big springs.

Traverses of Grund Trail abandoned drainage passages and mapping of beds has developed a more comprehensive understanding of features that distinguish vertical shafts from retreating canyons. Leads fall into two categories: passage cut-arounds representing successive stands of the drainage conduit, and tributary passages that formerly contributed water to the main drain. Other data on vertical shaft locations were a product of the cartographic program.

Work was started during the summer on the hydrology of the presently active drainage system of the Central Kentucky Karst. Most of the water which recharges into the carbonate aquifer system from sinking streams, from the sinkholes of the Sinkhole Plain, and from the vertical shafts along the Chester Escarpment is collected into a sub-base level drainage system. Discharge is beneath the Plateau into Green River at the big springs. However, most of this water is entirely unobservable in the cave systems. It is becoming more and more apparent that the "rivers" seen in the caves are shaft drain water of local origin. To obtain some understanding of the major ground water flow system, the storage, flood response, and drainage pattern will require indirect methods.

Methods must be devised to gauge the big springs so that total discharge and flow hydrographs can be obtained. Runoff and infiltration on the Plateau and on the Sinkhole Plain must be determined. Design of this instrumentation is now underway.

Hydrologic Features of the Sinkhole Plain (A.N. Palmer, CRF and State University of New York)

One and one half weeks were spent in August in the Pennyroyal Plain east of Mammoth Cave National Park in a preliminary attempt to determine patterns of drainage and cave development and to correlate findings with the more intensely studied cave area of the adjacent sandstone-capped uplands. With the exception of Hidden River Cave, no large, integrated caves were located, although numerous truncated segments of major passages were found. These often exhibited extensive fill and collapse. Of approximately 20 caves located, all shared roughly the same flow trend: north to northwest, down a major component of the dip. All appeared to be developed in the St. Louis limestone. Caves were found to be strongly concordant to the bedding and to exhibit strong bedding plane control with wide elliptical passages. Several major underground stream systems were located but none extended more than a few hundred feet through traversable passages because of a strong tendancy toward ceiling collapse and sumping. Promise of large cave systems was indicated by strong blasts of air from openings in several deep uvalas and sinkholes. A few caves contained an oily smell apparently related to nearby oil wells and natural gas pipelines - a potential source of danger to cavers in some parts of the Pennyroyal.

Problems that will be considered in future field work in the Pennyroyal include the following: What is the pattern of drainage in the vast areas of sinkhole plain east of the Horse Cave quadrangle in which no active caves are known? Some of the subsurface tributaries to Green River appear to be perched -- what is the reason for the great differences in both elevation and stratigraphic horizon exhibited by spings in the river valley, especially on the Hudgins quadrangle? Small caves were located in all sandstone-capped knobs on the Sinkhole Plain as far east as Maxey Knob -- what is their genetic relationship to the extensive drainage systems in the Sinkhole Plain and to the caves of the Plateau? Can levels of development be correlated between the Sinkhole Plain and the adjacent uplands? Adequate answers to these questions will be difficult to find in view of the general lack of large known caves in the Pennyroyal.

PROGRAM IN SEDIMENTATION, MINERALOGY, AND PETROLOGY

MACA-N-13 Petrology of the Mid-Mississippian Limestones (J.F. Quinlan, CRF and University of Texas)

This project has not been active during 1969. Further work on the specimens is planned when the investigator finishes his Ph.D. dissertation.

MACA-N-16 Base Level Sedimentation in Flint Ridge (Roy Carwile and Edward Hawkinson, CRF and The Ohio State University)

This project was the B.S. thesis project of the investigators. It has been completed and the final report, in the form of the thesis, has been submitted to the National Park Service. The conclusions are summarized below. Typical experimental results were included in the 1968 Annual Report.

Literature on cave sediments in the Central Kentucky Karst is very limited. Collier and Flint (1964) concluded on the basis of measurements between October, 1959 and June, 1962 that sedimentation in Mammoth Cave was closely related to flooding of nearby Green River. They argue that the main source of the sediment is from Green River by a back-flooding mechanism. Watson (1966) disagrees and argues that the cave systems are the chief local sources of sediment and that the sediment and floodwater move toward Green River. Sediments are derived from the Sinkhole Plain and surrounding areas and are carried through the underground drainage network. Davies and Chao (1959) found that most of the sediments in the big trunk drain conduits of Mammoth Cave consisted of gravel (mostly rounded quartz pebbles from the basal Caseyville formation), sand, and silt. Clay was uncommon.

Graphs of size versus cumulative percentage and columnar sections showed that the sediments become progressively coarser towards the bottom of the section. Collier and Flint cannot justify the presence of such a large amount of sand and gravel by their backflooding mechanism. The deposition of the sediments may be in two parts. The clay and silt at the top of the sections may be deposited and reworked by repeated rise and fall of flood waters. There may exist a situation in which sediment is being added to the cave at the top of the floodwater zone while a larger volume of sediment is being transported through and out of the cave at the base of the main water-carrying conduits. The sands and gravels may have been washed in from the Sinkhole Plain above and deposited earlier in the history of the deposition.

The major outlet and inlet of floodwaters is Pike Spring which is separated by at least 3000 feet horizontally and 12 feet vertically from the entrance to Columbian Avenue. It is difficult to imagine floodwaters maintaining sufficient velocity and turbulence through 3000 feet of twisting and turning cave passage to carry particles larger than silt.

Other interesting features of Columbian Avenue are the water drains. These drains appear to be the major drains for floodwaters leaving the passage. They are suspected to go down to the bedrock floor where they discharge their water into a relatively permeable gravel layer at the base of the section. A large base flow was noticed in this gravel layer during collection of the samples. It seems likely that a small amount of sediment may move through and out of the cave in the permeable layer at the base of the main sediment body. Evidence for this is the large number of sand units completely free of silt and clay in the lower part of the cores.

A tentative history of Columbian Avenue is: (i) Active solution of the limestone cavern at or near the water table and formation of an elliptical-shaped passage. (ii) Green River downcuts, thus lowering base level and residual material from the Sinkhole Plain is deposited in the passage as it acts as a major drain for the cave system. (iii) Major drainage is pirated by Eyeless Fish Trail and Columbian Avenue is abandoned as an active stream-depositional site. (iv) Base level lowers still more and Columbian Avenue receives less and less water. It becomes a site for clay and silt deposition from floodwaters. (v) "Sinks" develop in the passage which allow water to flow in the more permeable lower layers rather than on the impermeable silt and clay at the sediment surface. (vi) There is an overall loss of sediment (especially fines) as a result of subsurface flow. (vii) Further lowering of base level will eventually bring Columbian Avenue above floodwater level and fluvial sedimentation will cease.

<u>Cave Sediments of the Near East (Paul Goldberg, University of Michigan)</u>

During the past summer sampling was completed in the Tabun Cave and good stratigraphic controls were obtained. The work is now involved with the initial stages of analysing sediments from both Tabun and Qafzeh Caves. Analyses being applied include X-ray diffraction and DTA, sieving and hydrometer, heavy minerals, pH, organic phosphates, calcium carbonate, organic matter content, and finally thin section examination.

Pollen Studies in the Central Kentucky Karst (H.E. Wright, University of Minnesota and R.A. Watson, CRF and Washington University)

Sediment samples have been taken from the Archaeological excavation, from Dismal Valley and Mummy Valley in Salts Cave and from Lee Cave to examine for pollen. No pollen was found in the material from the archaeological site.

A search was made for sinkhole ponds suitable for coring. Two possibilities are "Mud" pond, 5 miles west of Horse Cave and "Hundred Acre" Pond, 18 miles east of Horse Cave. These will be cored sometime within the next year.

Clastic Sediments in West Virginia Caves (Thomas E. Wolfe, McMaster University)

During 1969 the field work for this project involved the completion of pilot studies in Martens Cave and Poor Farm Cave, Pocahontas County and the mapping of sedimentary structures in Poor Farm Cave. Completed base maps of Poor Farm Cave and Bob Gee Cave, Greenbrier County were prepared and structural data collected in the caves was added to the base maps.

The Culverson Creek Basin and its associated cave systems were the object of the main field studies this past summer. Sampling procedures at the following localities were carried out:

a. bedrock conglomerate source material at the headwaters of the present drainage net. These were the Mauch Chunk sandstones, the Princeton conglomerate, and the oldest conglomerate in the Pottsville series.

b. quartz pebbles and transported conglomerate boulders along the main trunk channel to where a major sink receives all runoff.

c. quartz pebbles from marker beds in caves flanking the trunk valley flood plain.

d. quartz pebbles from within the present subterranean trunk conduit and at higher levels in the cave.

e. ejecta from the present rising along Spring Creek.

f. quartz pebbles from along a presumed high level ancient surface runoff channel for a distance of 12 miles.

Preliminary results from laboratory tests in progress show a decrease in size and show an increase in sphericity and roundness of quartz pebble samples on a downstream direction along the ancient runoff channel, in the cave and along the present surface stream. Structural characteristics in the cave fills show an invasion of quartz pebble deposition. This is probably due to flooding sequences.

An example of a once-in-one-hundred-or-more-years flood occured while field work was in progress. This provided a rare opportunity for study of sedimentation under such conditions. Cave sediment traps which had during the previous year showed only silt and clay deposition were completely filled in with pebbles and small boulders.

In addition to the Platygonus compressus removed from Poor Farm Cave sediments last year, remains of an Equus complicatus (?) were found in the upper portion of sediments in nearby Steam Cave, Pocahontas County. Although it is not the intent of this project to study pleistocene fauna, the in situ deposition of such remains is of value in sediment dating.

Rate of Growth of Gypsum in Caves (J.F. Quinlan, CRF and University of Texas and E.R. Pohl, CRF)

The present hypothesis for the origin of gypsum in the caves of the Central Kentucky Karst is that it is deposited by slowly percolating solutions whose source is the pyrite zone in the Big Clifty sandstone and upper Girkin limestone. Gypsum should thus be forming continously but at a very slow rate. In 1936 Pohl measured the length of gypsum crystals that had grown at the scratches on the wall made on an undisturbed 1846 signature in the Black Chambers of Mammoth Cave. These crystals and others on a signature by Pohl in Crystal Cave were re-measured by Quinlan in 1966. The rate of growth of gypsum, for the 2 sites measured, is 1.0 mm/100 years.

Mineralization in Lee Cave (W.B. White, CRF and The Pennsylvania State University)

Newly discovered Lee Cave contains sulfate minerals which on superficial examination appear to be different from those known elsewhere in the Central Kentucky Karst. As part of a preliminary reconaissance of the scientific potential of Lee Cave, some 15 specimens were collected for X-ray diffraction and chemical analysis. Gypsum and epsomite are the common minerals in Lee Cave. All of the curved and hair-like crystals from walls and ceilings appear to be epsomite. Floors and breakdown blocks in the main reaches of the trunk channel have a crust of white powdery mineral which has apparently drifted down from the ceiling. X-ray diffraction patterns of these crusts do not match those of any of the common sulfate minerals found in caves. Infrared spectra indicate that the minerals are sulfates. They are water-soluble. At this reporting they are still unidentified. Mirabilite, the most common mineral in Mammoth Cave and the Flint Ridge System has not yet been identified from Lee Cave.

PROGRAM IN KARST GEOMORPHOLOGY

Reviews of the Central Kentucky Karst

The general review paper on the Central Kentucky Karst which was prepared under the authorship of White, Watson, Pohl, and Brucker has been completed and accepted for publication by Geographical Review. It will appear in the January, 1970 issue.

A second review paper emphasizing geomorphological relationships in the karst was prepared by J.F. Quinlan and submitted to the French journal Mediterranee. It will appear in early 1970.

The broader review paper emphasizing the biological aspects of caves prepared by Poulson and White was published in the Sept. 5 issue of Science.

MACA-N-10 Measurement of the Cave Environment (M.F. Ehman, CRF)

The temperature measurement stations remained in place during 1969 and a few additional data were collected. The planned continuation of this project is to determine the spacial variation of environmental parameters and this part has not yet been started.

Geomorphology of the Central Kentucky Karst (J.F. Quinlan, CRF and University of Texas)

A reconaissance investigation was made of terraces along Green River. The two lower terraces-- one at 6 to 10 feet and another at 25 feet above pool stage -- are tracable over considerable distances. Higher terraces are more difficult to identify and trace. Additional work is planned to map the terraces and other landforms and to determine the genetic and chronologic relations between cave development, surface topography, and position of the ancestral Green River.

PROGRAM IN ECOLOGY

MACA-N-14 Terrestrial Cave Communities (T.L. Poulson, D. C. Culver, and Russell Norton, CRF and Yale University)

Most of this year's effort has been directed toward analysis of species diversity in terrestrial communities (Poulson and Culver), competition between Pseudanophthalmus and Neaphaenops (Poulson and Norton), and Neaphaenops-Hadenoecus predator-prey interactions (Norton).

Analysis of species diversity: The conclusion that species diversity in Flint Ridge is negatively correlated with climatic rigor (flooding) and climatic variability (flooding, temperature, and relative humidity) and positively correlated with physical structure of the environment (substrate heterogeneity) and food supply (Poulson and Culver, 1969) is not much altered by the addition of 30 more census sites in areas remote from entrances. The only alteration is that there is now a negative correlation of species diversity with another aspect of climatic rigor, namely evaporation of water. This new correlation is due to inclusion of some sites in upper level dry passages under the cap rock where, except for occasional adult Hadenoecus, no animals are to be found.

The most exciting new data this year concern the meaning of the evenness component (H/H_{max}) of species diversity ($\log H = -\Sigma p_i \log p_i$). Up to now there has been a body of theory explaining species number but no theory has been formulated to explain the relative abundance, i.e. evenness, of distribution of individuals among the species. With reference to Table 1, H/H_{max} is highest in those stream passages with the lowest flooding rigor and highest predictability (temperature, humidity, and food supply are the same in the three passages). If the highly mobile and opportunistic species (Hadenoecus, the cave "cricket" and Neaphaenops, the common carabid beetle) are removed from consideration, neither number and biomass nor H/H_{max} is much affected in Gravel Avenue but all three parameters are considerably lowered when Hadenoecus and Neaphaenops are removed from consideration in the August Eyeless Fish Trail sample (when its overall species diversity equals that in Gravel Avenue). Ratios of abundance for the two sampling dates in each passage, percentage trapped, and number of troglophiles present all suggest that a high H/H max reflects a stable community: i.e. Gravel Avenue is stable but Eyeless Fish Trail is not. Floods in Eyeless Fish Trail regularly kill the fauna; only the highly mobile and opportunistic species can recolonize before the next flood and take advantage of the food left by the receding floodwaters. Other species are rare and so H/H max is low. A similar situation is observed in Colossal River with additional instability contributed by inwash of troglophilic springtails (Onychiurus and Arrhopalites) from the Bedquilt entrance area where there is considerable leaf debris.

Competition between Neaphaenops and Pseudanophthalmus: The basis for absence of Pseudanophthalmus from upper level passages frequented by Neaphaenops is not a difference in rates of desiccation (studies of weight loss at 50% RH in Wright's Rotunda). More studies are required to see whether the smaller Pseudanophthalmus tolerates a lower percentage weight loss or reaches its weight loss limit sooner than Neaphaenops. In areas like Marion Avenue the RH is 100 per cent so desiccation cannot explain the absence of Pseudanophthalmus. One possibility is that Pseudanophthalmus has lower metabolic demands and is not as able to capitalize on the cricket egg resource, that comprises virtually all the food in upper level passages as is Neaphaenops (see below). We are starting to investigate this by studies of metabolic rate. In the lower level passages along streams, Neaphaenops is not much more common than P. striatus and habitat selection may keep them apart. The mean free path is higher and turning rate lower for Neaphaenops than for P. striatus on mud substrate worked by worms (Chaetogaster) and conversely, P. striatus moves faster than Neaphaenops over sand or silt substrates filled with Neaphaenops" diggings. Laboratory observations suggest how this apparent substrate selection could be reinforced. Neaphaenops avoids contact with P. striatus 75 per cent of the time (20 per cent, no reaction) by turning and increasing its rate of movement. Studies on laboratory substrate selection are underway.

The Neaphaenops-Hadenoecus predator-prey system: During the feasibility study of 1968, the main emphasis of the work done by Russell Norton centered on the bioenergetics of the Neaphaenops-Hadenoecus community. This year attention has been focused on the Neaphaenops-Hadenoecus predator-prey interaction and the possibilities for theoretical analysis and modeling of this system.

Several aspects of the feasibility study have yielded some interesting data. For example, even though a practical marking technique for Neaphaenops has not been developed, limited success with various methods has indicated that Neaphaenops may move approximately 1200 feet in 12 to 20 days. This mean movement of 60 feet (or more) per day was through a region of excellent Neaphaenops habitat. Thus, Barr's estimate (Barr, 1968 and personal communication) of 500,000 Neaphaenops in Mammoth Cave is suspect on several grounds:

1) the Neaphaenops population is evidently highly mobile;

2) the enamel paint used by Barr has a tendency to flake off the elytra;

Table 1.

Species diversity (H) and eveness of relative abundance (H/H_{max}) of terrestrial arthopods in three Flint Ridge stream passages

Locality and Date	Climate		Components of Diversity		
	Rigor Flood	Predictibility Food/Flood	H	H/H_m	No. troglophilic species/ No. troglobitic species
Lower Lower Gravel June, 1968			--	--	1 + 6
	1.0	4.0			
August, 1969			1.6	.93	1 + 6
Colossal River June, 1968			--	--	3 + 5
	2.5	3.0			
August, 1969			0.7	.67	2 + 4
Eyeless Fish Trail June, 1967			0.3	.50	1 + 1
	3.5	1.5			
August, 1966			1.4	.74	2 + 4

Abundance Ratios Species in common / All species	Biomass/ Individuals Mg/No.		Species Biology % Trapped	Species Biology Dominants
2.5/2.3	8.1/14	all species	--	None
	49/11	no Hadenoecus		
	32/9	no Hadenoecus Neaphaenops	23	None
3.4/6.5	60/14	all species	--	Onychiurus Hadenoecus
	26/7	no Hadenoecus		
	12/5	no Hadenoecus Neaphaenops	68	Neaphaenops Arrhopalites
6.6/19.2	320.40	all species	100	Hadenoecus
	100/18	no Hadeneocus		
	8/5	no Hadeneocus no Neaphaenops	100	Neaphaenops Hadenoecus

3) painted beetles seem to hide more than unmarked beetles (Poulson, personal communication);

4) Barr's study area at Frances' Dome (Kaemper manuscript name) is very near Sophy's Ave. and Marion Avenue, both with high populations of Neaphaenops; and

5) the percentage of cave inhabited by Neaphaenops, the length and extent of the cave, and the amount of Neaphaenops habitat inaccessible to researchers are not known.

The Neaphaenops-Hadenoecus interaction is being studied in several ways. Since the central portion of this interaction is a predator (Neaphaenops)- prey (Hadenoecus eggs) relationship with a mobile predator and a non-mobile prey, it is important to know how Neaphaenops searches and how cricket eggs are distributed.

Neaphaenops searching is being investigated in Marion Avenue. Through over 500 observations made during August 1969, Neaphaenops can be characterized as an animal which spends most of its time searching for egg sites and much less time digging for eggs or investigating holes. The question of how often a Neaphaenops must get a cricket egg to exist, may be answered by metabolic studies in progress. By knowing the respiratory quotient (RQ = CO_2 produced/ O_2 consumed), it is possible to determine what the beetle is metabolizing. By then measuring the weight loss of a starved beetle over time, metabolism in calories/time can be calculated with reasonable accuracy.

The distribution of Hadenoecus eggs is also being investigated. Eggs may be deposited in loose sandy substrate, singly or multiply in one of two types of sites. One type involves a mound roughly 1 cm high X 1.5 cm diameter with ovipositer marks radiating 3 cm in an arc of 90° from the center of the mound; the second type involves seemingly random ovipositer marks over a general area variable in size. The structure of these sites, with relation to egg distribution within them, is being examined carefully with experiments involving artificial sites in mind. Experiments of this sort could yield information concerning optimal egg distribution strategies for Hadenoecus. T. L. Poulson (personal communation) has observed a Hadenoecus inserting its oviposter into the substrate repeatedly. Thus the possibility is presented that false "egg sites" enhance the chances for an egg to escape predation.

Why Hadenoecus is in the deep cave environment at all is also of interest. Marking studies in Marion Avenue have demonstrated that recovery rates are very low after a few days and that crickets may move about 250 meters/ day (CRF Annual Report, 1968). Thus the Hadenoecus population seems transient. This, coupled with a high percentage of time spent in copulo in the cave (CRF Annual Report, 1968) and the presence of many egg sites in the deep cave suggests the hypothesis that crickets enter the deep cave primarily to breed and lay eggs. Gut analyses indicate that most feeding may be done outside the cave. Reichle and Park (unpublished data) found that a gut analysis of crickets near entrances yielded many identifiable leaf and arthropod parts. To date, I have found nothing readily identifiable in the guts of deep cave Hadenoecus. Further work, however, is required to verify the hypothesis that Hadenoecus enters the deep cave primarily for the purpose of reproduction.

References:

Barr, Thomas C. Jr. 1968. Cave ecology and the evolution of troglobites. In: Evolutionary Biology Volume 2, pp 25-102. Th. Dobzhansky Ed. (Appleton-Century Croyts, New York).

MACA-N-15 Aquatic Cave Communities (T. L. Poulson, CRF and Yale University)

The only activity this year was a census along the passage from Styx to Echo River in Mammoth Cave. There were many Orconectes in July but few in August. In August, on the other hand, several very large Amblyopsis were spotted in Echo River.

Analysis of Simple Cave Communities (David C. Culver, Yale University)

This study considers various ecological relationships of Stygonectes spinatus, Stygonectes emarginatus, Gammarus minus, and Asellus holsingeri in caves in the Greenbrier Valley of West Virginia. Those caves that are susceptible to spring flooding tend to have fewer species than those that are more isolated from the epigean environment. Stochastic processes are also important in controlling the number of species present in the caves studied, but caves are more than collecting basins for animals that get washed in via subsurface water. My data are consistent with Simberloff's non-interactive equilibrium model of island biogeography, but species interaction may also play a role in determining the number of species present. Two clear-cut cases of reduction of realized niches due to interspecific competition were found. Stygonectes emarginatus is limited to small trickles of water when Gammarus minus is present in the stream. Asellus Holsingeri is limited to gravel-bottomed pools when Gammarus minus is present in riffles. All four species did equally well on rotting leaves or mud, and thus feeding differences appear to be minor. Laboratory experiments indicate that competition in the field is primarily for a place to avoid the current. Exclusion is accomplished by avoidance reactions rather than by aggressive reactions. If competition is measured by the number of interspecific contacts, in a patchy environment competition acts to reduce, but not eliminate these contacts. The routine and standard metabolic rates of cave populations of Gammarus minus were not lower than those of spring populations. Likewise, the metabolic rates of Stygonectes spinatus and Stygonectes emarginatus were not lower than that of Stygonectes tenuis potamacus from surface seeps. Spring high water seems to be the major factor controlling amphipod species abundance. Stygonectes species are less abundant than Gammarus minus in large part because of the higher wash-out rate of the Stygonectes species. Experiments with an artificial stream indicate that washout rate is density dependent at least in Gammarus minus, with some density independent washout under extreme environmental conditions. Washout can be increased by increasing current velocity, increasing density, decreasing the size of the animals, or by reducing the amount of available food.

Paleoecology of lacustrine bored shells and ultrastructural Diagenesis (Alan P. Covich, Yale University)

Shells from two 7 m. cores and from surface sediments of Laguna Chichancanab, an inland saline lake in Quintana Roo, Mexico (19° 50' N.Lat., 88° 45' W.long.), were penetrated by holes ranging in diameter from 60 to 500 microns. Most bored shells were snails but bivalves, ancylids and ostracods were also found. The bored and non-bored snails ranged in length from 1.8 to 4.9 mm.; bored shells averaged 3.4 mm. (for 200 snails from one surface sample) and non-bored shells averaged 3.1 mm. which might indicate some size selection by a predator. The shape of perforation varies from a linear slit to circular and is sometimes beveled in cross section. Most shells had single, circular holes and some appear either partially bored or recalcified. Bored shells occurred in low absolute numbers throughout the two 7 m. cores of laminated marl but increased in the younger, upper sediments from approximately 3 to 12% of total shells found. The cores record fluctuations in relative and absolute abundancees of Pyrgophorus, Aplexa and Trobicorbis shells during the last 6,000 years. The oscillation in biological assemblages is correlated with changes in $0^{18}/0^{16}$ ratios in Pyrgophorus shell carbonate. Electron microscopic study of single stage replicas demonstrates the presence of filamentous organisms on the exterior surface and in the inner shell layers etched with EDTA. It is uncertain if these organisms are fungi or algae and if they produced the holes. Edges and partially bored holes were studied with the scanning electron and deep field microscopes. Calcite crystals have deep clefts which might indicate mechanical rasping or post mortem diagenesis.

PROGRAM IN ARCHEOLOGY

Salts Cave Excavations (P.J. Watson, CRF and Washington University

The objective here was to locate intact prehistoric occupation debris, and in this we have been successful. The excavations in the Salts Vestibule began as a 1.5 x 3 m. trench against the north wall. Here we found at least 2 horizons of midden debris at ca. 50-60 cms. and ca. 1 m. down respectively. The midden contains animal and human bone, charcoal, occasional chert flakes or projectile points, worked bone, a few fragments of ground stone (celts and pestles). The Washington University physical anthropologist, who is a specialist in dental anthropology, will do a study of tooth-wear patterns on the human teeth from the Vestibule, and will probably also be able to get some comparative information from the X-rays of Little Al.

The Cave search project was to locate the aboriginal route to Indian Avenue. Success was achieved by Brucker and Ehman's team in so far as pinning down the general area was concerned: the floor of Dismal Valley. There has been post-aboriginal collapse of this passage so the specific route utilized by the Indians no longer exists. However, we now have a dug entrance directly to the F-survey in Lower Salts from the floor of Dismal Valley.

Sequence of Events in Salts Cave Vestibule
as Indicated by Stratigraphy in the Test Trenches

SURFACE

Breakdown with resultant ponding of water in the Vestibule; deposition of clay in and around the breakdown rocks; mass wasting from the entrance slope.

Active (though probably small and shallow) stream; channel and bar deposits (sand and silty sand).

HUMAN OCCUPATION: people living or camping on surface of earlier stream deposits.

Active stream deposition and cutting; channel and bar, followed by time of stagnant water and then drier conditions in the area of the trench.

HUMAN OCCUPATION: people living or camping on surface of stream deposits.

Active stream deposition (channel and bar) followed by time of stagnant water and then drier conditions in area of trench.

Breakdown with resultant stagnant conditions and deposition of much organic material.

Channel sands indicating a stream of fairly high velocity (one estimate was 1/2-1 foot per second).

BOTTOM OF TRENCH

(at ca. 2.15 m)
Bedrock not reached so far

Context and Stratigraphy (C.L. Redman, University of Chicago)

The summary that follows is an abstract of a M.S. Thesis in Anthropology:

The research described here is an attempt to determine the depositional history of the archeological and geological sediments in the test excavations in the vestibule of Salts Cave, Kentucky. The primary goals of the archeological research in the Flint Ridge Cave System is to describe and explain the aboriginal occupation and utilization of the caves and their resources.

Excavations have been carried out in the vestibule of Salts Cave in order to discover in a stratigraphic situation the range and disposition of the artifacts and human refuse of the aboriginal occupants. The sediments in this area are mostly of a water-laid nature which would imply that the artifacts had been transported and rearranged since their original deposition. It is of prime importance to determine which, if any, of the archeological material are found in a primary contextual situation.

The question of primary or secondary deposition of artifacts was approached in three ways. First, great effort was put into the meticulous excavation of the test square by stratigraphic units. Second, the directional orientation of every oblong object found <u>in situ</u> was recorded together with its locational coordinates. This method is based on the proposition that the oblong pieces deposited by a stream current would be more perfectly aligned than pieces thrown down on a dry surface. This assumption was examined in light of experiments carried out by myself in a stream and by several geologists with a flume. The third approach was the examination of the matrix of the sediments themselves to determine their depositional character. This was done with the assistance of Cave Research Foundation geologists and sedimentologists.

The results of all three approaches suggest that there are two human occupational levels which are of a primary nature, and the remainder of the deposits are secondary. The additional care given these primary deposits facilitated the discovery of several archeological features that had probably served as refuse pits for the aboriginal inhabitants.

An attempt to determine the length of prehistoric occupation of these deposits was made by an examination of the imbedded lenses of light and dark sand in the stratigraphic section. A model of depositional history was formulated by utilizing weather records for the past fifty years. Four alternate hypotheses were proposed that accounted for the observed variations. These hypotheses will be tested by future work.

The primary contribution of this work is a demonstration that archeological excavations carried out with sufficient attention to depositional history and geological phenomena will yield information and increase the reliability of results.

Indian Habitation Sites in the Central Kentucky Karst (P.J. Watson, CRF and Washington University)

The search for a possibly contemporaneous surface site has not been successful so far. We have found quite a lot of chipped stone on the west side of the Sink but there is no occupation deposit there (if there ever was one, it was probably eroded away). We had to suspend operations during late spring and summer because of vegetation and heavy ground cover, but will begin again later. At that time, we will check some of the sites located by Schwartz several years ago and will reconnoiter the Green River in the light of a boat trip down it to locate and examine rock shelters and possible river flat sites.

Examination of the Salts Cave Mummy (Louise Robbins, University of Kentucky and P.J. Watson, CRF and Washington University)

"Little Alice" was found to be "Little Al", a 9-year old boy, when first subjected to examination. Fecal material in the lower intestine is very similar to that from Salts interior. Though we do not yet have word on the radiocarbon determination (tissue was sent to the U. of Michigan for this purpose), we are confident the body is indeed aboriginal relative dating by fecal contents). The blood group seems to be 0 as expected but there is one more confirmatory test to be run. A field party searching the area near Mummy Valley for traces of Little Al's resting place found the famous inscribed rock which bears a message written with a blunt pencil (partly written, partly gouged or incised) perhaps by Cutliffe?:

Sir
I have found one of the Grat wonders of the
world in this cave, whitch is a muma
Can all seed hearafter found March the 8 1875

T. E. Lee
J. L. Lee
an W.d. Cutliffe
dicuvers

Examination of Museum Materials (P.J. Watson)

A considerable amount of documentation was obtained on items in New York (Museum of the American Indian and American Museum of Natural History; some of N. C. Nelson's material from his excavations in the Mammoth Cave Vestibule were discovered at the AMNH) and Boston (Peabody). There may be some things at the University Museum, U. of Pennsylvania, and at Western Ky. College in Bowling Green.

THE SOCIOLOGY, HISTORY, AND ECONOMICS PROGRAMS

Wilderness and Human Values (P.M. Smith, CRF and National Science Foundation and R.A. Watson, CRF and Washington University)

For a number of years Watson and Smith have been doing research and writing in the general areas of Wilderness, conservation, population, and resources. Of most specific interest to the Mammoth Cave region is Smith's work on the issues of wilderness in Mammoth Cave National Park and regional planning in the Mammoth Cave region.

Of direct concern to speleology is a paper Smith and Watson have prepared, "Underground Wilderness" which will probably appear in somewhat revised form in The Living Wilderness. In this paper they answer the question of what wilderness is, contrasting the Wilderness Act definition of wilderness "as an area where the earth and its community of life are untrammeled by man" with the further clarification in the Act that says that wilderness is land that "generally appears to have been affected primarily by the forces of nature" (italics added). They also contrast the National Park Service mandate to "maintain the parks in absolutely unimpaired form" with the further clarification that follows this statement that this is to be done "for the use of present and future generations". Obviously there are explicit contradictions in each of these contrasts. Finally they contrast the notion of pure wilderness as any portion of the earth that has been uninfluenced by the activities of man with the notion of protected wilderness which consists of natural areas that are relatively protected from major human influences despite the ubiquitous presence of man and his carbon dioxide from fossil fuels, radiation from atomic bombs, pesticides, land alteration, and water pollution, and so on in every corner of the earth. Out of this they argue first that the protection of wilderness--given the ambiguity of the laws--depends primarily on the intent and integrety of land administrators, and second that since pure wilderness does not exist on earth today it is necessary to administer and manage protected wilderness areas.

Smith and Watson then go on to define underground wilderness as consisting of cave systems that generally appear to have been affected primarily by the forces of nature, with the imprint of man's work substantially unnoticeable. This definition is a specialization of that in the Wilderness Act. On such a definition, most caves over a few thousand feet in length have areas that qualify as wilderness. Then they define wilderness experience as consisting of feelings of aesthetic appreciation, of self-reliance, and of remoteness from the ordinary activities and works of man. They argue that a primary use of protected wilderness is to provide people with wilderness experience and that caves are superlative places for this purpose. Even in Mammoth Cave National Park, where hundreds of cars and thousands of tourists may be only a few hundred feet away on the surface, wilderness experience can be had. It is for this reason that they urge that large portions of the underground of national parks in which there are caves be designated as wilderness.

Finally Smith and Watson discuss the Flint Ridge Cave System in Mammoth Cave National Park. It is the longest cave in the world, with more than 70 connected miles of passage surveyed. Mammoth Cave has about 45 miles of mapped passages. The past history and present difficulties of protecting the Flint Ridge Cave System are discussed and the hope is expressed that knowledgeable protection will be given the Flint Ridge wilderness.

In another paper, "500 Million", Watson and Smith consider the general problem of establishing man in ecologic balance with nature on earth. This paper may be published in revised form in The National Parks Magazine. They give various reasons for establishing the optimum human population on the earth at 500 million people. They discuss the wastefulness of our present extractive technology that disperses waste material in forms that cannot be reused, and argue that a new technology of equilibrium must be developed that recycles for reuse the valuable resources of the earth. They argue that many problems will be solved--including those of overburdened national parks and wilderness use--by the establishment of a stable optimum population. They describe how the earth can be renovated by the use of ecological principles.

A crucial part of this paper is the argument that if steps are not taken immediately, humankind will probably be in danger of extinction from famine, pestilence, and war in the near future. Resources are being used up at an alarming rate, and no one seems yet to have comprehended the stringent seriousness of the population explosion. Man is literally in danger of breeding himself off the face of the earth. The concern is with the perpetuation of the human species for several million more years. This can be accomplished only with action in accordance with conservationist and ecological principles.

In a third paper, "Pioneer Virtues and Vices in the Industrial State", Watson and Smith argue that the freedom of the pioneer is not possible in the modern world, yet the community spirit pioneering fosters must be maintained. It is suggested that some reconsideration must be given to the creed of the West that work for private gain will result in the best servicing of public needs. More concern for public good is needed today.

Watson, with Patty Jo Watson, has published a book, Man and Nature (N.Y.: Harcourt, Brace, and World, 1969) in which models are described of man in relation with his physical environment, from protohuman to atomic man. Chapters on elemental man and on man as a domesticator of plants and animals are of particular interest in understanding the basic relationships with the environment that have sustained man for most of his time on earth. The conclusions are again basically conservationist, and in line with the subtitle of the book: An Anthropological Essay in Human Ecology.

PUBLICATIONS IN 1969

PAPERS AT PROFESSIONAL MEETINGS

Seminar in Analytical Techniques of Human Paleoecology

Louise Robbins, "Analytical Ramifications of a 'Mummy'"

14th Annual Midwest Ground Water Conference

William B. White, Panel Discussion: "Concepts in Limestone Hydrology"

American Association for the Advancement of Science

Thomas L. Poulson, Panel Discussion: "Biology of Cave and Deep Sea Organisms: A Comparison"

Thomas E. Wolfe, "Cave Sediments and Sedimentary Environments along the Allegheny Front"

John P. Freeman, Gordon Smith, Thomas L. Poulson, Patty Jo Watson, and William B. White, "Lee Cave, Mammoth Cave National Park, Kentucky"

William B. White and Elizabeth L. White, "Channel Hydraulics and Free Surface Streams in Caves"

ABSTRACTS OF 1969 PUBLISHED PAPERS

Four journal articles were published in 1969. Abstracts for three of them appear below. The fourth, the review article in Science did not have a published abstract.

Conceptual Models for Carbonate Aquifers

by William B. White[a]

Abstract

The very diverse types of ground-water behavior in carbonate terrains can be classified by relating the flow type to a particular hydrogeologic environment each exhibiting a characteristic cave morphology. The ground water may move by diffuse flow, by retarded flow, or by free flow. Diffuse flow occurs in less soluble rocks such as extremely shaley limestones or crystalline dolomites. Integrated conduits are rare. Caves tend to be small, irregular, and often little more than solutionally widened joints. Retarded flows occur in artesian environments and in situations where unfavorable stratigraphy forces ground water to be confined to relatively thin beds. Network cave patterns are characteristic since hydrodynamic forces are damped by the external controls. Solution occurs along many available joints. Free flowing aquifers are those in which solution has developed a subsurface drainage system logically regarded as an underground extension of surface streams. These streams may have fully developed surface tributaries as well as recharge from sinkholes and general infiltration. Characteristic cave patterns are those of integrated conduit systems which are often truncated into linear, angulate, and branchwork caves. Free Flow aquifers may be further subdivided into Open aquifers lying beneath karst plains and Capped aquifers in which significant parts of the drainage net lie beneath an insoluble cap rock. Other geologic factors such as structure, detailed lithology, relief, and locations of major streams, control the details of cave morphology and orientation of the drainage network.

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SINUOSITY IN LIMESTONE SOLUTION CONDUITS*

GEORGE H. DEIKE, III, and WILLIAM B. WHITE

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ABSTRACT. Cave passages are regarded as segments of drainage conduits, and those with sinuous patterns are compared with the meander belts of surface streams. Caves were sampled from central Kentucky, Missouri, and various Appalachian and European reports. Caves that exhibited parallel uniform walls which did not branch in the measured reach were selected. Two types of non-linearity were found: an angulate form generated by water flow down a hydraulic gradient diagonal to a rectangular joint set and a curvilinear form with sweeping S-bends apparently related to meanders in surface streams. The average bend spacing (L) and channel width (W) of the sinuous form are related by a power function $L = KW^n$. The coefficient K and the exponent n are respectively 6.8 and 1.05 for the Missouri caves and 8.2 and 0.92 for all other caves. The constants are similar to those proposed for alluvial rivers.

DIVERSITY IN TERRESTRIAL CAVE COMMUNITIES

THOMAS L. POULSON AND DAVID C. CULVER[1]

Yale University and Cave Research Foundation

(Received April 14, 1968. Accepted for publication September 18, 1968)

Abstract. Local species diversity of terrestrial arthropods was determined from a combination of trapping and census in an area of variable passage type in Flint Ridge Cave System in Mammoth Cave National Park, Kentucky. We measured evaporative rate, substrate moisture, substrate organic content, predictability and stability of food and microclimate, substrate diversity, and intensity of flooding. We found significant correlations of species diversity with substrate diversity, substrate organic content, and intensity of flooding.

MASTER PUBLICATION LIST OF THE CAVE RESEARCH FOUNDATION

December 1969

Contributed Papers

1. Roger W . Brucker; Recent Exploration in Floyd Collins Crystal Cave. Nat. Speleo. Soc. Bull. 17 42-45 (1955)

2. Philip M. Smith; Discovery in Flint Ridge, 1954-1957. Nat. Speleo. Soc. Bull. 19 1-10 (1957)

3. Fred Benington; Preliminary Identification of Crystalline Phases in a Transparent Stalactite. Science 129 1227 (1959)

4. Frederick Benington, Carl Melton, and Patty Jo Watson; Carbon Dating Prehistoric Soot from Salts Cave, Kentucky. Amer. Antiquity 28 238-241 (1962)

5. Philip M. Smith; The Flint Ridge Cave System: 1957-1962. Nat. Speleo. Soc. Bull. 26 17-27 (1964)

6. Richard A. Watson: Similitude in Direct and Thought Experiments in Cave Geology. Nat. Speleo. Soc. Bull. 27 65-76 (1965)

7. Brother G. Nicholas and Roger W. Brucker; Establishment of a Quadrat System for Quantitative Ecological Studies in Cathedral Cave, Kentucky. Nat. Speleo. Soc. Bull. 27 97-103 (1965)

8. E. R. Pohl and William B. White; Sulfate Minerals: Their Origin in the Central Kentucky Karst. Amer. Mineral. 50 1461-1465 (1965)

9. Michael F. Ehman; Cane Torches as Cave Illumination. Nat. Speleo. Soc. News 24 34-36 (1966)

10. Richard A. Watson; Notes on the Philosophy of Caving. Nat. Speleo. Soc. News 24 54-58 (1966)

11. Roger W. Brucker and Denver P. Burns; The Flint Ridge Cave System. Folio, 3 pp. + 31 plates, Cave Research Foundation, 1966

12. Roger W. Brucker; Truncated Cave Passages and Terminal Breakdown in the Central Kentucky Karst. Nat. Speleo. Soc. Bull. 28 171-178 (1966)

13. Richard A. Watson; Underground Solution Canyons in the Central Kentucky Karst, USA. Internat. Jour. Speleo. 2 369-376 (1966)

14. William B. White; Sulfate Mineralogy in Some Caves in the United States. Proc. IVth Internat. Congr. Speleol. 3 253-259 (1968)

15. Richard A. Watson and Philip M. Smith; The Flint Ridge Cave Research Center, Mammoth Cave National Park, Kentucky. Proc. IVth Internat. Congr. Speleol. 3 645-654 (1968)

16. Thomas L. Poulson and David C. Culver; Diversity in Terrestrial Cave Communities. Ecology 50 153-158 (1969)

17. George H. Deike III and William B. White; Sinuosity in Limestone Solution Conduits. Amer. Jour. Sci. 267 230-241 (1969)

18. Thomas L. Poulson and William B. White; The Cave Environment. Science 165 171-181 (1969)

Supported Papers

1. Douglas A. Wolfe and David G. Cornwell; Carotenoids of Cavernicolous Crayfish. Science 144 1467-1469 (1964)

2. M. Reams; Laboratory and Field Evidence for a Vadose Origin of Foibe (Domepits). Internat. Jour. Speleo. 1 373-390 (1965)

3. Frederic R. Siegel; Aspects of Calcium Carbonate Deposition in Great Onyx Cave, Kentucky. Sedimentology 4 285-299 (1965)

4. Robert E. Henshaw and G. Edgar Folk, Jr.; Relation of Thermoregulation to Seasonally Changing Microclimate in Two Species of Bats (Myotis Lucifugus and M. Sodalis). Physiol. Zool. 34 223-236 (1966)

5. Ralph O. Ewers; Bedding-Plane Anastomoses and Their Relation to Cavern Passages. Nat. Speleo. Soc. Bull. 28 133-140 (1966)

6. Richard A. Watson; Central Kentucky Karst Hydrology. Nat. Speleo. Soc. Bull. 28 159-166 (1966)

7. H. E. Wright, Jr., Barbara Spross, and R. A. Watson; Pollen Analyses of the Sediment from Sinkhole Ponds in the Central Kentucky Karst. Nat. Speleo. Soc. Bull 28 185-188 (1966)

8. Patty Jo Watson; Prehistoric Miners of Salts Cave, Kentucky, Archaeology 19 237-243 (1966)

9. Patty Jo Watson and Richard Yarnell; Archaeological and Paleoethnobotanical Investigations in Salts Cave, Mammoth Cave National Park, Kentucky. Amer. Antiquity 31 842-849 (1966)

10. Burton Faust; Saltpetre Mining in Mammoth Cave, Ky, Filson Club Hist. Quart. (1967)

11. William B. White; Conceptual models for Carbonate Aquifers. Ground Water 7 [3] 15-21 (1969)

Advisory Reports

1. Cave Research Foundation; Speleological Research in Mammoth Cave Area, Kentucky. Yellow Springs, Ohio 18 pp., 1960

2. Roger W. Brucker; Groundwater Problems in Flint Ridge. Cave Research Foundation, 11 pp. undated

3. Philip M. Smith; The Flint Ridge Cave System: A Wilderness Opportunity. Cave Research Foundation, 15 pp. 1961

4. Philip M. Smith; The Role of the N.S.S. in the Cave-Related Sciences. Nat. Speleo. Soc. News 20 160-162 (1962)

5. Richard A. Watson and Philip M. Smith; The Mammoth Cave National Park Research Center. Yellow Springs, Ohio, 50 pp. (1963)

6. Philip M. Smith and William B. White; Regional Protective Associations: A New Force in Cave Conservation. Nat. Speleo. Soc. News 25 36-40 (1967)

7. Philip M. Smith; Some Problems and Opportunities at Mammoth Cave National Park. Nat. Parks Mag. 41 (233) 14-19 (1967)

8. Philip M. Smith; New Approaches to National Park Service Administration and Management. Nat. Parks Mag. 42 (245) 14-18 (1968)

Theses

1. Max W. Reams, "Some Experimental Evidence for a Vadose Origin of Foibe (Domepits)" M.S. in Geology, University of Kansas

2. Bro. G. Nicholas Sullivan, "Observations on the Population Dynamics of a Cavernicolous Ecosystem" PhD in Biology, Notre Dame University.

3. Robert E. Henshaw, "Acclimatization during Hibernation in Two Species of Bat (Myotis lucifugus and and Myotis sodalis) observations of Thermoregulation, Energy Metabolism, Heart Rate, Water Balance, and Microclimate Selection." PhD in Physiology, State University of Iowa

4. George H. Deike III, "The Development of Caverns in the Mammoth Cave Area" PhD in Geology, Pennsylvania State University

5. Roy H. Carwile and Edward F. Hawkinson. "Baselevel Sedimentation, Flint Ridge, Kentucky" B.S. in Geology, The Ohio State University

6. Charles L. Redmann. "Context and Stratigraphy: The Need for Observations". M.A. in Anthropology, The University of Chicago.

7. David C. Culver, "Analysis of Simple Cave Communities". PhD in Biology, Yale University

8. Alan P. Covich, "Paleoecology of Lacustrine Bored Shells and Ultrastructural Diagenesis". PhD in Biology, Yale University.

Papers Given at Professional Meetings: 1957-1968 (Ref. to published abstract given in parenthesis)

1957

1. R.A. Watson; Pitdome Complex in Flint Ridge, Kentucky. AAAS, Indianapolis, Ind. (no abstract published)

1960

2. R.W. Brucker; Relationship of Vertical Shafts to Other Cavern Features. NSS, Carlsbad, N.M. (NSS News 18 76 1960)

1961

3. F. Benington and C.W. Melton; An Examination of Brown-Black Ceiling Deposits from Mammoth and Salts Cave. NSS, Chattanooga, Tenn. (NSS News 19 91 1961)

4. Philip M. Smith; Fluctuations in the Green River at Mammoth Cave, Kentucky. NSS, Chattanooga, Tenn. (NSS News 19 94 1961)

5. Roger W. Brucker; Truncated Cave Passages and Terminal Breakdown. NSS, Chattanooga, Tenn. (NSS News 19 96 1961)

6. William B. White and Elizabeth L. White: Crystal Wedging as a factor in Cavern Breakdown. AAAS, Denver, Colo. (no abstract published)

1962

7. Bro. G. Nicholas; Nocturnal Migration of Hadenoecus subterraneus. NSS, Custer, S.D. (NSS Bull. 26 62-63 1964)

8. William B. White and Fred Benington; Sulfate Mineralogy of the Flint Ridge Cave System. Geol. Soc. Amer., Houston, Tex. (GSA Spec. Pap. 73 262 1963)

9. Fred L. Siegel; Mineralogy of Great Onyx Cave, Kentucky. Geol. Soc. Amer., Houston, Texas (GSA Spec. Pap. 73 242-243 1963)

10. Elizabeth L. White and William B. White; Processes of Cavern Breakdown. AAAS, Philadelphia, Pa. (NSS Bull. 26 69-70 1964)

11. Max W. Reams; A Comparison Between Laboratory Models and Naturally Occurring Domepits. AAAS, Philadelphia, Pa. (NSS Bull. 26 70 (1964)

1963

12. William B. White; Sedimentation in Caves: A Review. NSS, Mountain Lake, Va. (NSS News 21 152-153 1963)

13. R.E. Henshaw and G.E. Folk; Water Balance in Hibernating Bats. A.I.B.S. (Ecol. Soc. Bull. 44 (3) 1963)

14. R.E. Henshaw and G.E. Folk; Observations of Seasonal Changes in Metabolic and Cardiac Rates in Hibernating Bats. AAAS, Cleveland, Ohio (Ecol. Soc. Bull. 44 (4) 1964)

15. G.W. Moore and Bro. G. Nicholas; Out of Phase Seasonal Fluctuation of the Top of the Geothermal Gradient at Cathedral Cave, Kentucky. AAAS, Cleveland, Ohio (NSS Bull. 26 84 1964)

16. Thomas L. Poulson and Philip M. Smith; The Importance of Base Level Fluctuations in the Biology of Cave Organisms. AAAS, Cleveland, Ohio (NSS Bull. 26 80 1964)

17. E. Robert Pohl and William B. White; Origin of Sulfate Minerals in the Central Kentucky Cave Area. AAAS, Cleveland, Ohio (NSS Bull. 26 84 1964)

18. Richard A. Watson, William B. White, Roger W. Brucker, and E. Robert Pohl; The Central Kentucky Karst: A Review. AAAS, Cleveland, Ohio (NSS Bull. 26 85 1964)

19. William B. White and George H. Deike III; Preliminary Results on the Paleohydrology of Mammoth Cave and the Flint Ridge Cave System. AAAS, Cleveland, Ohio (NSS Bull. 26 86 1964)

1964

20. James F. Quinlan, Jr.; The History of the Evolution of the Map of Mammoth Cave, Kentucky. NSS, New Braunfels, Texas (NSS Bull. 27 61 1965)

21. R.E. Henshaw and G.E. Folk; Acclimatization During Winter Hibernation in Two Species of Myotid Bat. A.I.B.S. (Amer. Zool. 4 (3) 1964)

22. Richard A. Yarnell; Early Woodland Plant Remains and the Question of Cultivation. Amer. Anthro. Assoc., Detroit, Mich. (no abstract published)

1965

23. R. E. Henshaw; Thermal Conductance During Hibernation: Differences in Two Species of Bat. F.A.S.E.B. (Fed. Prof. 24 1965)

24. Patty Jo Watson and Richard A. Yarnell; Archaeological and Paleoethnobotanical Investigations in Salts Cave, Mammoth Cave National Park, Kentucky. Soc. Amer. Archeol., Urbana, Ill. (no abstract published)

25. Michael F. Ehman; Cane Torches as Cave Illumination. NSS, Bloomington, Ind. (NSS News 23 129 1965)

26. Thomas L. Poulson and Philip M. Smith; The Basis for Seasonal Growth and Reproduction in Aquatic Cave Organisms. 3rd Int. Congr. Speleo., Ljubljana, Yugoslavia (abstracts of all Congress papers were published in a small booklet distributed at the Congress)

27. Patty Jo Watson: Archaeological Investigations in Salts Cave, Mammoth Cave National Park, Kentucky. 3rd. Int. Congr. Speleo., Ljubljana, Yugoslavia.

28. Richard A. Watson; Big Canyons in the Central Kentucky Karst. 3rd. Int. Congr. Speleo., Ljubljana, Yugoslavia.

29. Richard A. Watson and Philip M. Smith; The Flint Ridge Cave Research Center, Mammoth Cave National Park, Kentucky. 3rd. Int. Congr. Speleo., Ljubljana, Yugoslavia.

30. William B. White; Sulfate Mineralogy in Some Caves in the United States. 3rd. Int. Congr. Speleo., Ljubljana, Yugoslavia.

31. Ralph O. Ewers; Bedding-Plane Anastomoses and Their Relation to Cavern Passages. AAAS, Berkeley, Calif.

32. Richard A. Watson: Central Kentucky Karst Hydrology. AAAS, Berkeley, Calif.

<u>1966</u>

33. James F. Quinlan and Alfred Traverse; Humic Acid and Humate Deposits in Salts Cave and Mammoth Cave, Kentucky: A Preliminary Report. NSS, Sequoia, Calif. (NSS Bull. <u>29</u> 98-99 1967)

34. Philip M. Smith and William B. White; Regional Protective Associations: A New Force in Cave Conservation. NSS, Sequoia, Calif. (no abstract published)

35. Denver P. Burns; Explorations in Flint Ridge. AAAS, Washington, D.C. (NSS Bull. <u>29</u> 114 1967)

36. Thomas L. Poulson; Biospeleology: Past, Present, and Future. AAAS, Washington, D.C. (NSS Bull. <u>29</u> 100 1967)

37. James F. Quinlan Jr.; Classification of Karst Types: A Review and Synthesis Emphasizing the North American Literature, 1941-1966. AAAS, Washington, D.C. (NSS Bull. 107-109 1967)

38. James F. Quinlan Jr. and E.R. Pohl; Vertical Shafts Actively Promote Slope Retreat and Dissection of the Solution Escarpment and the Chester Cuesta in the Central Kentucky Karst. AAAS, Washington, D.C. (NSS Bull. <u>29</u> 109 1967)

39. William B. White and Elizabeth L. White; The Speleological Approach to Limestone Hydrology. AAAS, Washington, D.C. (NSS Bull. <u>29</u> 113 1967)

40. Elizabeth L. White and William B. White; Dynamics of Sediment Transport in Limestone Caves. AAAS, Washington, D.C. (NSS Bull. <u>29</u> 113-114 1967)

1967

41. Richard A. Yarnell and Patty Jo Watson; The Prehistoric Utilization of Salts Cave, Kentucky. Society for American Archaelogy, Ann Arbor, Mich.

42. Alan E. Hill; Possible Application of Acoustical and Holographic Techniques to Locate and 3-Dimensionally Photograph a Cave from the Surface. NSS Birmingham, Ala.

43. Alan E. Hill; The Physics of Underground Radio Communication and Practical Tranceiver Design Implications. NSS, Birmingham, Ala.

44. Craig S. Peterson and William B. White; Water-Soluble Minerals in the Cave Sediments of the Central Kentucky Karst. NSS, Birmingham, Ala.

45. David Culver; Structure of Some West Virginia Cave Stream Communities. AAAS, New York, N.Y. (Amer. Zool. 7 809 (1968)

46. George H. Deike; Limited Influence of Fractures on Cave Passages in the Central Kentucky Karst. AAAS, New York, N. Y.

47. George H. Deike and William B. White; Sinuosity of Limestone Solution Conduits. AAS, New York, N.Y.

48. Thomas L. Poulson; A Review of Cave Adaptation. AAAS, New York, N. Y.

49. Thomas L. Poulson and David Culver; Diversity in Aquatic and Terrestrial Cave Communities of Flint Ridge, Mammoth Cave National Park. AAAS, New York, N.Y. (Amer. Zool. 7 809 (1968)

1968

50. William B. White; Conceptual Models for Carbonate Aquifers. NSS, Springfield, Mo.

CAVE RESEARCH FOUNDATION

Twelfth Annual Report

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DIRECTORS OF THE CAVE RESEARCH FOUNDATION

Cave Research Foundation
464 M Street, SW
Washington, D.C. 20024

Cover Photo: Lower section of Fossil Avenue in Mammoth Cave.

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HIGHLIGHTS OF 1970

Archaeology continues to be on the forefront of research at Flint Ridge. The continued support of the National Geographic Society has permitted Dr. Patty Jo Watson and her collaborators to conduct additional digs in the Salts Cave Vestibule and to make additional analyses of the prehistoric materials from Salts Cave.

The discovery of Lee Cave last year has triggered a new mode of cave description and reporting. The Foundation is conducting a series of cartographical,general geological, and biological reconnaissances which will be reported as individual descriptive papers on significant caves or portions of caves. One of these concerns Lee Cave itself, a second described Timpanogoes Cave, Timpanogoes Cave National Monument, in the Wasatch Mountains of Utah. The third, at the request of the National Park Service, describes the portion of Mammoth Cave known since 1939 as "New Discovery". These descriptive efforts will provide the caving community with fairly detailed descriptions of particularly significant caves and will provide the National Park Service with valuable resource documents for interpretation and management.

The Cave Research Foundation fellowship for 1969 went to Mr. John W. Hess, Department of Geology, The Pennsylvania State University, to support his PhD dissertation on the hydrology of the Central Kentucky Karst.

Several special seminars concerning the hydrology of the Central Kentucky Karst occurred in 1970. In May a workshop and field trip on carbonate terrain hydrology was held at the Pennsylvania State University for the benefit of the IHD Working Group on Carbonate Terrains. Research reported included Mr. Wolfe's work on cave sediments in the Appalachian Mountains of West Virginia. An informal seminar on the hydrology of the Central Kentucky Karst was held on Flint Ridge in August. Those attending included most CRF workers active in hydrology, and representatives of the National Park Service, the U.S. Geological Survey, Louisville Office, and the University of Kentucky.

A distinguished visitor to Flint Ridge was Mr. Atilla Kosa, the Secretary of the Hungarian Speleological Society.

Dr. Thomas L. Poulson gave an invited popular lecture before the National Parks Association at the Smithsonian Institution Auditorium in Washincton DC. He spoke to a capacity audience on the subject, "Caves: the Hidden Frontier."

THE SCIENTIFIC PROGRAMS

THE CARTOGRAPHIC PROGRAM

D.P. Burns, J.P. Freeman, J. Wilcox

The cartographic program was active in the three major cave-bearing ridges in Mammoth Cave National Park during the past year. In Flint Ridge there were numerous connections between previously surveyed passages and several important finds were made. In Mammoth Cave Ridge the highlight was the survey in the New Discovery Section. Much new passage was found and several important areas were rediscovered, apparently known to earlier explorers who have since left the area. In Joppa Ridge, Lee Cave was greatly lengthened by the penetration of a low side passage that led to a complex of passages.

Flint Ridge: The Flint Ridge Cave System is the longest surveyed cave in the world with a length of 84.12 miles as of October 1, 1970. A reexamination of all the surveys comprising the Flint Ridge System was made to ensure there were no overlaps or duplicate surveys. When the lengths of the remaining surveys were compiled the figure was greater than the figure previously reported. During the eleven-month period from November 1, 1969, to October 1, 1970 newly surveyed passages in Flint Ridge totaled 3.93 miles. Resurvey totaled 1.31 miles.

Areas important in Flint Ridge during the past year include the following:

A. Miller Trail (Left of the Trap)

Three parties made the strenuous trip Left of the Trap and resulted in more than 3400 feet of survey.

B. Hosken Trail

Hosken Trail yielded several thousand feet of survey and two important connections. One connection, at high level, was to Penk Trail and the other was a low-level connection to the north end of Lower Lower Gravel. The link to Lower Lower Gravel indicates a drainage divide under Floating Mill Hollow. Water from the upper reaches of the Hollow drains through the lowest level of Hosken Trail then to Lower Lower Gravel and north, presumably to Pike Spring. Water from the southwestern portion of Floating Mill Hollow flows south and west along the Blue Tube and the Northwest passage to the Green River near Taylor Coates Hollow. Lower Lower Gravel is now known to drain Candelight River, Bretz River, and Hosken Trail.

C. Rope-Pit Drain

This passage can be reached via Turner Avenue and Rope Pit or by the way of Candelight River. Rope Pit is situated under the center of Eaton Valley and the drain passage extends west down the axis of Eaton Valley. Surface contours above the passage drop as low as 520 feet.

D. Eller Alley

Eller Alley is the name used for a passage going due north off Finch Avenue for more than 1900 feet. Eller Alley leads to another passage that has a side passage five feet high by seven feet wide and more than 800 feet long. Both passages remain unsurveyed and the 5 by 7 passage was partially filled with greenish mud and organic material in March 1970. High leads and much air flow out of several pits promise more cave. The entranceway to Eller Alley has been completely flooded for the past six months.

E. Salts-Unknown Link

Several trips were made to the Link to find a way into the northern part of Eller Alley. The connection has not yet been made but passages totaling about 1000 feet were surveyed. Leads remain.

F. Ehman Trail

Several passages in the Ehman Trail area of Colossal were surveyed and new leads were found and remain to be examined.

G. Salts Cave

More than one mile of passages were surveyed in Salts, mostly on an intermediate level between Indian Avenue and Upper Salts.

Mammoth Cave Ridge: Surveys were continued in the western half of Mammoth Cave including Stevenson Way, Burley's Way, the Dragon Pit area, Sillimans Avenue and Serpent Hall. Numerous passages remain to be surveyed in these areas. Surveys were begun in the New Discovery area and have yielded many virgin leads and the rediscovery of some passages known to the early explorers in New Discovery but apparently unknown in recent years.

Joppa Ridge: Proctor Cave yielded 3264 feet of passage to double its known length. Proctor Cave is now 1.19 miles long. Lee Cave yielded 7183 feet of survey to increase its length to 3.58 miles.

Cooperative Study: A cooperative study was launched with the Department of Geodetic Science of The Ohio State University, to provide the accurate location of cave entrances in the Park. The study consists of an aerial survey with a simultaneous adjustment of the survey net to provide entrance locations within plus or minus two feet. The computer programs have been developed and a preliminary flight was made in February.

Paleohydrology of Mammoth Cave and the Flint Ridge Cave System

George H. Deike III

Field work on this project was carried out in July and early August at Mammoth Cave National Park, Kentucky. The primary goal was to collect data on the size and shape of cavern passages for comparison to the geometry of surface streams where such data have greatly added to understanding of river hydrology.

Preliminary studies suggest that the width of the cave channel is more diagnostic of hydrologic parameters than is the height. It is also easier to measure accurately. The procedure was to measure, with survey tape, the width (and height, for further study) at measured 100-foot intervals. Data were collected as shown in Table I.

TABLE I

Cave or Passage	No. of 100' Stations	Characteristics
Great Onyx Cave	51	Passage forks, not at grade
Cleaveland Ave.	50	A main trunk in Mammoth Cave
Four branches of Cleaveland Ave.	58	Tributaries at gate
Marion Ave. and two branches	50	The major tributary to Cleaveland Ave. at grade
Colossal Cave, Grand Ave.	54	Complex trunk, may correlate with other passages
Long Cave	29	Tubular trunk with tributary at grade
Turner Ave.	104	Very long complex trunk, few tribut.
Mather Ave.	72	Trunk related to Turner Ave., may correlate with Colossal Cave
Total	468	

To supplement the measurements, about 130 careful cross-sections were drawn. Also, 120 photographs were taken, lighted so that detailed cross-sections to scale could be prepared from them, and further measurements made.

Ultimately every part of the 130 miles of known cavern passage should be examined to make historical reconstructions of the underground drainage. This is beyond the scope of the present project, however, and only certain areas having known or suspected relationships to the areas where data were collected on this and previous trips were investigated. These investigations include sketching passage relationships and shapes, determining elevations, measuring flow direction and velocity indicators, and attempting on-the-spot reconstructions of the ancient drainage. Such hydrologic and geologic reconnaissance was made in eleven areas of the cave systems.

Hydrology of the Central Kentucky Karst

J.W. Hess

The ground work for the thesis research on the hydrologic balance of the Central Kentucky Karst was laid during the 1970 field season. The inputs on the Sinkhole Plain, and the output springs along the Green River were investigated. This work, along with planned tracing of the sinking streams on the Sinkhole Plain to their outputs along the Green River, will be used to define the final area of study.

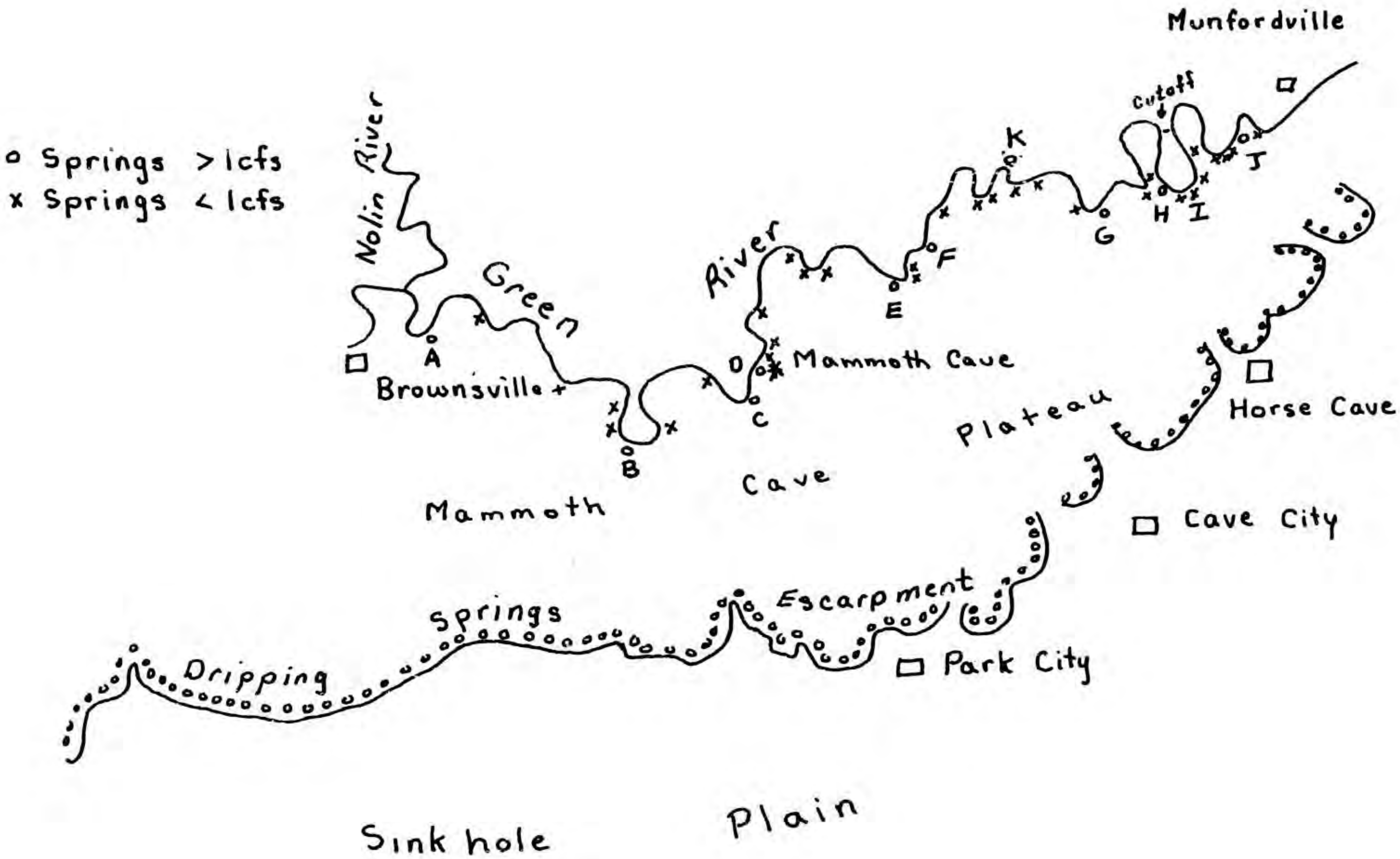
The sinking streams on the Sinkhole Plain and their drainage basins were field-checked and investigated for cover, ponor location, and drainage divide location. The landowners were questioned concerning frequency and magnitude of flooding of the streams. Maps of caves on the Sinkhole Plain with active streams are being collected to help piece together the drainage system.

A temperature survey of the Green River was made from Munfordville to Brownsville to locate new springs. A thermistor was towed along side a canoe and the river temperature was noted for cool spots. Several new large springs and many small springs and seeps were located (Fig. 1). An underground meander cutoff was located on Mansfield Bend along with evidence for a paleocutoff on the same bend.

Pike Spring was dove to measure its cross-sectional area and to locate a point to place a flow velocity meter. Turnhole Spring was dove to look for the spring opening with no luck.

Owl Cave, a possible gauging point for Turnhole Spring, was mapped in cross-section and investigated for possible location of the gauge. A possible under-water point was located which will have to be checked.

Garvin Spring Cave and Blow Hole Cave surveys were started. These two caves possibly connect and are the possible resurgence for the water from Hidden River Cave. These caves are also of interest because they represent the only place we can see what is happening at the down-stream end of the cave system.



SPRINGS OF THE CENTRAL KENTUCKY KARST

TABLE II

MAJOR SPRINGS OF THE CENTRAL KENTUCKY KARST

MAP CODE	NAME	SUMMER FLOW[1]	OTHER
A	Houchins Ferry Spring	1.8 cfs	
B	Turnhole Spring	20 cfs	
C	Echo River Spring	5 cfs	
D	Styx River Spring	1.5 cfs	
E	Pike Spring	6 cfs	30' wide x 5' high passage 25' under water
F	Mile 205.7 Spring	1 cfs	Small rise pool
G	Blue Spring (south)	5 cfs	Large rise pool
H	Garvin Spring	3 cfs	1100 feet of passage back to siphon
I	Blow Hole Cave and Spring	none	Several thousand feet of passage, may connect to Garvin
J	Gorn Mill Spring	60 cfs	Large rise pool
K	Blue Spring (north)	20 cfs	On north side of river

[1]July and August 1970

Vertical Shaft Research

Roger W. Brucker, John W. Hess and W.B. White

Vertical shafts are roughly cylindrical voids in carbonate rocks. They range in diameter from inches to tens of feet and in height from inches to hundreds of feet. They are produced by vertically descending ground water from perched ground water reservoirs. These features are common throughout the Interior Lowlands and the Appalachian Plateaus Provinces. Vertical shafts drain to the base level and are enlarged radially and axially by thin sheets of flowing water. Vertical shafts form the headwater termini of complex drainage networks and play a key role in the vertical movement of water. They carry a large sediment load and indeed most of the mass wasting of the nonsoluble rocks above the carbonate sequence is through underground routes. Shafts form in groups and clusters with drain systems that aggregate the waters into master drains which carry the water to big springs. The drains evolved through time as base level is lowered but retain a dendritic pattern. Shafts are very short-lived and are only at the edge of the clastic caprock in the study area in Southcentral Kentucky. Shafts abandoned by the retreat of the caprock are filled with travertine by water from the limestone surface. There is evidence that special flow dynamics need to be invoked to account for the large volume of the shaft compared with the small volume of the feeder channels and the drains.

Measurements of the flow velocity and the thickness of the moisture film on shaft walls fall into the region indicated on Fig. 2. The velocities are remarkably high, up to 5 feet per second, and the points fall into the supercritical laminar regime shown on the fence diagram. The carbonate chemical parameters, Ca^{++}, Mg^{++}, HCO_3^-, pH, and Temperature were measured on a number of shaft waters in the Appalachian caves of West Virginia. All shaft waters appear to be undersaturated with respect to calcite. Of particular interest is Swago Pit where data were obtained at the top and the bottom of a 54-foot shaft. At the top Ca^{++} = 14.0 ppm and HCO_3^- = 42.5. At the bottom Ca^{++} = 15.0, and HCO_3^- = 56.5. The increase in carbonate content is large enough to be measurable over a 54-foot reach and implies that shaft formation is an extremely rapid process on a geological time scale. These chemical results agree with the field evidence that shafts are forming very rapidly and are always in equilibrium with the evolution of the overlying landscape.

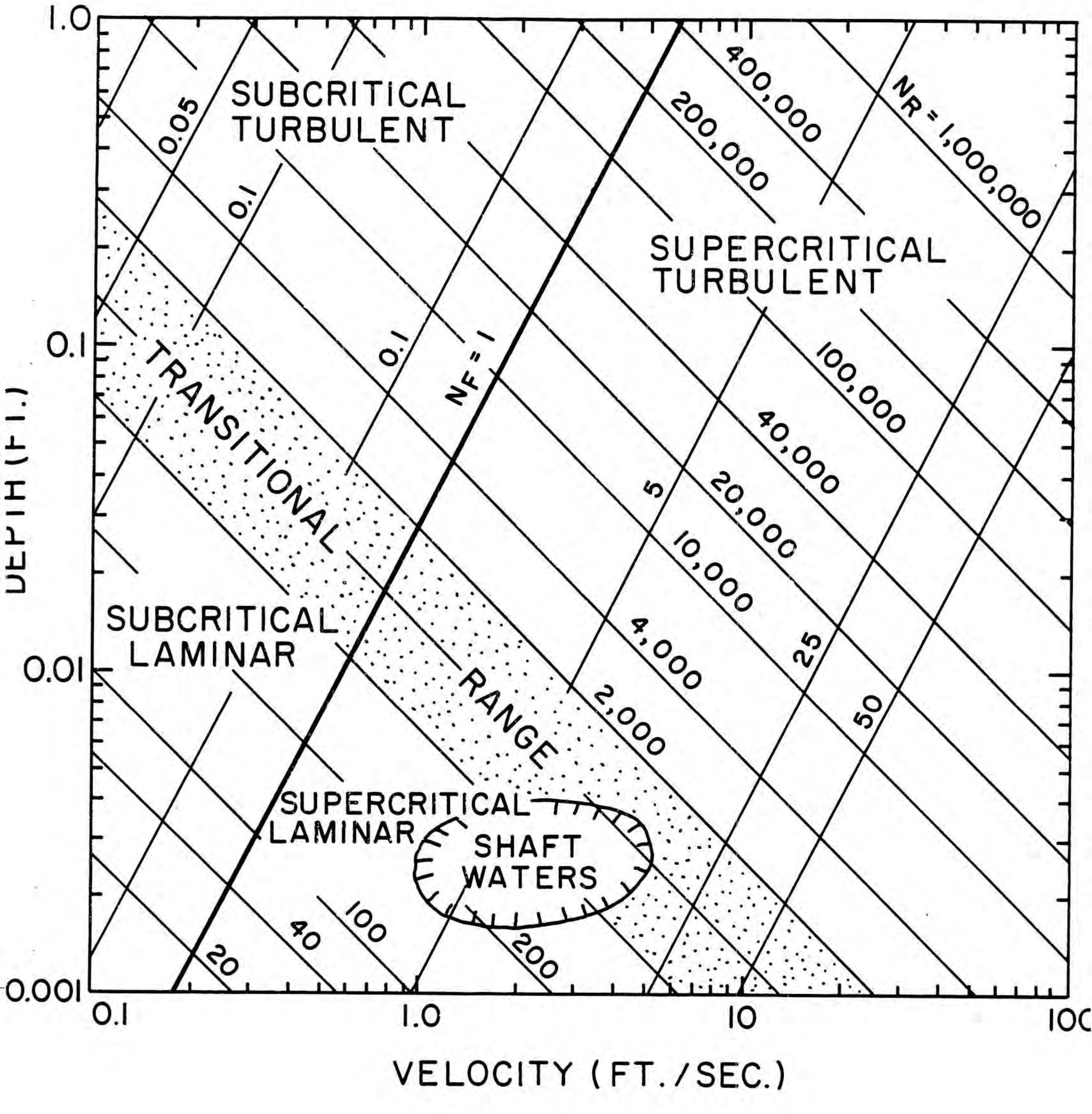
PROGRAM IN SEDIMENTATION, MINERALOGY, AND PETROLOGY

Clastic Sediments in West Virginia Caves

Thomas E. Wolfe

This report on some of the geomorphological aspects of clastic cave fills is concerned with sedimentation in caves of the Greenbrier limestone along the base of the Allegheny front in southeastern West Virginia. Previous studies are criticized for their failure to define the drainage net as the most important unifying factor in an attempt to relate surface and subsurface deposition. By treating each basin as a whole and examining streams, surface sedimentation and cave fills within the basin it can be shown that a relationship does exist.

The careful choice of a study site is emphasized. The Culverson Creek system is used as an example. Here a relatively simple areal geology, linear outcrops of clastic source material, and a strike-oriented drainage pattern control some of the troublesome variables in sediment source and distribution. Through the use of traceable "identifiers" such as quartz pebbles derived from the Princeton and Pottsville formations a hypothesis of stream reversal and subterranean piracy is verified. Samples of the following were taken for study: (a) bedrock conglomerate source material at the headwaters of the present drainage net; (b) quartz pebbles and transported conglomerate boulders along the main trunk channel to



1.0
0.1
0.01
0.001
DEPTH (FT.)
0.1
1.0
10
100
VELOCITY (FT./SEC.)
SUBCRITICAL
TURBULENT
SUPERCRITICAL
TURBULENT
TRANSITIONAL
RANGE
SUBCRITICAL
LAMINAR
SUPERCRITICAL
LAMINAR
SHAFT
WATERS
NF = 1
NR = 1,000,000
400,000
200,000
100,000
40,000
20,000
10,000
4,000
2,000
200
100
40
20
0.05
0.1
0.1
5
25
50

where a major sink receives all runoff; (c) quartz pebbles from marker beds in caves flanking the trunk valley flood plain; (d) quartz pebbles from within the present subterranean trunk conduit and at higher levels in the cave; (e) ejects from the present rising along Spring Creek; (f) quartz pebbles from along a presumed high-level ancient surface runoff channel for a distance of twelve miles.

Preliminary results from laboratory tests in progress show a decrease in size and show an increase in sphericity and roundness of quartz pebble samples in a downstream direction along the ancient runoff channel, in the caves and along the present surface trunk stream. Structural characteristics in the cave fills show an invasion of quartz pebble deposition. This is probably due to flooding sequences.

An example of a once-in-one-hundred-or-more-years flood occurred while field work was in progress. This provided a rare opportunity for study of sedimentation under such conditions. Cave sediment traps which had during the previous year showed only silt and clay deposition were completely filled in with pebbles and small boulders. Other spectacular examples of cutting and filling by flood action attest to the author's opinion that such infrequent floods are more significant in the removal, deposition, and reworking of surface and subsurface clastic fills.

During 1970 X-ray diffraction of clay minerals from over 100 sites was completed. All field work in connection with sample collection and field mapping was completed. Statistical analysis of the data collected over the last three years is now in progress.

Cave Sediments in the Near East

Paul Goldberg

Research on the relation of cave sediments to Pleistocene history and climate in Israel is nearing completion. Field work during 1970 consisted of surface observations and interpretation of the geomorphology of the area. Grain size and heavy mineral analyses of the Tabun Cave material are underway.

Sulfate Minerals in Central Kentucky Caves

W.B. White

The Flint Ridge Cave System has long been known to contain a suite of sulfate minerals consisting of gypsum, mirabilite, and an unnamed double salt $2Na_2SO_4 \cdot CaSO_4 \cdot 2H_2O$. These minerals occur in greatest abundance in Turner Avenue, particularly in the area of Benington Grotto and White Way, although gypsum and mirabilite are found in many dry parts of the cave. Considerable field work and some laboratory analyses were performed in the early 1960's.

The sulfate mineral suite in Lee Cave is greatly, and surprisingly, different from that in the Flint Ridge Cave System. Gypsum is common but the second most abundant mineral is epsomite, $MgSO_4 \cdot 7H_2O$. The sulfate minerals occur as loose material in cracks and fractures in the ceiling and as crusts on upward-facing surfaces on the floor (where they have sifted down from the ceiling). Well developed crystalline forms such as the gypsum flower shapes are very rare. Within these sulfate crusts are at least two and possibly more unidentified minerals. Analyses to date have shown that they are sulfates only and not carbonates or nitrates. The X-ray powder diffraction patterns do not agree with any in the standard reference files. They may be minerals for which inadequate descriptions exist in the literature or they may be completely new minerals (as was the labile double salt described above).

Mammoth Cave contains in addition to quite extensive gypsum displays also some mirabilite. Mirabilite occurs as thin feathery crystals growing from ceilings or from soils near Tribble's Trouble in the Main Cave and has been observed to sprout from the soil of Cleaveland Avenue during the damp months of late Winter and early Spring.

New Discovery, which lies under Jim Lee Ridge between Mammoth Cave Ridge and Joppa Ridge, seems to contain little in the way of unusual sulfate minerals. The exotic mineral display at Paradise is mainly gypsum as are the mineral occurrences so far examined that crop out here and there along Big Avenue.

Analyses of rock fragments from Lee Cave shows that some dolomite occurs in the ceiling beds. This provides a convenient source for the magnesium and a possible explanation for the occurrence of epsomite. The source of sodium for the mirabilite is not known.

PROGRAM IN KARST GEOMORPHOLOGY

Geology and Interpretation of Crystal Cave

Arthur N. Palmer

In an effort to make the results of the CRF leveling program more meaningful, a study was undertaken in Floyd Collins' Crystal Cave in August, 1970, in which details of the geological setting are being tied in with a systematic hand-level survey of the major passages in the cave. Although an analysis of the resulting data has only begun, it appears that the survey will aid in interpreting the genesis of the cave and the geologic factors that have influenced its pattern. A major end product will be a geologic map of the cave.

The following information is being obtained from the present survey:

1. Elevations for passage floors and ceilings in sufficient numbers that continuous profiles or cross-sections can be drawn showing passage gradients and vertical relationships of passages.

2. Elevations for key survey stations in the cave.

3. Geologic structure; attitude of bedding planes and lithologic boundaries in the limestone and its effect on passage pattern.

4. Detailed stratigraphic section; effect of different lithologic units on passage character.

5. Hydrographic notes--pattern and nature of present flow, and of past flow as indicated by scallops.

6. Interpretation of the history of passage development.

7. Character, location, and extent of cave sediments and speleothems.

8. Nature of passage intersections and terminations.

9. Evaluation of geologic features controlling initial passage development: bedding planes, joints, etc.; concordance vs discordance of passages to geologic structure.

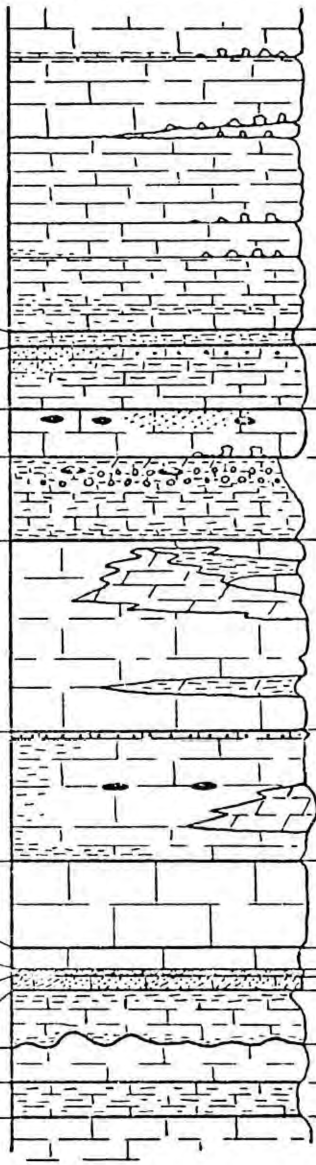
Partial interpretation of the survey notes from the August trip has begun with the construction of a stratigraphic column for the parts of the cave studied between Scotchman's Trap and Mud Avenue (Ste. Genevieve and Girken Limestones) as shown in figure 3. The arbitrary rock units shown in the section were determined by lithologic characteristics and their control of passage development, rather than by biostratigraphic means, and no attempt has been made as yet to apply the accepted stratigraphic nomenclature to the units. Popular terminology has been used in the lithologic descriptions so that the units can be easily recognized by persons not having a professional training in geology.

In spite of a considerable amount of lateral variation in lithology and thickness, most of the units described in the section can readily be traced throughout the parts of the cave that have been studied. Perhaps the most prominent geologic horizon is the "D/E" contact, which appears in the cave as a sharp indentation in the cave walls generally several feet deep.

Structural profiles through the cave indicate a consistent dip of 69 to 72 feet/mile to the northwest, about twice the value for the regional dip, but compatible with the dips throughout much of Flint Ridge that are shown on the USGS geologic map of the Mammoth Cave Quadrangle. The prominent anticlinal or domal structure shown on the geologic map at Floyd Collins' Crystal Cave at the base of the Big Clifty Formation apparently has no expression in the underlying cave-bearing limestones.

Surveys with a properly calibrated hand level are accurate enough to detect minor structural irregularities superimposed on the regional dip. The single completed loop during the August survey contained an error of 0.05 foot in a traverse of 890 feet, which extrapolates to one foot in 17,000. Other surveys conducted during the summer indicate a consistent error well within a foot per mile, even under severe cave conditions. Because of the rambling nature of the Flint Ridge System, it should be possible to obtain a detailed structural map of the ridge based on information from several different limestone horizons. The application to the analysis of passage orientation in the cave is

Stratigraphic Section in Floyd Collins' Crystal Cave: Crawlway to Mud Ave.



UNIT	LITHOLOGY/WEATHERING CHARACTER IN CAVE	OBSERVED THICKNESS	DESCRIPTION, TYPICAL EXPOSURE
A		> 34 ft.	Limestone, fine grained, gray and gray-brown, weathers with cream to white clay film, medium bedded; local beds of shale and shaly limestone near base; thin-bedded, limy shales, commonly less than one inch thick, above and/or below some major bedding planes; prominent anastomoses along major bedding planes; Crawlway, route to Bottomless Pit.
B		1.5 ft.	Shale, limy, silty, friable; mottled dark gray; Turnpike, ledge at top of Bottomless Pit.
C		6 – 7.2 ft.	Limestone, oolitic and cross bedded to fine grained and shaly, grading downward to very fine-grained limestone; dark gray, weathers to light gray; thin bedded; Dining Room.
D		3.7 – 6.1 ft.	Limestone, crystalline, medium to light gray, weathers golden brown with rough, granular surface; massive; local cross bedding; sparse chert nodules near top; Dining Room.
E		6.5 – 8.3 ft.	Limestone, fine grained, in incompetent conglomeratic or brecciated beds with matrix of limy shale; dark gray, weathers brown; massive, gray, shaly limestone at base; locally shaly, dolomitic, or siliceous at top; sparse chert nodules near top; Waterfall Trail, pit at Turnpike.
F		19.2 – 23 ft.	Limestone, crystalline, crinoidal; medium to light gray, weathers brown with rough, granular texture; massive, with beds as thick as 15 feet; commonly exhibits vertical solution flutes; intermittent lenses of fissile, limy shale and massive, light gray, limy dolomite as much as 6 feet thick; Ebb and Flow Falls and adjacent pits, bottom of pit at Turnpike.
G		12.7 – 13.3 ft.	Limestone, very finely crystalline to lithographic; light gray-brown, weathers same, with smooth texture; medium bedded; one-foot, white to light gray oolitic bed at top; local lenses of shaly and/or dolomitic limestone; sparse chert nodules 5 feet below top; Floyd's Jump-Off.
H		7.2 – 10.8 ft.	Limestone, crystalline, medium gray, weathers to light gray with granular texture; massive; commonly exhibits vertical solution flutes; local cross bedding; route from Jump-Off to Mud Ave.
J		1.4 – 2.1 ft.	Limestone, lithographic, dark gray, weathers dark gray-brown; medium bedded; route from Jump-Off to Mud Ave.
K		0.4 – 0.9 ft.	Limestone, very fine grained, medium gray, weathers brown; abundant calcareous worm tubes; Mud Ave.
L		1.0 – 1.7 ft.	Limestone, granular and cross bedded to finely crystalline; Mud Ave.
M		5.6 ft.	Limestone, fine grained; medium gray, weathers same; thin to medium bedded; medium gray shaly limestone at top, less than one foot thick; disconformity at base with as much as three feet of local relief, overlain by thin shale; Mud Ave.
N		3.9 ft.	Limestone, fine grained; medium gray, weathers same; massive; Mud Ave.
P		≥ 3.5 ft.	Limestone, shaly, gray, medium bedded; Mud Ave.

A.N. Palmer Sept. 1970

apparent, as the passages surveyed to date show a strong concordance to the structure and exhibit a present or past flow direction down various components of the dip.

The leveling/geology survey will be conducted throughout the remaining major passages of Floyd Collins' Crystal Cave during the summer of 1971, and the feasibility of extending the survey throughout the Flint Ridge System and neighboring cave systems will be evaluated.

Description and Interpretation of Lee Cave

J.P. Freeman, T.L. Poulson, G.L. Smith, P.J. Watson, and W.B. White

Lee Cave is located in the northwestern edge of Joppa Ridge in Mammoth Cave National Park. Entrance through a shaft and canyon complex leads into a large trunk passage at the Western terminal breakdown. The trunk, evidence that a major cave system does exist under Joppa Ridge, extends 7000 feet with cross-sections up to 50 x 100 feet to an eastern terminal breakdown. Below the main trunk is a complex of smaller tubes, canyons, and vertical shafts.

The trunk contains a thick clastic sediment sequence which facies from cobbles in the west to fine silts and clays in the east.* Breakdown activated by sulfate replacement and crystal wedging is common. Gypsum and epsomite occur as clumps of curved crystals and other sulfates occur as thick crusts drifted onto up-facing sediment and breakdown surfaces. Cave life is sparse: there is a small bat colony and much evidence of cave rats, although no live rats have been observed. Smaller animals, except for crickets, have not been observed.

Pre-Columbian Indians entered the cave, probably through an entrance now closed, in the eastern breakdown. Fragments of cane-torch material are scattered along much of the main trunk passage. Two stone cairns of unknown purpose occur. There is, however, no evidence of the mining activity common to Mammoth and Salts Caves. Lee Cave was named for T.E. Lee, pioneering cave explorer of southcentral Kentucky, who descended the entrance pit in 1876.

Description and Interpretation of New Discovery

D.P. Burns, T.L. Poulson and W.B. White

New Discovery is an isolated segment of Mammoth Cave that occurs under the southern spur of Mammoth Cave Ridge known as Jim Lee Ridge. It is, for most practical purposes, a separate cave. The connection with the rest of mammoth is through small passages near the base level. The objective of the present study is to provide background reconnaissance geology and biology of the cave. In addition to the survey and leveling program by the cartographers, field work on the geology and mineralogy of the cave has been carried out.

*Fig. 4

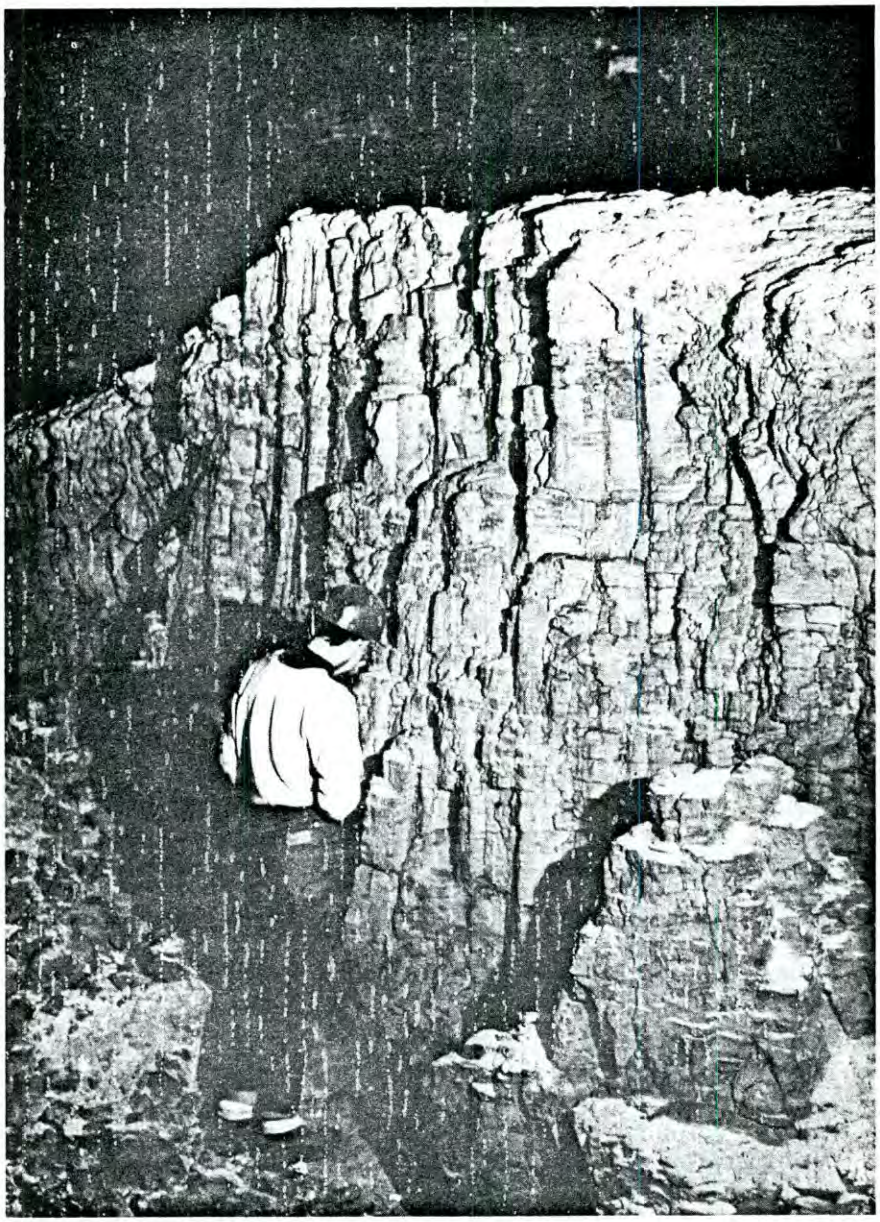


Fig. 4. Banks of massive red silt with columnar jointing in the main trunk passage of Lee Cave. Small piles of sulfate minerals have drifted onto all upward-facing ledges.

The New Discovery main trunk is Big Avenue, a passage of comparable size to the largest trunks in Flint Ridge or Mammoth Cave, which heads in a terminal breakdown at drill hole and extends more than a mile into a complex of passages near Green River. The main portions of the trunk are completely dry but the downstream terminus is in the floodwater zone. The up-stream tributaries of Big Avenue are apparently extensions of known passages of Mammoth Cave; the Rimstone Dam Passage appears to be the continuation of Cleaveland Avenue beyond the Carmichael Entrance collapse sink. The New Discovery entrance passage, Fossil Avenue, is apparently related to the Fairy Grotto passage in the historic section of Mammoth Cave.

Fossil Avenue is of interest because of the change in passage morphology from the entrance to the Big Avenue confluence. The entrance section has the shape of a rectangular canyon 6 feet wide and high. Farther downstream the passage becomes an elliptical tube 25 feet wide and 10 to 15 feet high. Most conduits in the Central Kentucky Karst maintain their cross-sectional area over long distances so that this behavior of Fossil Avenue is unusual. Likewise there is some evidence for a reversal in flow direction which is being further investigated.

Sedimentation processes have also been complex. At the mouth of Fossil Avenue is a bar of sandstone pebbles and cobbles. Coarse clastic debris is strewn over the breakdown blocks farther down Big Avenue and small remnants of the cobble armor from a stream channel remain some feet up on the wall of the passage. It is apparent that a major high velocity stream used Big Avenue for a period in its early history. High-lying sediments in the side loops off Big Avenue contain a thick red silt sediment. Large selenite crystals occur at depth in this material, the first such found in the cave systems.

Mineralization in New Discovery consists of a few dripstone deposits near the upper end of Fossil Avenue, in Onyx Avenue, and a few places along Fossil Avenue; the big rimstone dam and associated deposits; and some gypsum crystals at various places. The gypsum flower display in Paradise Canyon is one of the most profuse known in the cave systems.

Description and Interpretation of Timpanogoes Cave

W.B. White and J.J. VanGundy

Timpanogoes Cave is the central feature of Timpanogoes Cave National Monument. The cave is located at an elevation of 6700 feet on the wall of American Fork Canyon in the Wasatch Mountains of Utah. Surface karst and underground features were studied during late June, 1970. The cave was mapped and a general geological and biological reconnaissance performed.

The cave is in the Mississippian Deseret limestone, a limestone sandwiched between mainly dolomitic carbonates. The structural setting is exceedingly complex. American Fork Canyon lies close to the intersection of the main Wasatch fault system and the perpendicular Uinta fault and fold system. Rocks at the cave dip about 20° but are block-faulted on a small scale. The cave passages apparently formed along faults and some open fractures and fractured flowstone indicate that some of these are still in motion.

The cave consists of mainly high narrow passages in a minor network arrangement. None of the usual indicators of high-velocity flow are present. The walls are intricately sculptured; wall and ceiling pockets are common. Clastic sediments are uncommon and where exposed are composed of sand and yellow silt.

The cave contains a spectacular carbonate mineralization. The usual dripstone deposits here give way to complex helictites and other erratic forms. Aragonite is common in all areas as needles and anthroditic forms. Moonmilk occurs sparsely as tufts of material on the tips of dripstone deposits. Samples analyzed so far are composed of hydromagnesite--a surprise, for at this altitude and climate calcite moonmilk would have been expected. Many of the dripstone deposits are colored. A deep yellow is common and a blue-green occurs. These are intrinsic colors of the carbonate minerals and not stains. Reflectance spectra of these materials are those expected from transition metal ions. Chemical analyses are now underway to identify the elements responsible.

The fauna of the cave are extremely sparse. Other than a few bats, no animals were seen. The pools in the cave appear to be barren of aquatic animals.

The landforms of the Wasatch Mountains provide interesting examples of alpine karst. At high altitudes on Mount Timpanogoes, rinnenkarren and pinnacle karren are forming under snow melt conditions on the Bridal Veil Falls limestone. The Deseret limestone supports a pinnacle karst with a relief of tens of feet along the canyon walls. There is some evidence that this more extreme relief karst is a relic from Pleistocene climatic conditions and that it is being destroyed by present day weathering conditions.

PROGRAM IN ECOLOGY

Terrestrial Cave Organisms

T.L. Poulson

A detailed leveling survey from River Hall to Lake Lethe in Mammoth Cave showed that the distribution of kinds and numbers of animals previously measured corresponds closely to the distance from mean high flood mark. At mean high flood mark the number of species and their evenness of distribution are maximum. Above and below this point rigor and variability of the environment decrease and predictability decreases. Above the mean high flood mark desiccation and food supply are problems, whereas below the mark, flooding is the major problem.

New studies in White Cave (entrance to dark zone gradient) and in New Discovery are providing further tests of the hypothesis that environmental rigor, stability, and predictability are important determinants of community structure.

Aquatic Cave Communities

T.L. Poulson

The aquatic ecologic data for six cave stream passages, collected over the last 10 years, is being written up for publication.

Paleolimnologic Studies of the Yucatan Peninsula

Alan P. Covich

Fossil shells are extracted from cores of sediments and compared among three lakes over several thousand years. Although there are only five or six aquatic species, their distributions of relative and absolute numbers remain stable for nearly 8,000 years at two of the lakes (X-caamal and Chichancanab) despite major lake-level fluctuations and changes in nutrient conditions. At a third lake (Peten Itza) there is an increase in the number of species following five periods of intensive deforestation by early Mayan agriculturalists. Simultaneously, Cochliopina infundibulum has markedly declined in abundance at Peten Itza which parallels a similar decline in this species some 28,000 years ago at Chichancanab. It is not clear if this change in community composition resulted from cumulative environmental changes or from interspecific competition or predation.

A eustatic sea-level rise following deglaciation in high latitude regions raised the ground-water table in the peninsula and rapidly filled the basins at X-caamal and Chichancanab. A period of deep water is followed by a second period of shallow water during the last 8,000 years. The early and late shallow-water phases are characterized by increased evaporation (determined by O^{18} analyses of shell carbonate) and by increased concentration of exchangeable calcium, organic matter, and sedimentary laminae. Absolute abundances of snails, particularly Pyrgophorus coronatus, also increase in the cores during periods of shallow water.

It is concluded that these few species of mollusks are remarkably stable in their association despite major environmental changes. It is suggested that communities generally of low species diversity and high stability can be characterized by a high degree of genetic plasticity and and polymorphism, as well as by broad physiological adaptations. They are ecologically unspecialized except for their capacity to utilize a wide variety of food resources and water conditions. Selective predation may also act to maintain community stability by regulating relative and absolute numbers of mollusks.

PROGRAM IN ARCHAEOLOGY

Salts Cave Excavation

Patty Jo Watson

The objective here was to locate intact prehistoric occupational debris, and in this we have been successful. The excavations in the Salts Cave Vestibule (Fig. 5) began as a 1.5 m x 3 m trench against the north wall (Test C) which was later expanded (Tests E, G, H, and J). Here we found at least two horizons of midden debris at depths of ca 50-60 cm and 1 m below the surface. This debris contains animal and human bone, charcoal, occasional chert flakes and projectile points, worked bone, a few ground stone objects (celts and pestles). The human skeletal fragments are being studied by two physical anthropologists (Louise Robbins, University of Kentucky, and Stephen Molnar, Washington University), and the animal bone by an environmental archeologist (Lathel Duffield, University of Kentucky). Mussel is being identified by a specialist in naiad ecology (David Stansbery, Ohio State Historical Museum, Columbus, Ohio).

Five radiocarbon determinations on charcoal from the Test E excavations have been obtained by the Gakushuin Radiocarbon Laboratory, Gakushuin University, Tokyo, Japan.

Summaries of the first and last test trenches follow.

Test C

Excavation in the Vestibule began April 8, 1969, when a 1.5 m x 3 m trench was laid out against the north wall. The trench was designated Test C (Tests A and B were two trenches dug in the cave interior in 1963). Test C was excavated in 10-15 centimeter levels to a total depth of ca 2.15 meters. Though bone and charcoal were present throughout the upper 1.5 meters, study of the section resulted in the conclusion that at least 2 layers of actual occupation debris were present: one at ca 50-60 centimeters below the surface and the other ca 1.0-1.2 meters below the surface). Below the second occupation horizon were a series of sand, clay, and rubble layers which were sterile of cultural debris as far down as ca 2.15 meters where excavation in Test C was stopped. Our tentative conclusion is that the 1.0 meter occupation horizon represents the earliest habitation in the Vestibule.

Test J

This is a 2 x 2 meter square dug April 4 to April 11, 1970, ca .5 m west of Test C. It was excavated stratigraphically to a maximum depth of ca 1.25 m. The nature of the deposition was a combination of that in the Test F pit and that in the Test C-Test E area. The first stratigraphic unit was the same as that of Tests C and E, but below that in the western half of the square the fill resembled that in Test F and excavation there ceased at a depth of about 60 cm because of an excess of breakdown rock filling that part of the square. In the damper eastern half of the square the fill and general sequence of deposition was more like that in C and E.

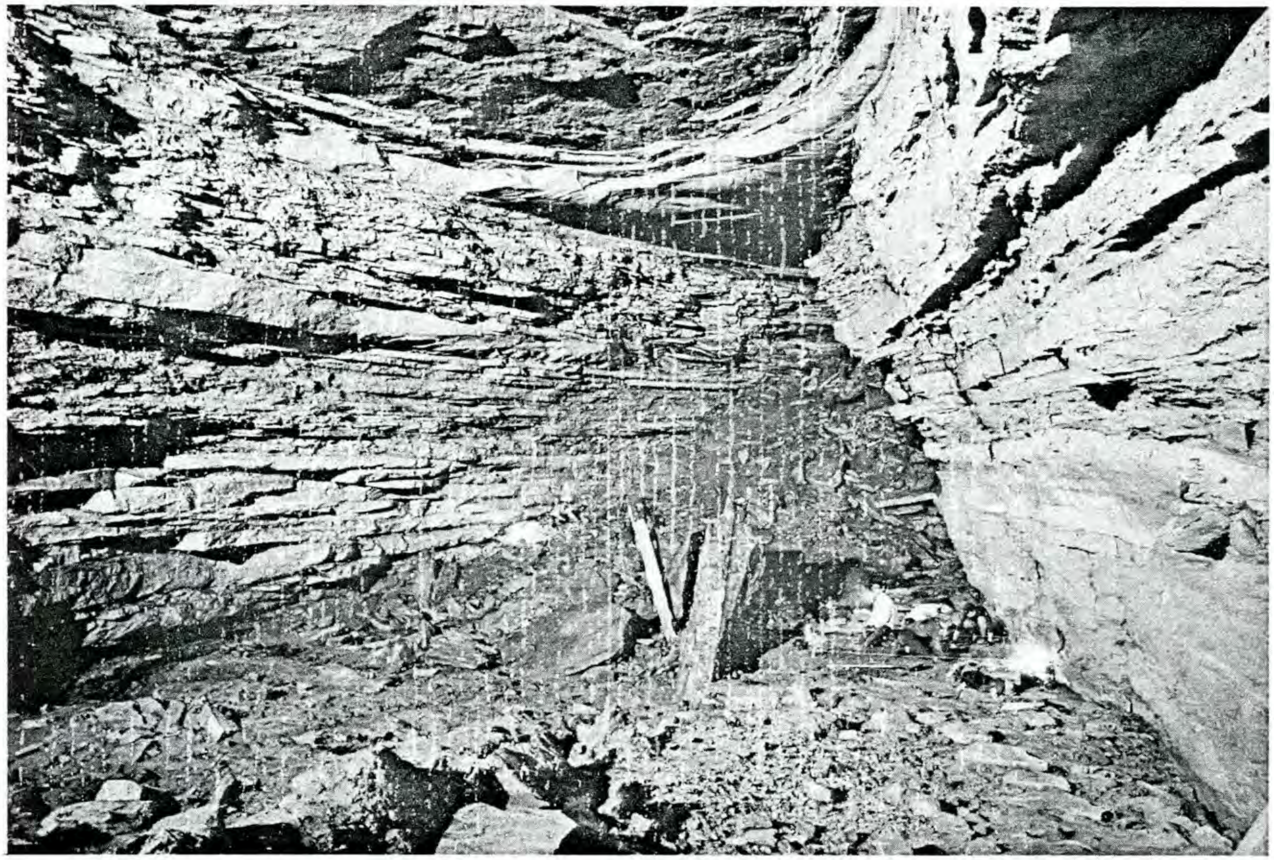


Fig. 5. Archaeological excavations in progress in the Salts Cave Vestibule. Photo by W.T. Austin.

Several artifacts (2 celts, a bell-shaped pestle, a bone needle, a few pieces of chert including a complete projectile point) and a quantity of animal bone (including fish bone and fish scales) were found in this square as well as some fragments of human bones and teeth. All of the excavated dirt below the uppermost stratigraphic unit from a 1 m x 1 m square (J IV) in the southeast corner of the square was saved, carried out of the cave, and floated in order to recover charred plant remains.

Search for Surface Habitation Sites

Patty Jo Watson

Intensive survey of the surface in the immediate vicinity of Salts Sink began on April 5, 1969, and continued until April 11, 1969. Our purpose was to determine whether there were an open-air occupation site near the Sink which might be attributed to the prehistoric people who had utilized the cave.

Four transects were laid out radiating north, south, east, and west from the Sink. Each transect was 1 meter wide and 40 to 60 meters long. The surface of the ground was laid bare in each of these strips by clearing away the leaves and sticks with rakes, hoes, and small-bladed shovels.

Only the west transect contained any chipped stone. Further examination of the surface on the west side of the Sink revealed a considerable scatter of chipped stone there, so a rough grid was laid out on the west slope and the entire area was cleared of leaves and sticks. After the initial survey which indicated the presence of chipped stone in this area, we kept all items found in separate bags for each grid unit, which we later tabulated according to these units. However, test pits (numbers IV A, B, C and V and VI) failed to locate any sign of occupation debris even in the areas of densest surface scatter. One possible explanation is that this area around the Sink was never intensively occupied but was only visited or camped on by small, transient groups of late Archaic-Early Woodland people. Another possible explanation of the situation we found (which could be combined with the first one offered) may be that recent cultivation (up to ca 1935) and consequent increased erosion of the western slope into the Sink has destroyed any archeological deposits once present.

In the southeastern and northeastern quadrants, strips 20 m long and 1 m wide were cleared every 10 m but only a few chert chips were found in these areas.

An intensive survey of both banks of the Green River (which is about 1 1/4 miles north of Salts Sink between Denison's Ferry and Three Sisters' Island (a total distance of about 1 mile) revealed only one possible site, again a surface scatter of chipped stone. We found all the low land near the river to be thickly covered with recent silts and flood sediments, hence any prehistoric sites present must be deeply buried.

Examination of the Salts Cave Mummy

Louise M. Robbins

The body of "Little Al" has been subjected to a metrical and morphological analysis to ascertain its resemblance to other prehistoric populations of the area and to age and sex the individual as precisely as possible. This technique proved to be of limited value because the body is in a fully flexed position, knees drawn toward the chest and arms bent at the elbow with hand near the mouth, with flesh missing only from the left side. Some of the bones of the left side were disarticulated and provided some information, though epiphysial fusion was lacking. Few observations could be made of the dentition because of the rigid flesh covering the face, but arrangements were made with the X-ray Department at the University of Kentucky Medical Center to X-ray the individual in the hopes of obtaining more information on dentition and age. The deciduous and permanent dentition is readily apparent in the X-rays, with the 6-year permanent molar and 7 and 8 year permanent incisors being fully occluded, but the deciduous, or milk, teeth on the occlusal plane for the canine and premolar teeth (the permanent canine appears about 11 years of age and the first premolar at ca 10 years of age). According to the dentition, the individual was over 8 but not yet 10 years of age.

Because the epidermal layer of skin was missing from the left side of the body, dissection of tissue for additional analyses was made from that side, leaving the right side of the body intact for purposes of displaying the "mummy" to the public in the future. Tissue from the abdominal and lower thoracic regions was collected for radiocarbon determinations, with care being given to the selection of a suitable quantity of uncontaminated samples. Forty grams of tissue were needed by the University of Michigan Radiocarbon Laboratory to run two tests for dating the individual, so two 20-gram samples were removed from different regions of the body. One sample (M-2258) gave a date of 1960 ± 160 B.P., and the second sample (M-2259) gave a date of 1920 ± 160 B.P. These dates are somewhat younger than the youngest of the series already available for Salts Cave, but indicate that the individual was a member of a Woodland population, rather than earlier Archaic group of people.

Analysis of Feces and Other Cave Materials

Richard A. Yarnell and Patty Jo Watson

The following analytical procedures are now underway on the Salts Cave archaeological material.

1. Isolation and identification of pollen in the human paleofeces from Salts Cave.

2. Wet analysis (using ammonium chloride) of food remains in the Salts Cave and Mammoth Cave paleofeces by botanist Robert B. Stewart, Sam Houston State University, Huntsville, Texas. This project will supplement the dry analysis performed earlier by Yarnell on 100 Salts Cave fecal specimens.

3. Isolation (by means of water flotation) and identification of charred plant material from the Vestibule excavations. A preliminary series of flotation samples from various proveniences in Salts Cave was processed during fall and winter, 1969. A much longer series was obtained from Test J during April, 1970.

4. Isolation and identification of parasites in the human paleofeces from Salts and Mammoth Caves, both those from the cave interiors and that from Little Al's lower intestine. This work is being undertaken by Miss Elizabeth Dusseau at the University of Michigan School of Public Health. So far 3 samples have been examined and no parasites found.

SOCIOLOGY, HISTORY AND ECONOMICS PROGRAMS

History of the Peoples and Caves of Flint Ridge, Kentucky

Stanley D. Sides

The purpose of this study is to understand the cultural heritage of the people who settled and lived on Flint Ridge, and the context in which they and later cave explorers interrelated with the cave environment to use the caves for recreation and economic gain. The methodology involves searches of the historic literature of the region, court records, family histories, and names recorded in the caves.

ADVISORY ACTIVITIES

WILDERNESS RESOURCES OF MAMMOTH CAVE NATIONAL PARK

J.K. Davidson and W.P. Bishop

At the invitation of the National Park Service, the Cave Research Foundation is preparing a report on the underground resources of Flint Ridge and Joppa Ridge in Mammoth Cave National Park. The study began in late 1969 and has continued through 1970. Two of the major goals of the report are to recommend uses for these areas and to organize the present knowledge about them, through cave passage classification, in a manner useful for Park management.

The primary problem in cave passage classification has been the basis for the different classification zones. What is needed is a classification scheme where the passages within each zone have sufficiently similar properties that the effects of use on one passage in a zone would be about the same as the effects of that use on another passage in the same zone. During the course of its study in 1970, the Cave Research Foundation has developed a passage classification scheme that fulfills this need.

As the study has progressed, close communication has been maintained with the Mammoth Cave National Park Master Plan Study Team. In September, 1970, Dr. William P. Bishop, a Foundation Director, met with the Team to discuss the contents of the report and the progress made on its preparation.

Also at the invitation of the National Park Service the Cave Research Foundation was represented at a closed seminar at Carlsbad Caverns National Park in March of 1970. The seminar was called by the Master Plan Study Team for Carlsbad Caverns National Park and Guadalupe Mountains National Park to assess the opinion of interested individuals and organizations concerning these parks. The Foundation presented a statement that pointed out four conclusions regarding the preservation and use of cave natural resources. The four conclusions have been reached through more than thirty years of studies in the Mammoth Cave region. Most significant of these is the realization that wilderness karst is a necessary condition for research by cave scientists. To the extent that the wilderness character of caves is preserved, cave research can proceed and we can support the enrichment of knowledge about them. A second conclusion reached is that the interaction of the various environmental processes--on the surface and underground--is a complex affair. Engineering decisions taken without due consideration of these interactions can cause irrevocable damage, and damage that is wholly unexpected. A third conclusion reached is that karst research has barely begun to unravel the mysteries of these areas. Research must be planned on a long-term basis, spanning decades, in order to assess hydrologic and biologic processes. And, fourth, Cave Research Foundation experience at Mammoth Cave National Park has shown that the discussion of wilderness--and the application of the Wilderness Act to caves--can become an exceedingly complicated matter.

INTERPRETATION AT MAMMOTH CAVE NATIONAL PARK

Training Session

T.L. Poulson

In 1970 the Cave Research Foundation operated an interpretive training session for seasonal and permanent staff at Mammoth Cave National Park. The session lasted for one day and featured classes in geology, archeology, and biology of the caves, a surface field trip to such features as the sinkhole plain, Woolsey Valley, Turnhole and Cedar Sink, and a cave field trip into Mammoth Cave.

The session was the first to operate under an Agreement on Interpretation between the NPS and CRF and it was largely financed through funds the NPS sought and obtained.

Trail Guides

T.L. Poulson

A manuscript is being prepared for an NPS booklet to be used by visitors on the self-guided tour in Mammoth Cave. It will give a background on the formation of the major caves and relate specific features in the Historic Section to the general background story. There will be some 20 interpretive stations and the booklet will use 3-color diagrams. There will be feature sections, interspersed with the main geological thread, on archeology and biology.

MANAGEMENT OF THE CAVE RESEARCH FOUNDATION

THE DIRECTORATE

At their meeting in November, Mr. John P. Freeman was elected a Director, replacing Mr. Philip M. Smith who has resigned. Mr. Freeman is a chemist at the Ohio State University. Mr. Smith was the Foundation's founding President and has served on the Directorate since the beginning.

Dr. William P. Bishop was elected Secretary of the Foundation, replacing Thomas L. Poulson, giving Dr. Poulson more time to spend with the interpretive program. Mr. Freeman has assumed the position of Personnel Officer, replacing Dr. Bishop.

PERSONNEL

During the course of the field operations in 1970, more than 400 man-days were spent in and around Mammoth Cave National Park collecting data for Foundation projects. This represents more than 4400 man-hours of work in the data collection alone.

The field operations in Mammoth Cave National Park carried out by Foundation personnel involved a total of 262 Joint Venturers, many of whom participated in the 16 field expeditions during the 1970 calendar year. Biographical data for Foundation Joint Venturers are summarized in the following tables and lists. Well represented are those with college educations (88% have or are pursuing a college degree), scientists (61%), educators (24%), and students (34%). Professionals of all kinds and students make up a large part of the Foundation personnel.

Table III

BIOGRAPHICAL DATA: CRF JOINT VENTURERS

EDUCATIONAL LEVEL:	NUMBER			% OF TOTAL		
	1968	1969	1970	1968	1969	1970
PhD level (includes MD, etc)	46	50	56	18.4	18.5	21.4
All advanced degrees	84	100	85	33.6	36.9	32.5
All college degrees	167	192	197	66.4	70.9	75.2
Have or are pursuing a degree	214	234	229	85.2	86.5	87.6
HIGHEST DEGREE:						
MD, DDS	7	9	8	2.8	3.3	3.1
PhD or equivalent	39	41	48	15.6	15.2	18.3

Table III (cont'd)

	NUMBER 1968	1969	1970	% OF TOTAL 1968	1969	1970
MA, MS or equivalent	38	50	46	15.2	18.5	17.6
BA, BS or equivalent	83	92	94	33.2	34.0	35.9
PhD candidate (some from above)	33	37	27	13.2	13.7	10.3
MA/MS candidate (some from above)	18	15	22	7.2	5.5	8.4
BA/BS candidate	47	42	32	18.8	15.5	12.2
No degree listed or in progress	38	37	36	15.2	13.7	13.8

EDUCATION FIELDS OF JOINT VENTURERS (HIGHEST DEGREE)

	1968	1969	1970		1968	1969	1970
Geology (all areas)	41	44	46	Philosophy	5	4	4
Engineering (all areas)	29	31	28	Foreign Languages	5	3	2
Biology (all areas)	24	26	25	Home Economics	2	3	3
Archeology/Anthropology	8	21	23	Literature/English	1	3	5
Chemistry	13	18	17	Sociology	3	3	3
Education (all areas)	16	11	12	Classics	2	2	2
Medicine/Dentistry	9	11	12	History		2	1
Fine Arts	4	10	8	Recreation		2	2
Economics/Business	10	9	7	Speech/Drama	1	2	2
Physics	6	7	7	Forestry	1	1	1
Psychology	2	6	4	Journalism		1	1
Mathematics	8	5	5	Library Science		1	1
Geography	3	4	4	Agriculture	3	2	2
				Industrial Arts			1

OCCUPATIONS OF JOINT VENTURERS (Categories somewhat arbitrary)

		1968	1969	1970
STUDENTS	Graduate	48	51	49
	Undergraduate	51	43	33
	High School	9	8	7
TEACHERS	College Professors	29	38	41
	Public School	9	14	12
SCIENTISTS	Administration			2
	Research (Senior staff, consultants, etc.)	28	22	22
	Engineer	8	13	13
	Technician	6	8	10
BUSINESS	Executive (Supervisory, purchasing, etc.)	5	6	4
	Businessman (Sales, small business, farmer, etc)	16	14	11
	Accounting/Economics			2
MEDICAL	Physicians and Surgeons	7	8	7
	Dentists			1
	Nurses			1
SERVICES	Library (Executive, etc.)	1	1	2
	Journalism/Writing			2
	Social Work, YMCA, etc.	2	2	3
	Art/Drafting			6
ARMED SERVICES/PEACE CORPS		11	16	11
OTHER		18	22	26

PUBLICATIONS IN 1970

JOURNAL ARTICLES

Contributed Papers

19. Patty Jo Watson. THE PREHISTORY OF SALTS CAVE, KENTUCKY. Illinois State Museum Rpt. Investigations No. 16, 86 pp. (1969).

20. J.F. Quinlan. CENTRAL KENTUCKY KARST. Etudes et travaux de "Mediterranee" No. 7, 235-251 (1970).

21. Elizabeth L. White and William B. White. DYNAMICS OF SEDIMENT TRANSPORT IN LIMESTONE CAVES. Bull. Natl. Speleol. Soc. 30, 115-129 (1968).

22. William B. White, Richard A. Watson, E.R. Pohl, and Roger Brucker. THE CENTRAL KENTUCKY KARST. Geograph. Rev. 60, 88-115 (1970).

23. P.M. Smith and R.A. Watson. THE DEVELOPMENT OF THE CAVE RESEARCH FOUNDATION. Studies in Speleol. 2, 81-92 (1970).

Supported Papers

12. Thomas C. Jegla and Thomas L. Poulson. CIRCANNIAN RHYTHMS--I. REPRODUCTION IN THE CAVE CRAYFISH, ORCONECTES PELLUCIDUS INERMIS. Comp. Biochem. Physiol. 33, 347-355 (1970).

13. David C. Culver. ANALYSIS OF SIMPLE CAVE COMMUNITIES I. CAVES AS ISLANDS. Evolution 24, 463-474 (1970).

14. John R. Holsinger and David C. Culver. MORPHOLOGICAL VARIATION IN GAMMARUS MINUS SAY (AMPHIPODA, GAMMARIDAE) WITH EMPHASES ON SUBTERRANEAN FORMS. Postilla, No. 146, 24 pp. (1970).

15. David C. Culver and John R. Holsinger. PRELIMINARY OBSERVATIONS ON SEX RATIOS IN THE SUBTERRANEAN AMPHIPOD GENUS STYGONECTES (GAMMARIDAE). Amer. Midland Nat. 82, 631-633 (1969).

PAPERS AT PROFESSIONAL MEETINGS

Canadian Association of Geographers (St. Catherines, Ontario, January)

Thomas E. Wolfe, "Sediments along the Allegheny Front"

Central Appalachian Carbonate Workshop (University Park, Pa., May)

Thomas E. Wolfe, "Cave Sediments and Sedimentary Environments along the Allegheny Front"

National Speleological Society (University Park, Pa., August)

Arthur N. Palmer, "Origin of Maze Caves"

Thomas E. Wolfe, "An Attempt to Classify Cave Sediment Environment Provenance Types"

TALKS, SEMINARS, AND SYMPOSIA

Thomas L. Poulson:

"Caves the Hidden Frontier" National Parks Association Lecture at Smithsonian, Washington.

"Models for Evolution of Species Diversity: Caves" Seminar at University of North Carolina, University of Kentucky, University of Notre Dame, University of Connecticut, Pennsylvania State University, Indiana University, and Northwestern University.

William B. White:

"Hydrogeology of Carbonate Terrains" Department of Geology, University of Pennsylvania.

"Recent Research in the Central Kentucky Karst" Philadelphia Chapter, National Speleological Society.

ABSTRACTS OF PAPERS PUBLISHED IN 1970

Preliminary Observations on Sex Ratios in the Subterranean Amphipod Genus Stygonectes (Gammaridae)

ABSTRACT: *Samples of populations of different species of* Stygonectes *made from a variety of habitats indicate a differential sex ratio favoring females. The predominance of females in cavernicolous species of the genus is much greater than in non-cavernicolous species, and the possibility of parthenogenesis in cave populations is considered.*

MORPHOLOGICAL VARIATION IN GAMMARUS MINUS SAY (AMPHIPODA, GAMMARIDAE), WITH EMPHASIS ON SUBTERRANEAN FORMS

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(Received November 26, 1969)

ABSTRACT

Gammarus minus Say is a common amphipod species in springs and caves of limestone areas of the eastern and middle-eastern United States. Samples of populations from the central Appalachians were examined closely and morphological variation between spring and cave populations was analyzed. This species occurs in three morphological forms: a spring form, an intermediate cave form and an extreme cave form. The latter form was termed variety *tenuipes* by some earlier workers but has no nomenclatural validity. In contrast to the spring form, the cave forms show a reduction in eye structure, a change in pigmentation of the integument and a proportionate increase in the length of some of the appendages. It is concluded that *G. minus* is an extremely vagile and highly variable species that can occupy a variety of habitats, ranging from surface springs to small or large cave systems in certain karst areas.

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ANALYSIS OF SIMPLE CAVE COMMUNITIES
I. CAVES AS ISLANDS

DAVID C. CULVER

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SUMMARY

The occurrences of *Gammarus minus, Stygonectes spinatus, Stygonectes emarginatus,* and *Asellus holsingeri* in 28 caves in the Greenbrier Valley of West Virginia were recorded. Those caves that are susceptible to spring flooding tend to have fewer species than those that are more isolated from the epigean environment. Spring flooding reflects a rigorous, unstable environment, but a predictable one. Stochastic processes are important in controlling the number of species present in caves, but caves are more than collecting basins for animals that get washed in via subsurface water. Spring flooding reduces the amount of interaction and my data are consistent with Simberloff's (1969) non-interactive equilibrium model of island biogeography, but species interactions may also play a role. The caves studied differ from islands primarily in their lack of area effect and in the nature of the food input.

The various explanations of diversity are discussed. Interactions with biological, energetic, and physical aspects of the environment take place against a background of time and stochastic processes.

Dynamics of Sediment Transport In Limestone Caves

By Elizabeth L. White* and William B. White**

ABSTRACT

Groundwater moving through maturely karsted limestone aquifers may carry, in addition to a dissolved load extracted from solution of the wall rock, clastic material as suspended load or as bedload. All of the insoluble residues from the solution of the limestone and in some cases, large quantities of material from overlying or adjacent clastic rocks must be transported out of closed drainage basins by the action of cave streams. Portions of the transported material are deposited en route to form the richly varied clastic cave sediments. Application of standard engineering formulae for sediment transport indicate that flows with a threshold velocity on the order of tenths of a foot per second are necessary to transport the coarse sediments. Suspended load is important in the transport of fine sediments but requires flows at least in the turbulent regime. A tentative conclusion is drawn that clastic load transport by fast-moving water is an integral part of the development of many karst drainage nets and that extensive development of integrated drainage nets by percolating waters is unlikely.

THE DEVELOPMENT OF THE CAVE RESEARCH FOUNDATION

P. M. SMITH and R. A. WATSON

Past Presidents of the Cave Research Foundation

SUMMARY

The Cave Research Foundation was established in the U.S.A. in 1957 to support exploration and research in caves, to assist in the interpretation of cave and karst features to the public and to aid conservation in caves. Initially work was restricted to the Central Kentucky Karst. An outline of the history of the exploration of caves in the Mammoth Cave area of Kentucky from pre-Columbian times to the present-day is followed by a description of the organisation of the C.R.F. and of exploratory, cartographic and scientific work carried out by this body.

Comp. Biochem. Physiol., 1970, *Vol.* 33, *pp.* 347 *to* 355. *Pergamon Press. Printed in Great Britain*

CIRCANNIAN RHYTHMS—I. REPRODUCTION IN THE CAVE CRAYFISH, *ORCONECTES PELLUCIDUS INERMIS**

THOMAS C. JEGLA and THOMAS L. POULSON

Departments of Biology, Yale University, New Haven, Conn., and Kenyon College, Gambier, Ohio

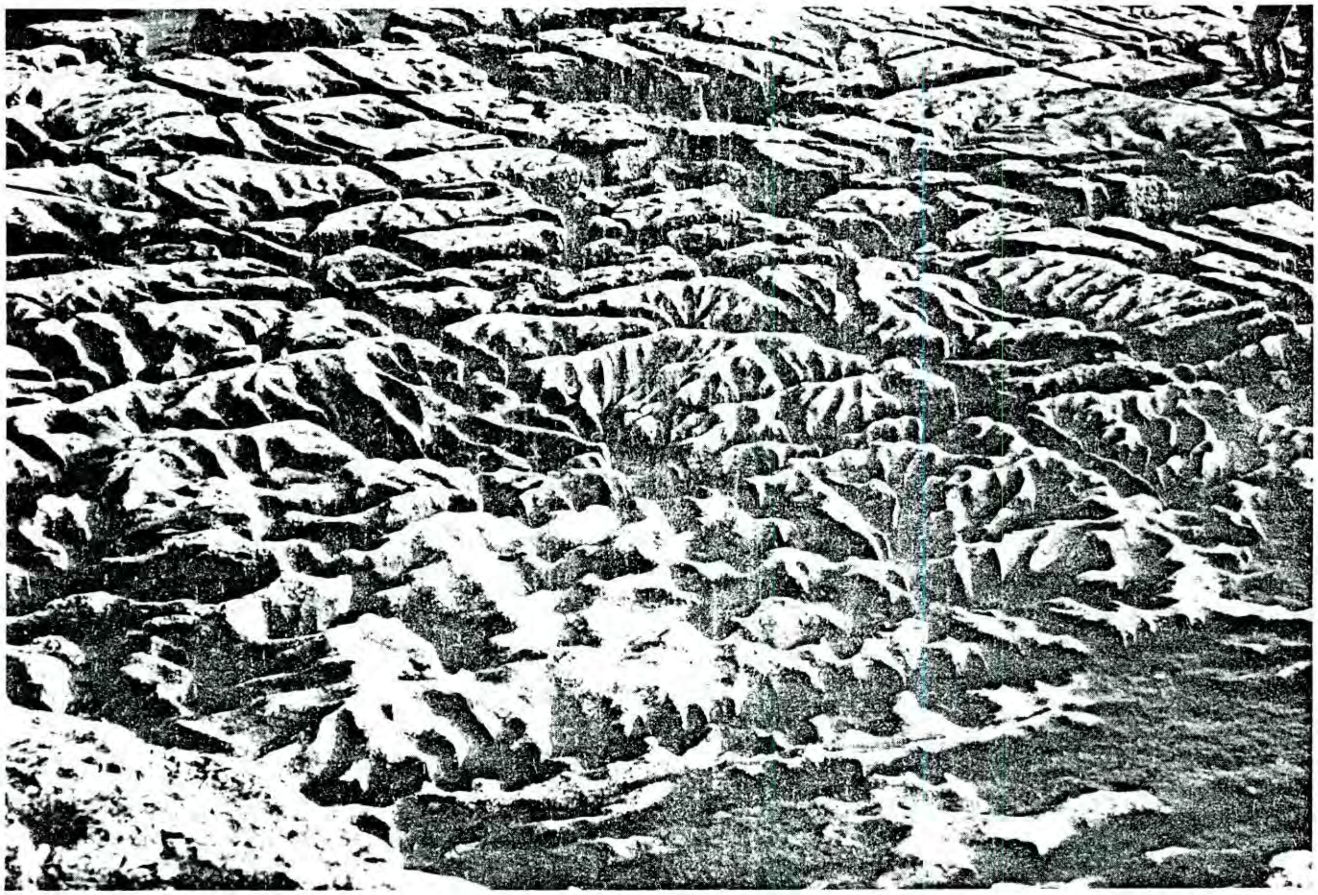
(*Received* 25 *July* 1969)

Abstract—1. The cave crayfish, *Orconectes pellucidus inermis*, has a circannian rhythm since (a) under constant laboratory conditions the twelve animals that lived more than a year continued to show cycles of molt and reproduction and (b) the periodicity of the cycles ranged from 338 to 396 days and so the individuals drifted out of phase with each other and the calendar year.

2. Field evidence suggests that some event associated with heavy run-off from surface precipitation triggers egg-laying and synchronizes the individuals' circannian rhythms in the cave.

CAVE RESEARCH FOUNDATION

Thirteenth Annual Report



December 1971

Cave Research Foundation
206 W. 18th Avenue
Columbus, Ohio 43210

Cover Photo: Limestone Pavement at Head of Malham Cove, Yorkshire, England

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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 Timpanogos Cave National Monument have contributed greatly to the success of these projects and is gratefully acknowledged.

The archeological research in Salts Cave has been supported by a grant from the National Geographic Society. This support is gratefully acknowledged.

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HIGHLIGHTS OF 1971

Wilderness Resources in Mammoth Cave National Park was published in early 1971. This three-year study conducted at the request of the National Park Service presents a summary and critique for the unique natural resources of the Park. It provides guidelines for the classification of cave passages for various uses and makes a strong plea for a broad based management that takes account of the interfaces between cave and surface, and between the Park as a whole and the Region in which it is implanted.

A distinguished German scientist, Dr. Franz-Dieter Miotke from the University of Hannover, has taken up residence at the Flint Ridge Field Station for a year-long study of the geomorphology of the Central Kentucky Karst and the climatic, chemical, and lithologic factors that influence karst development.

The 1971 Cave Research Foundation Fellowship was awarded to Mr. Horton H. Hobbs III of the Department of Biology, Indiana University to support his thesis research on crayfishes and their epizootic ostracods in Pless Cave, Indiana.

The hydrologic study of the Central Kentucky Karst has been funded by the Office of Water Resources Research through the Pennsylvania State University's Water Resources Center. This external funding will permit the construction and installation of automatic recording stations for flow, temperature and electrical conductivity in two of the big springs.

The Cave Research Foundation was represented at the International Symposium on Karst Denudation (sponsored by the International Speleological Union) held at Oxford, England in early September. The symposium consisted of two days of formal papers followed by an eight day field trip through the classic karst areas of England and Ireland.

1971 set a new record for the cartographic program with 19.22 miles of cave mapped in Mammoth Cave National Park.

THE SCIENTIFIC PROGRAMS

THE CARTOGRAPHIC PROGRAM

J. P. Wilcox, W.&P. Crowther, T.E. Cottrell

The cartographic program reached an unprecedented level of activity this year. During the thirteen-month period from October 1, 1970 to November 1, 1971, CRF teams surveyed 19.22 miles of cave in Mammoth Cave National Park. Though some of this mileage was in areas of Mammoth Cave that had been partially surveyed by earlier explorers, 96 percent of it was previously unsurveyed by the Foundation.

Major breakthroughs in Lee Cave and in the New Discovery portion of Mammoth Cave opened up areas of the ridges where cave was not previously known. The survey project in Old Mammoth continued at a high rate of effort. A substantial amount of new passage was found there, and numerous virgin side leads remain unexplored. Though these activities diverted some manpower from the Flint Ridge Cave System, it continued to grow at about its usual rate, primarily by the addition of side passages that had been by-passed by early surveys in the older portions of the cave.

Flint Ridge: There were several areas of concentrated activity in the Flint Ridge System. The passage through which water enters the top of Jones Shaft was reached by chimneying in an adjacent dome. It was followed upstream to the northwest and yielded 3500 feet of new cave at a level higher than other passages in the area. The Geology and Interpretation program in Old Crystal brought attention to several leads, one of them yielding access to the lowest levels ever reached in Crystal Cave. Exploration is continuing here. Examination of the Overlook area has disclosed several unsurveyed side passages and undescended pits, with potential remaining for future work. In Colossal, an upper level canyon paralleling Deike Trail yielded significant new survey. An upper level connection with Austin Avenue to the west of Jones Shaft was discovered, providing an easier route from the Colossal Entrance than the Salts-Colossal Link. In Pohl Avenue, Cow Falls was ascended. The passage at the top is not related to previously known cave, and is still under exploration.

The current length of the world's longest surveyed cave is 85.49 miles. Great Onyx Cave contains an additional 2.70 miles of survey.

Dickey Pit is a separate cave in the northwest portion of Flint Ridge. When it was first visited in 1964, the entrance appeared to have recently formed by the partial collapse of the ceiling of a very large pit, and the bottom of the pit was largely choked with mud. Subsequent flushing has opened up a walking passage to the south and a crawl to the north from the bottom of the pit. Four-tenths of a mile has been surveyed, with access to several deeper pits and a multi-level canyon. There is potential for continuing to the southeast.

Mammoth Cave Ridge: In Old Mammoth, the Stevenson Avenue survey has been extended through Opossum Avenue to Belfry Avenue and beyond to a connection with Kentucky Avenue. The entire Belfry Avenue area shows little evidence of previous visitation, and some of the survey is in virgin cave. About 1.5 miles of passage not shown on earlier maps has been surveyed, and another mile has been explored but not yet surveyed. Much potential for exploration remains. Rogers Avenue, Miller Avenue, and parts of Nicholson Avenue have also been surveyed.

In New Discovery, CRF surveys have been extended to include most of the previously-known cave, though numerous unexplored side passages remain. The breakdown at the west end of Big Avenue was penetrated, opening up a new segment of trunk passage extending southward for 1300 feet. Its cross sections, up to 124 feet wide and with a vertical development of 120 feet, are the most impressive in New Discovery. There are several side passages and an access to a base level river passage that is a major drain for Deer Park Hollow. This section of the cave, which shows no evidence of previous visitation, has yielded over 1.5 miles of survey. Exploration is still active.

CRF survey in Mammoth Cave now totals 19.2 miles. Of this, 10.1 miles were surveyed in the past year and 4.4 miles are in previously unsurveyed cave. The total surveyed length of Mammoth Cave, including earlier surveys by Kaemper, Walker, and others as compiled by J. F. Quinlan in 1969, is approximately 49 miles.

Joppa Ridge: In the fall of 1970, a surface reconnaissance party explored a crawl at the bottom of a small pit near the floor of Carpenter Hollow and gained access to a much deeper pit with a passage off the bottom. More than three miles have since been surveyed through this entrance in a completely virgin area of Joppa Ridge. The main passage is a 30-foot-high canyon that once carried water northward from under Smith Valley. Several smaller canyons contain active rivers. A surveyed connection was recently established with Lee Cave, and the new cave is now considered to be a part of Lee. Lee Cave has thus more than doubled in length during the past year. It contains 7.44 miles of survey as of November 1, and is the fourth longest surveyed cave in Kentucky.

In Proctor Cave, the Mystic River Pit was descended. The bottom is 80 feet below the known cave in that part of Joppa Ridge. A passage there has not yet been fully explored.

Cooperative Study: An aerial photography project with the objective of accurately locating the cave entrances in plan and elevation is being conducted in cooperation with the Department of Geodetic Science of the Ohio State University. A final photography run was made in January, and the data is in process of reduction.

HYDROLOGY PROGRAM

Hydrology of the Central Kentucky Karst

J.W. Hess, Jr. and W.B. White

The present problem is concerned with spring hydrograph analysis in order to investigate the flow system of the Central Kentucky Karst. During the year, a rain gage network was set up, monitoring equipment was designed, water chemistry measurements were made, and Owl Cave was dived. Other work included a temperature survey of the north side of the Green River to look for springs, and surface studies of the drainage patterns of the hollows along the Green River.

The rain gage network uses private observers who daily read a wedge precipitation gage and record the data on postcards which are then mailed at the end of each month. The present network consists of 30 gages spread out over the plateau and Sinkhole Plain with an average density of 1 gage per 6 sq. miles. An average of 86% of the observers have turned in their cards each month.

Pike Spring and Owl Cave will be monitored for discharge, temperature, and specific conductance continuously using strip recorders. All of the instrumentation has been designed and is 75% built. It still needs to be tested and calibrated before installation in the springs.

Owl Cave was dived in July to locate a point to install the monitoring equipment. Figure 1 is a sketch of what the divers found and the location of the possible gaging point in the upstream portion of the underwater passage. The main flow downstream appears to be in a passage 30 feet below the water level which would correspond with the depth of the Turnhole rise pool.

The temperature survey of the north side of the Green River revealed 26 cold spots which ranged in flow from no visible flow to 5 cfs. The pattern is like that of the south side; a few large flows and many small seeps and cold spots. The upstream end of the underground meander cutoff on Mansfield Bend was located. Water sinks into a series of holes along a 50-foot length of the river.

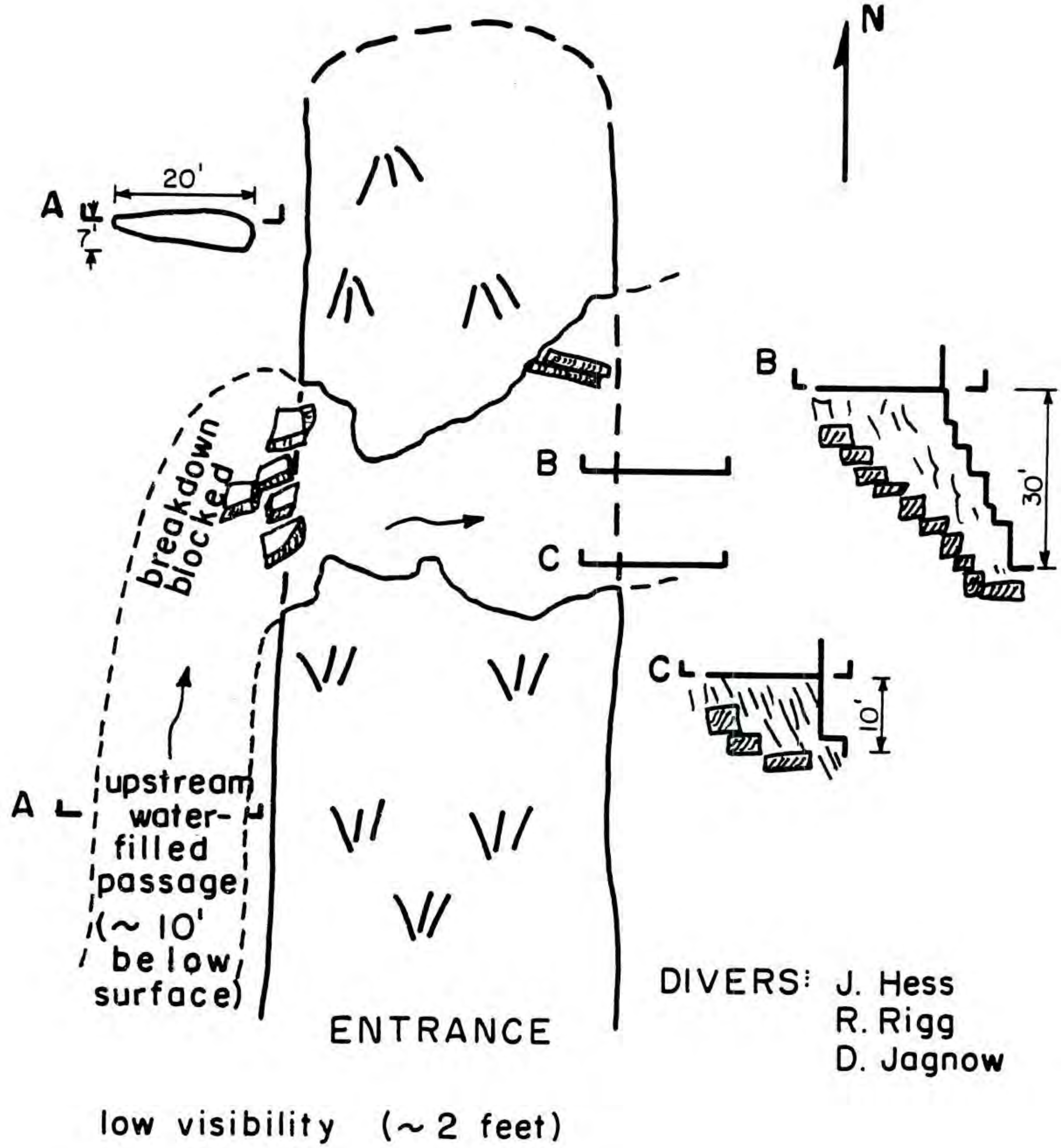


Fig. 1 Sketch map of Owl Cave made during July, 1971 Diving operation.

The hollows along both sides of the Green River were studied and they each have their own local drainage network containing both surface and subsurface components. These small systems may or may not connect with the main drainage coming in from the Sinkhole Plain. Water sinks at the limestone - sandstone contact and reappears as a small spring along the Green River. At the same time a surface channel may exist the whole way to the river and in times of high water, both flow paths will be used.

Denudation Processes in Carbonate Terrains of North America

R.S. Harmon, J.W. Hess, E.T. Shuster,
R. Jacobson, C. Haygood and W.B. White

Chemical analyses have been performed on a wide variety of carbonate waters in North America from Pennsylvania to Mexico. These have been combined with available data from the literature that was judged sufficiently precise (field measurement of pH and field titration of HCO_3^-) to produce a set of 230 measurements. The data were processed by the Jacobson computer program (see Fig. 2) to produce saturation indexes and theoretical carbon dioxide partial pressures.

Waters have been catalogued and fitted to an evolutionary scheme for karst waters within a complex drainage basin. It is shown that there is a great variation between waters of the different types. Grand averages are given in Table I.

TABLE I

	Ca^{++} (PPM)	LOG P_{CO_2}	SATURATION INDEX	NO. ANALYSES
Rain Waters	1	-2.14	-5.63	58
Surface Water (Pre-karst)	6	-2.15	-3.44	4
Soil Waters	15	-0.98	-2.59	11
Vertical Shaft Water	29	-2.67	-0.78	39
Cave Streams and Pools	45	-2.34	-0.59	19
Dripstone Waters	54	-2.36	+0.23	28
Well Waters	82	-1.97	-0.01	37
Spring Waters	60	-2.16	-0.49	54
Surface Streams (Post-karst)	76	-2.41	-0.07	7

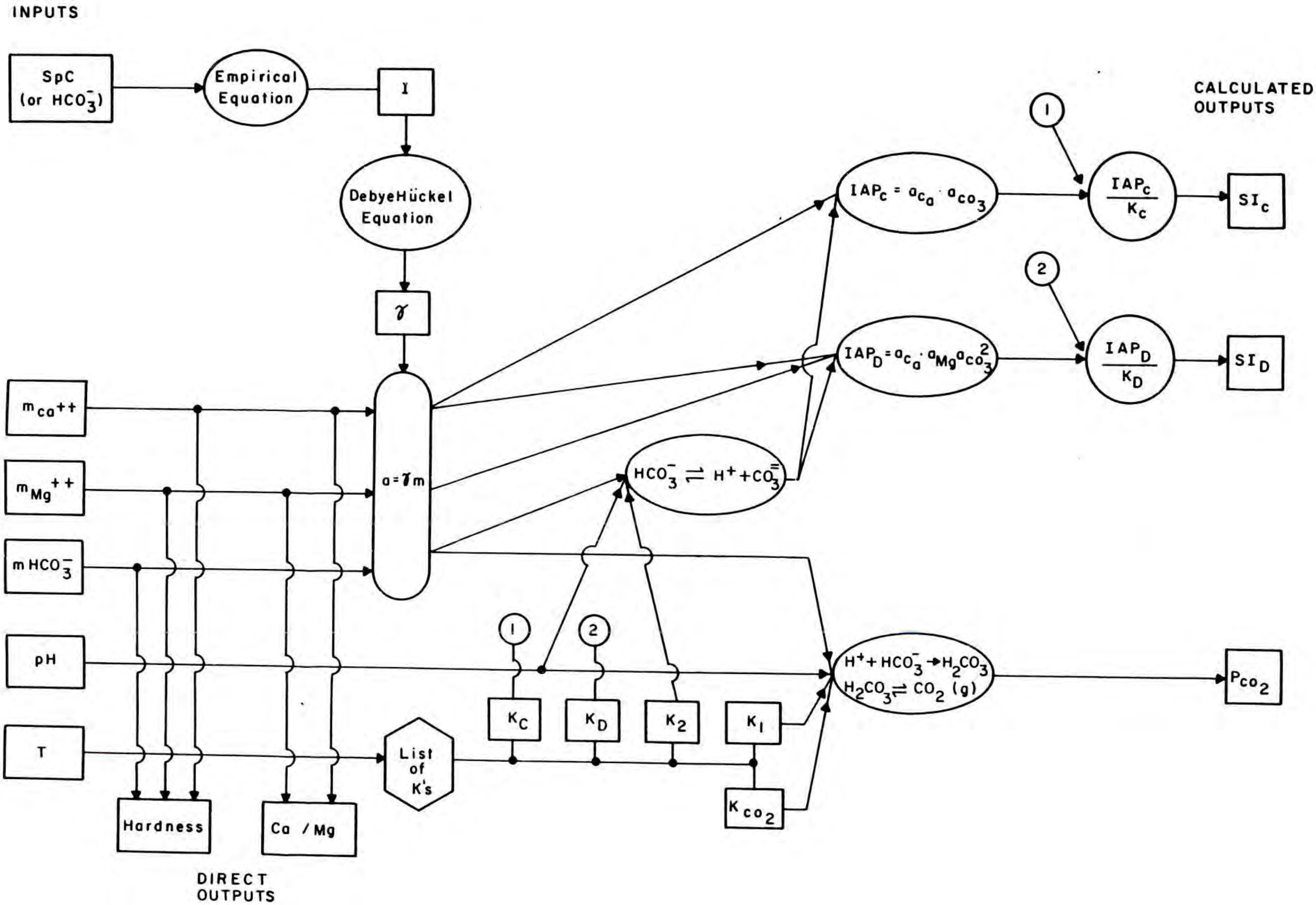


Fig. 2 Schematic drawing showing processing of chemical data for carbonate waters.

The water samples are clustered within relatively small areas in Pennsylvania, Virginia, West Virginia, Kentucky, Alabama, Texas, Florida, and Mexico. Averages taken within major water types allow a comparison of the effect of climate based on dissolved carbonates and carbon dioxide pressure. There is a linear increase in the grand averages with decreasing latitude from Pennsylvania to Mexico illustrating a distinct climatic influence.

The results also reinforce the hypothesis that most karst aquifers contain two chemically distinct kinds of water. The shallow, fast-through-put time waters are observed in cave streams and shafts and are usually highly undersaturated. The saturation index (= log ion activity product/calcite solubility product) is negative. The deeper, diffuse flow waters are seen as the drip waters of caves and are sampled in wells and have saturation indexes near unity. Karst springs are a mixture of both, and a careful chemical balance may lead to a calculation of the ratio of the surface to underground denudation rates.

The Groundwater Geochemistry of the Central Kentucky Karst

Russell S. Harmon, John W. Hess and William B. White

The objectives of this study are to determine the detailed areal and temporal variations in the water chemistry of the Central Kentucky Karst region.

Work during the fall of 1970 was directed toward determining the chemical character of waters within the present active interior drainage of the Flint Ridge Cave System. Vertical shaft and shaft drain waters were found to be very undersaturated with respect to calcite with one exception, where travertine was actively being deposited.

During the spring and summer of 1971 attention was shifted to the numerous springs discharging along the course of the Green River. These waters were found to contain more dissolved solids than the less saturated and more aggressive vertical shaft waters.

Most of the vertical shaft and spring sites were resampled during the latter half of 1971. In addition, some springs in the perched Haney limestone aquifer were sampled as these springs are important input sources to the vertical shafts.

Data on the carbon dioxide concentration of the soil and cave atmosphere by Dr. Franz-Dieter Miotke indicate that the partial pressure of CO_2 in the soil is about an order of magnitude higher than that in vertical shaft and spring waters, which in turn are about an order of magnitude higher than the CO_2 in the cave atmosphere.

Typical data of waters sampled to date are shown in Table II.

TABLE II

SAMPLE SITE	DATE	TEMP °C	Ca^{2+} ppm	HCO_3^- ppm	LOG SC	LOG P_{CO_2} atm
Colossal Dome (top)	27/11/70	13.0	35	117	-0.475	-2.515
Colossal Dome (bottom)	27/11/70	13.0	44	119	-0.281	-2.611
Cascade Pit (bottom)	27/11/70	13.0	74	205	0.131	-2.361
Keller Shaft (bottom)	28/11/70	12.0	48	89	-0.638	-2.481
Echo River Spring	26/11/70	10.8	41	134	-0.736	-2.143
Turn Hole Spring	23/3/71	12.0	43	128	-0.749	-2.115
Echo River Spring	23/3/71	12.0	34	99	-0.596	-2.573
Pike Spring	5/7/71	12.0	40	120	-0.154	-2.79
Styx Spring	5/7/71	12.0	33	110	-0.517	-2.58
Owl Cave	5/7/71	10.0	64	210	-0.100	-2.25
Collins Spring	26/6/71	12.0	22	97	-0.487	-2.88
Echo Spring	5/7/71	12.0	44	143	-0.248	-2.52
Cooper Spring	26/6/71	12.0	24	82	-0.919	-2.55
Sinking Creek	11/7/71	25.5	30	111	-0.335	-2.54
Little Sinking Creek	11/7/71	25.5	42	166	-0.1317	-2.286

Vertical Shaft Research

Roger W. Brucker, John W. Hess and William B. White

Water chemistry and flow dynamics were measured for a number of vertical shafts in northern Alabama. These data combined with shaft data from South Central Kentucky and West Virginia provide a reasonable explanation for the evolution of the shaft. The main transport of water down the shaft is through a thin (0.5 to 2 mm) film of very rapidly moving (15 to 150 cm/sec) water. The flow regime of these waters plots in the region of supercritical laminar flow bordering on the transition to supercritical turbulent flow. Shafts are highly undersaturated at both top and bottom. Waters in shaft drains are also undersaturated and it is unclear why their volume should be so small compared with the volume of the shaft they drain.

PROGRAM IN SEDIMENTATION AND MINERALOGY

Clastic Sediments in West Virginia Caves

Thomas E. Wolfe

Field work on the caves of the Greenbrier limestone in East Central West Virginia is now completed. Analysis of these materials has necessitated revising and extending the commonly used classifications for cave sediments. The proposed revision is given here.

There is no generally accepted classification of cave sediments. Various authors have grouped cave sediments within their personal interests of study. Kukla and Lozek (1958) classified cave sediments on the basis of source of material found in the caves. They used the terms "autochthonous" (derived from within the cave) and "allochthonous" (derived from outside the cave). They also divided the cave sediments into "entrance facies" and "interior facies." White (1963) proposed "clastic" (including autochthonous and allochthonous fills) and "chemical" deposits. Frank (1965) refers to "tardigenic" (slowly deposited by infilling through small cracks) and "torrigenic" (rapidly deposited through larger openings). Link (1966, 1967) proposed a textural classification using a three end-member triangle of clay, silt and sand.

In the broadest sense, all material found in caves other than the host rock in situ can be considered to be "cave sediment." In this study of fluvial sediments, process rather than source, texture or position of the deposits is the basis of their classification. The following classification utilizes the terminology of previous investigators with an emphasis on geomorphic processes responsible for deposition in the caves.

A Classification of Cave Sediments

I. Clastics

   A. Gravitational Fills: Products of weathering and gravitational transfer (without a transporting agent).

      1. Infiltrates: Material derived from outside the cave. This includes entrance detritus, soil, sinkhole fills, material which enters the cave via vertical shafts, joints or faults which does not show evidence of transport (see erosional fills).

      2. Breakdown: Material derived from within the cave. This includes fine weathering detritus, large blocks and whole sections of ceiling collapse. ("Autochthonous" fills of Kukla and Lozek, 1958).

   B. Transported Fills: Products of erosion which show evidence of transport by water, wind or ice.

1. Fluvial sediment: Material which shows evidence of stream transport. This includes all material derived from within or outside the cave which shows rounding, graded bedding. a systematic vertical variation in grain size, or any particle or structural features characteristic of fluvial transport.

2. Glacial sediment
3. Aeolian sediment
4. Marine sediment
5. Lacustrine sediment

} These are rarely found in most humid temperate, well drained inland karst regions. They are also difficult to identify where other processes have altered them.

II. Chemical Deposits (After White, 1964)

A. Carbonates

B. Evaporites

C. Manganese and Iron hydrates

D. Ice

E. Phosphates

III. Organic Deposits (not showing evidence of transport)

A. Floral remains

B. Faunal remains

IV. Archeological Deposits

A. Evidence of human presence or activity

Cave Sediments in the Near East

Paul Goldberg

The field work on the sediments of certain Israeli caves is complete as is most of the laboratory work on the specimens. Tentative conclusions drawn for et-Tabun Cave are:

1. Most of the cave debris was blown in from the adjacent coastal plain during a climatically dry period.

2. There was a period of extensive chemical alteration of the sediments which took place during a more moist climatic episode. This is manifested by

   a. The dissolution of unstable heavy minerals (epidote and hornblende) and the concentration of residual ones (rutile, zircon and tourmaline).

   b. The dissolution of detrital $CaCO_3$ in the sediments.

   c. The precipitation of hydroxyapatite and montgomeryite (CaAl phosphate).

Sulfate Minerals in the Central Kentucky Karst

W.B. White

An additional 16 specimens of the loose sulfate mineral crusts were collected from Lee Cave in November. X-ray diffraction analysis shows that the principal phases present are epsomite and an unknown. Presence of thenardite peaks in some patterns and the collection of moisture in the sample bottles indicate that some mirabilite is also present although not in major amounts. Hexahydrite peaks appear in the patterns of some of the hair-like crystals and the absence of moisture in the bottles indicates that it also may occur in the cave and not only as a decomposition product of epsomite. The principal unknown phase in the Lee Cave material has been identified as bloedite, $MgSO_4 \cdot Na_2SO_4 \cdot 4H_2O$. The two-year mystery over the origin of the unknown phase occurred because of an incorrect reference X-ray pattern in the literature. New data published in 1970 agree well with the data from the Lee Cave unknown. There may be still another unknown in the Lee Cave salts. The investigation is continuing.

Repeated visits to New Discovery at all seasons of the year reveal that a sulfate deposit grows in the trail and on breakdown blocks about half-way along Fossil Avenue during the winter and spring and then disappears during the summer. This is an unexpected behavior for a cave that is infrequently visited. The crystals are epsomite and their disappearance may be related to their decomposition to hexahydrite which would cause the crystals to crumble.

Through the observations of D. Jagnow and C. Hill, celestite has been discovered in the gypsum crystals in the historical part of crystal cave.

The sulfate minerals that have now been identified in the various caves of the Central Kentucky Karst are:

Gypsum	$CaSO_4 \cdot 2H_2O$
Mirabilite	$Na_2SO_4 \cdot 10H_2O$
Epsomite	$MgSO_4 \cdot 7H_2O$
Hexahydrite (?)	$MgSO_4 \cdot 6H_2O$
Bloedite	$MgSO_4 \cdot Na_2SO_4 \cdot 4H_2O$
"labile salt"	$2Na_2SO_4 \cdot CaSO_4 \cdot 2H_2O$
Celestite	$SrSO_4$

Carbonate Minerals from Timpanogos Cave

William B. White

In the process of completing the reconnaissance geology study of Timpanogos Cave and the surrounding karst area, a rather detailed study of the carbonate minerals of the cave has been undertaken. The carbonate minerals include calcite, aragonite, and hydromagnesite. Some of the flowstone, however, is colored. Many massive flowstone streamers on the walls are a canary yellow and the irregular wall coating near the Great Heart of Timpanogos is pale green.

Diffuse reflectance spectra measured directly from chips of the flowstone show the characteristic absorption bands of the divalent nickel ion (Fig. 3). This is confirmed by a chemical analysis which shows 200 to 600 ppm nickel in the bulk specimens. The position of the absorption bands in the spectrum of the yellow calcite agrees with theoretical expectations for Ni^{++} in $CaCO_3$. The green deposits are mainly aragonite and the spectrum although correct for Ni^{++} is not that expected for Ni^{++} substituting for calcium in the aragonite structure.

To resolve this anomaly, electron probe analyses were made of the green aragonites. These show isolated blebes of some second phase in the aragonite. The probe analysis indicates that these blebes are a magnesium silicate and that the nickel is located (substituting for magnesium) at concentrations of 1 to 2% in the silicate. Thus the pale green color arises from small amounts of a very finely dispersed green mineral in the more or less colorless aragonite matrix.

PROGRAM IN GEOMORPHOLOGY

Karst Development in South Central Kentucky

Franz-Dieter Miotke

A new and very broad scale investigation of the Central Kentucky Karst was launched in October. It has among its goals the following:

1. Description and mapping of karst landforms.

2. Relation of surface forms--particularly river terraces--with the main levels of cave development.

3. The measurement of the distribution of CO_2 in the soils and other surface environments and the influence of this distribution on karst development.

4. The analysis of underground waters and of CO_2 in the cave atmospheres.

5. The use of all data to interpret the historical evolution of the Central Kentucky Karst through geologic time.

One of the first results was the measurement of a carbon dioxide profile between the Austin Entrance and Upper Turner Avenue. The results are surprising, in that the pressures are much lower than those few measurements previously made in caves. The low pressures probably reflect the influence of the caprock which inhibits the CO_2 pumping from overlying soils.

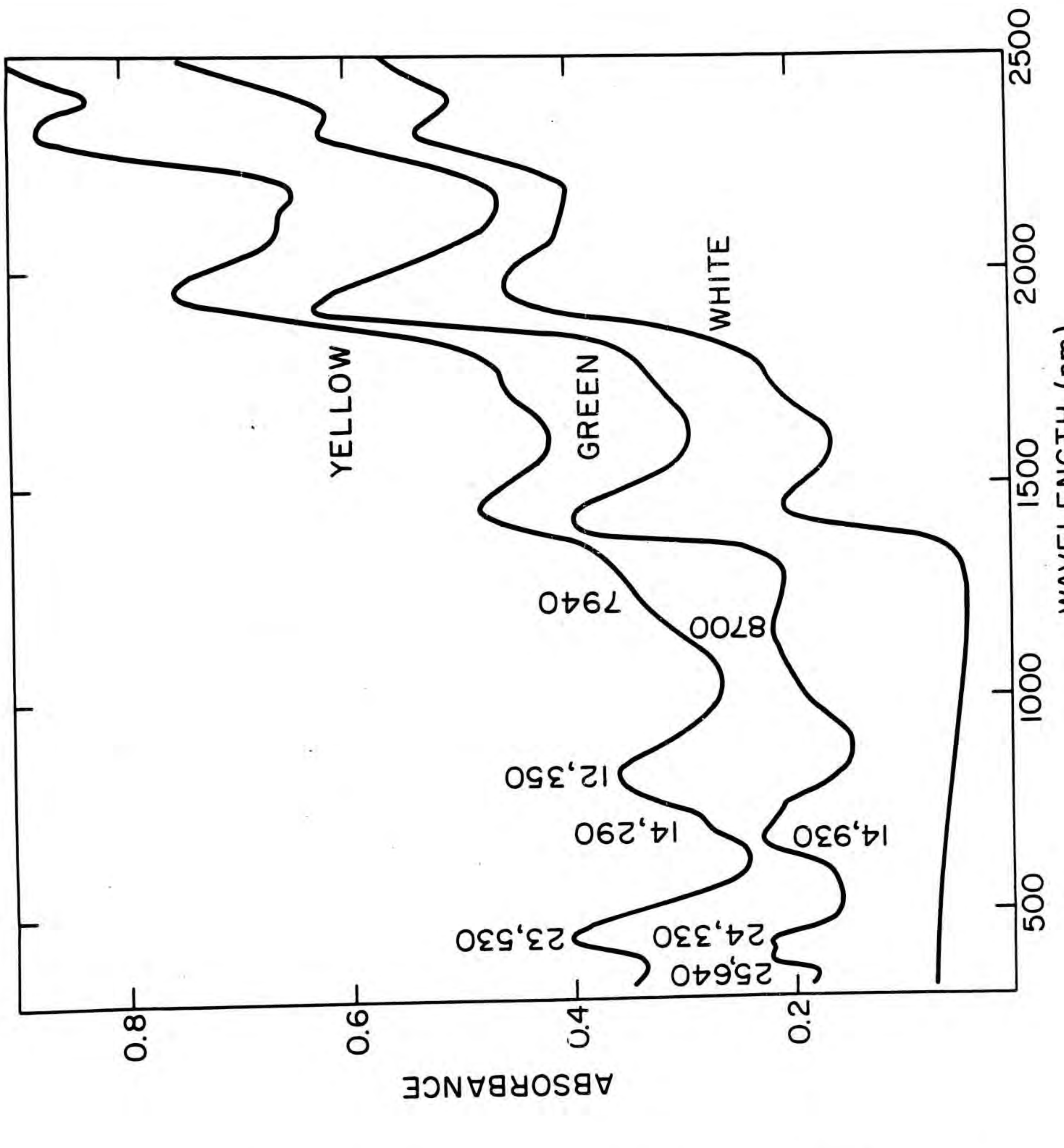
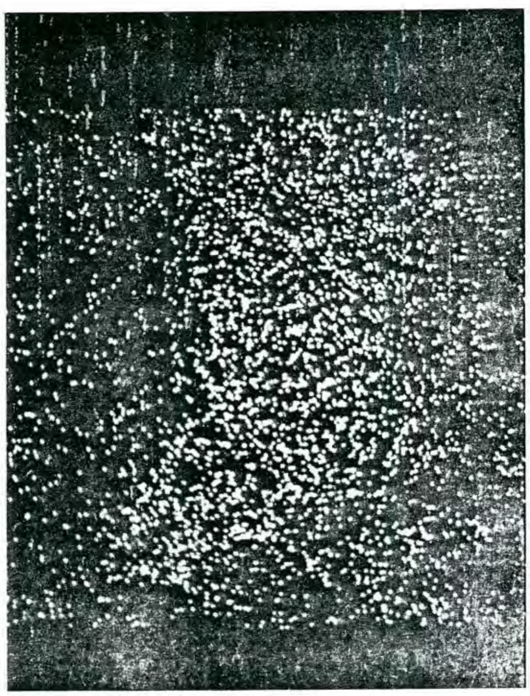


Fig. 3 Diffuse reflectance spectra of carbonate speleothems from Timpanogos Cave. Absorption bands labeled with Cm^{-1} values are due to electronic transitions within the Ni^{++} ion.

Mg IMAGE

Ca IMAGE



Ni IMAGE

Si IMAGE

Geologic Mapping of Floyd Collins' Crystal Cave

Arthur N. Palmer

Leveling and geologic mapping were conducted in Floyd Collins' Crystal Cave during three weeks in July and August, 1971, as the continuation of a project begun the previous year. To date, the leveling survey has been extended through most of the major passages in the cave as far as Lehrberger Link. An approximate thickness of 250 feet of limestones, dolostones, and shales have been described and tied in with the leveling survey, providing a continuous stratigraphic column from the base of the Big Clifty Formation ten feet above the Crystal entrance downward through the Girken and majority of the Ste. Genevieve Formation. The lowest stratigraphic exposures were obtained by descending several deep pits in the southern part of the cave, allowing a bed-by-bed description of vertical exposures as thick as 100 feet. Leveling in these areas revealed active shaft drains and canyons deeper both in stratigraphic position and in elevation than Mud Avenue, which has long been considered the lowest level of development in the eastern part of Crystal Cave.

Approximately 260 permanent stations from previous compass and tape surveys have been tied in with the leveling survey. Computer processing of survey notes has provided horizontal coordinates for stations in the cave, which are convenient reference points for plotting the geologic data. Forced closure of loops in both the leveling and compass and tape surveys is carried out as a linear function of surveyed distance. Error tolerances are much lower for the vertical component of the survey than for the horizontal component because of the need for accurate elevations in correlating stratigraphic horizons and geomorphic features. Consequently, a maximum acceptable error for closed loops in the leveling survey has been chosen arbitrarily at 0.05 percent. Although the present average error is roughly 0.2 percent, this value is expected to increase as the leveling extends through progressively less accommodating passages.

Although a detailed interpretation of the field data will not be undertaken until large-scale base maps of the cave are prepared, a few superficial observations can be made from the leveling and geologic data collected to date: Most major passages are extremely concordant to the local structure, especially those in the Ste. Genevieve Formation. Prominent bedding planes appear to have a greater influence on passage orientation than do variations in lithology. For this reason, major bedding-plane partings have been mapped as integral parts of the geologic column. The geologic structure is one of gentle undulations superimposed on the regional dip. Typically, undulations in bedding planes and lithologic contacts have crest-to-crest separations of 500 to 800 feet, with amplitudes commonly less than three feet. Major passages have gradients between ten and twenty feet per mile, with ceilings that rise and fall with variations in the geologic structure.

Roughly half of the field work has been completed toward the preparation of a detailed geologic map of Floyd Collins' Crystal Cave. If an assessment of the field data supports the feasibility and value of such an endeavor, the leveling and geologic survey will be extended into other major passages in the cave system.

Reconnaissance Geology and Biology of New Discovery

J.P. Wilcox, W.B. White, T.L. Poulson, and W.R. Crowther

The geologic and biologic description of the New Discovery Section of Mammoth Cave is nearing completion. The survey, particularly of recently discovered passages continued during the year. Analysis of the clastic sediments is the main unfinished item. These are quite complex and consist of clays and silts near the base level, gypsum-infiltrated red silts in higher levels, and complex gravel fills at several locations along Big Avenue. In particular fragments of an old stream bed armor consisting of basal Caseyville quartz pebbles cemented with iron oxides was discovered.

Reconnaissance of Lee Cave

J.P. Freeman, T.L. Poulson, G.L. Smith, P.J. Watson and W.B. White

The report on the unique upper trunk passage in Lee Cave is near completion. A level survey has been completed through the trunk and the unknown sulfate minerals have been identified. Two radiocarbon dates were received:

UCLA-1729A	Cane Torch Material	4100 ± 65 years
UCLA-1729B	Charred log	6050 ± 60 years

The date on the Indian debris places the aboriginal visitation of Lee Cave in the same time period as the Indian usage of Mammoth and Great Salts Cave. The age of the log, charred at one end and lying on the angular breakdown near the west end of the trunk passage, deepens the mystery. Its age predates by 2000 years any known Indian visitation of the caves. Its age certainly postdates any function of the main trunk as an active drain. A variety of hypotheses could be constructed, but all are in the realm of pure speculation in absence of other confirmatory data.

ECOLOGY PROGRAM

Terrestrial and Aquatic Cave Organisms

Thomas L. Poulson

The objective of this program is to understand the "rules" that govern community structure and function in complex non-cave ecosystems. For this, the simple communities in caves make an excellent model system. It is possible to study the physiology, life history, and behavior of the few species in enough detail to understand how each fits into the community. This understanding allows tests of the hypothesis generated by study of cave adaptation in amblyopsid fishes. The hypothesis is that rigor, predictability, and variability of microclimate dictate amount and predictability of food; that climate and food together dictate the evolutionary strategies of the species; and that the strategies dictate the complexity and stability characteristics of community structure. The extreme strategies and ecological and reproductive opportunism vs efficiency and specialization. The cave "cricket," Hadenoecus subterraneus, may exemplify opportunism with a high reproductive rate, short life, high mobility and broad ecological and physiological niche which allow it to quickly exploit food input due to unpredictable flooding even in climatically extreme parts of the cave. In contrast, the cave millipede, Scoterpes copei, may exemplify efficiency and specialization. It apparently has a low reproductive rate, long life, low mobility, and narrow ecological and physiological niche and lives only in the areas of lowest climatic rigor and variability with low but predictable food supply. Thus these characteristics will be assessed for each species by a combination field and laboratory approach to see whether they are causally related to low or high species diversity. Then perturbation experiments will be run to see whether the suite of strategies seen in a community automatically dictates its stability in time, relative abundance of species, and resistance to change. All of the studies in progress are related to one or another aspect of this general problem.

In the past the field studies have shown positive correlations between species diversity and both microclimate stability and food predictability and negative correlation with climatic rigor (Poulson and Culver, 1967; 1968-1970 CRF Annual Reports). This year's field work has added to the previous data base in three ways:

1. Transect census and trapping in Little Beauty and White Cave correct some deficiencies in the earlier study of epigean-cave community boundaries in Cathedral Cave (Culver and Poulson, 1971) since both contain a deep cave community. Studies in these caves are providing insight into the nature of competitive interaction between troglophiles and troglobites in variable climate and high food supplies near entrance vs constant climate and lower food supplies toward the back of each cave.

2. Quantitative census of three different kinds of guano communities in the deep cave zone confirm earlier observations that either mold excludes troglobites and/or that mold and high food levels allow troglophiles to outcompete troglobites. These observations were made in Dixon's (bat guano), White (cave rat and cricket), and Little Beauty Cave (cave rat and cricket) MCNP; Tumbling Creek Cave (bat), Ozark Underground Laboratory; and Blanchard Springs Cave (bat), Ozark-St. Francis National Forest. The Aspergillus-Penicillium type mold communities on the damp bat guano never have any fauna but the unmolded, wet, fresh guano swarms with mites or mites and cave crickets. The mycelial growth on cave rat guano has large, single-species concentrations of troglophilic collembola. The cricket guano has the most complex community. Its regular components are, in order of relative abundance: a cave snail (Carychium stygium at 5-20/cm^2); a springtail, (Onychiurus at 0-23/cm^2); a scavenger beetle (Ptomaphagus hirtus at 0-8/m^2; a millipede (Scoterpes copei at 0-3/m^2); and a pseudoscorpion (Chtonius packardi at 0-1/m^2).

3. Census and trapping at the river end of Orpheus Pass in Mammoth Cave has now provided an interesting picture. Both past visual census and this year's trapping plus visual census show that the highest species diversity occurs at the approximate high water mark for mean maximum yearly floods, as they occurred before the newest Green River dam was installed upstream, i.e. a 40-50 foot flood. This zone is least rigorous in terms of flood scouring and has a high concentration of fine organic matter left by receding flood waters. The latest high water line for large floods is marked by a high density of the snail Carychium stygium. Variation of substrate within this zone has become more marked due to drying since Green River last backflooded to this level in 1967. All the snails have died and now only the wet, muddy areas, i.e. those least rigorous microclimatically, have the high species equitability and diversity associated with occurrence of the species with narrow habitat niches such as the troglobitic millipede, Scoterpes copei, and harvestman, Phalangodes armata (e.g. site 3). Dirt-sand-debris areas (e.g. site 2) now attain as high a species diversity only when bait attracts the more mobile, opportunistic species such as the "cricket," Hadenoecus, a predaceous beetle, Neaphaenops tellkampfi, and the scavenger beetle, Ptomaphagus hirtus; the absolute numbers of these species compensate for the lower total number of species and low equitability component of species diversity.

Finally, two new projects with Dr. Richard Greene bear on the general problem of control of species diversity in areas of high food supply:

1. Studies of snail genus Carychium are aimed at comparing cave with surface forms to see if the cave form is troglophilic or troglobitic in its morphological, physiological, and behavioral adaptations. It appears to be an opportunistic species in cricket guano and flood areas.

2. Studies of plant communities around lights in Frozen Niagara areas will be aimed at determining: zonation with light, temperature, and moisture; rates of colonization and growth; and interaction with native cave microflora and fauna. These studies will suggest methods of control and eradication which will be tested in laboratory and field. Two methods to be tried are turning off lights whenever a party is not present (to disrupt the biological clock and so slow growth and stop reproduction) and providing continuous UV light in addition to visible lighting (to inhibit germination of spores and maybe kill existing plants). There are many other possibilities.

A Study of the Crayfishes and Their Epizootic Ostracods in Pless Cave, Lawrence County, Indiana

H. H. Hobbs III

Pless Cave lies within the Salem and St. Louis limestone formations of the Mitchell Plain, just south of the East Fork of the White River, approximately three miles southwest of Bedford, Lawrence County, Indiana. The three miles of cave passages follow along and are controlled by NS and EW trending joint systems. Three levels are known, the lowest of which carries a major NE - SW trending stream for its entire length. During normal flow the stream ranges in depth from a few inches to three feet, however certain areas (near the entrance) may flood to the ceiling even after light rains, making access impossible. Chemical and physical data indicate the cave environment is very "stable," except during periods of flood.

All known segments of the subterranean stream support a large population of the albinistic crayfish *Orconectes inermis inermis*, and considerably less abundant are two other pigment-bearing crayfishes: *Orconectes immunis immunis* and Cambarus (*Erebicambarus*) *laevis*.

Four species of entocytherid ostracods have been observed to infest the crayfishes in Pless Cave: *Sagittocythere barri* and *Uncinothere simondsi* were found in association with *O. i. inermis*; *Donnaldsoncythere donnaldsonensis* with *C. laevis*; and *Dactylocythere* sp. was found to infest *O.i. immunis*.

Work began in late October, 1970. A study area was chosen, consisting of approximately 3,000 feet of stream passages. All three species of crayfishes were internally and externally tagged as captured and then released to study movements. Subsequently, 200 specimens (all three species) have been tagged. Two hundred and eight were individuals of *O.i. inermis*, two were *O.i. immunis*, and ten were *C. laevis*. Of these, 36.4% have been recaptured at least once (the greatest number of recaptures for any one individual was eight). In addition to tagging individuals, sex, carapace length, relative position in molt cycle, and responses to light were recorded.

Based on the data obtained to date, the home range of O.i. inermis appears to be up to 200 feet both upstream and downstream from the point of initial capture. A rough estimate of the population size is between 500 and 1,000 individuals in the study area. With the small numbers of individuals marked and the low recovery rates, no attempt is made at this time to interpret the movements or to predict the home ranges of the other two species. More data are needed for all three species to determine home range, sex ratios, population densities and stabilities, activity, molt cycles, growth rates, and competition.

The commensal ostracods have presently received little attention. Most of the work completed has concerned S. barri. Numerous experiments are designed to determine host-commensal relationships (a possible specificity may exist between O.i. inermis and S. barri), how the ostracods reinfest the crayfishes following ecdysis of the host, whether the ostracods are dispersed indiscriminately over the setiferous areas of the exoskeleton of the crayfish or whether they tend to be restricted to a particular region, and whether or not the ostracods are able to live and reproduce in association with a host species other than that upon which they were found. A number of individuals of S. barri have been removed from their hosts and placed in a water-detritus medium to determine how long they can exist, and whether or not they may reproduce, isolated from their crayfish hosts. They were found to live for a minimum of 10 days and a maximum of 185 days. One pair was observed in copulation for 16 days, but no eggs were laid.

PROGRAM IN ARCHAEOLOGY

Excavations and Analyses in Salts Cave

Patty Jo Watson

Robert Stewart began a new series of paleofecal analyses the major purpose of which is to quantify the paleofecal components (seeds of food plants, hickory nutshell, fish scales, etc.) by weighing them. This is a tedious and time-consuming process but one which will enable us to make percent-weight comparisons between samples and between sites, and which will permit the use of more sophisticated statistical techniques.

Stewart has made arrangements with Vaughn Bryant (Washington State University) to examine the residues from the quantification study for pollen content. Bryant's results will supplement those obtained by James Schoenwetter (Arizona State University) in an earlier examination of eight Salts Cave paleofecal specimens for pollen. Schoenwetter will also continue his analyses on a larger series of samples.

Parasitological studies of eight paleofecal specimens from Salts Cave have been carried out by Elizabeth Dusseau (University of Michigan). She reports (in a letter dated April 28, 1971):

"The only findings thus far that may have significance have occurred in 23c (a specimen from Upper Salts). There are slender structures, curved in a way which is very characteristic of young nematodes...The size places them within the range of parasitic worm larvae, but lack of visualization of any characteristic morphology makes identification impossible."

Both Dusseau and another investigator (Gary Fry, Youngstown University) will continue searching for internal parasites in the Salts and Mammoth Cave paleofecal remains.

Louise Robbins (University of Kentucky) notes that the skeletal remains (ca. 2000 bone fragments) of the Salts Cave Vestibule human population are strange in a number of ways and somewhat difficult to work with. During the past year she has concentrated on the bone fragments from Test J (some 863 pieces) and briefly summarizes her work as follows (from a letter dated July 14, 1971):

"...according to mandibular fragments, there are as few as 6 individuals, but according to the different bone textures and densities, there are about 29 individuals. Ages range from fetuses (at least 2) through infants or newborn (0 to around 2 years), children (6-10), immature (11-15), young adults (16 to around 30 years), and mature adults. Both males and females are present, and cut marks on bones correlate with no particular age or sex group. Most bone was green when broken so it slivered instead of breaking clean. Some bones were burned while others (of the same individual) were unburned. And bone fragments from the same individual were found in several levels of J. Bone from J II and J IV belonged to the same individual; bone from J II and J III (levels 6 and 4 respectively) belonged to the same person. Bone fragments from level 3 of F extension and fragments from level 13 of J IV were reconstructed to form the shaft of a radius from a single individual. The people obviously did not bury all parts of one individual in one location, or if so, there was disturbance after burial. One thing that does interest me is the unusually high number of young off spring whose remains are present, i.e., 3 fetuses, 2 infants, 3 infants or fetuses, 6 children, 2 adolescents. Adult remains are: 8 females, 6 males, 9 sex uncertain."

Lathel Duffield (University of Kentucky) continued his analysis of the fauna from the vestibule excavations. Duffield says (letter dated July 23, 1971):

"We now have deer, turkey, bat, box turtle, cottontail rabbit, squirrel, raccoon, fish including cat fish, and possibly bass. We have dog, red fox, and one bone that closely resembles the gray fox. There is an incisor of a ground hog present. We have a mandible of a deer about 7 to 9 months old and this would indicate that the site, at least this level, was occupied in the late fall. One of the unidentified bones which I need to compare with a known specimen could be that of a very young or perhaps fetal deer. If this is the case then there must have been a spring occupation as well. However, the conclusion on that awaits the outcome of the identification."

During the coming academic year Richard Yarnell (now at the University of North Carolina) will complete his analyses of a long series of flotation samples from Salts Vestibule. He is now working on the material from a 1 x 1 meter control block in Test J. All fill in this 1 x 1 meter block below the upper 35 cms or so of breakdown rubble was floated. It appears so far that, as with the flotation samples from other trenches, the same plants are represented as in the paleofeces. One highly significant pattern that seems to be emerging, however, is an absence of the exotic tropical species--squash and gourd--in the lowest culture-bearing levels.

On March 20 and April 5, excavation of Test J in the Salts Vestibule continued until a layer of breakdown was exposed completely filling the 2 x 2 meter square. All fill from J IV (the southeast 1 x 1 meter square) was carried out to complete the flotation series begun in the spring of 1970. Very little cultural material was present and it is likely that we are below the level of occupation.

A reconnaissance trip was made on February 27 to assess the nature of the remains near the Chapman Entrance. Though there is considerable material to the south of the Chapman Entrance area, there is much less in the Q survey north of it. It seems unlikely that Indians used the Chapman Entrance, which is now fallen shut and apparently was never very large or serviceable.

Trips were made to Lower Salts on May 15, May 20, and June 12 for the purpose of observing and recording aboriginal remains in areas not previously visited by archeological parties. Because of the results of previous work, we believe the Indians reached Lower Salts via the floor of Desmal Valley. They explored and mined (for gypsum and perhaps for mirabilite and epsomite as well) a complex series of multilevel, superimposed, intermediately connecting canyon passages. The key to this confusing complex is the lowest-lying canyon, which has been mapped by the Cave Research Foundation as the S survey. The S survey connects to the north with Indian Avenue and runs on to the south for an as yet unknown distance. Indian material in the S survey is confined to the first 75 survey stations, however, possibly because the canyon becomes much wetter south of this point so that debris would not have been preserved. Above the narrow, twisting S survey are 4 other intermittently intersecting levels of canyon passages with a maximum vertical relief of some 90 feet. Moving along the upper canyons requires considerable caution in the areas where lower passages and upper passages intersect leaving one straddling a 2 to 3 foot wide slot which goes straight down 50 or 60 or more feet. The Indians certainly negotiated these areas freely for we find torch smudges and charcoal throughout with an occasional mined area (the latter, however, only in places where the passage has a floor).

Mammoth Cave

We went into Mammoth Cave April 6, 7, and 8 making observations, recording, and collecting radiocarbon dating material and paleofecal specimens. Aboriginal debris in the Ganter Avenue area which is where we worked, is virtually identical to that in Salts Cave except for the chert quarrying in Flint Alley and Jessop Avenues. In Flint Alley in particular there are conspicuous and abundant chert nodules and veins which certainly seem to have been exploited by the aborigines, to judge from the associated torch smudges and charcoal. We recorded aboriginal remains in Ganter Avenue and in the adjoining Cave Research Foundation N, L, B, and F surveys, as well as Jessop Avenue and Flint Alley.

The next place to be investigated is the series of canyons off Rider Haggard's Flight, which look very much like the intertwining canyons of Lower Salts above the S survey, and which have cane charcoal and torch smudges in them.

Wyandotte Cave, Indiana

We visited Big Wyandotte May 27 and 28, 1971, because George Jackson in his book, Wyandotte Cave (Livingston Publishing Company, Narberth, Pa.), describes and illustrates Indian material which sounds much like that of Salts and Mammoth Caves. Further, the cave was a commercial or semicommercial source of epsomite in the early 19th century. Hence, it seemed possible that a pattern of aboriginal utilization closely paralleling those of Mammoth Cave and Salts Cave might be found at Wyandotte.

There is certainly a great deal of presumably aboriginal bark lying about the Old Cave portion of Wyandotte, and also grass and bark ties very similar to those of Mammoth Cave National Park. However, there is very little gypsum so the Indians must have been seeking the epsomite and probably also the very conspicuous outcrops of Lost River chert which are easily accessible in several places along the main passages. Unfortunately we found no human paleofecal material, although nonhuman scats (probably raccoon) are abundant in the passages and rooms nearest the entrance.

Table III

SUMMARY OF AVAILABLE RADIOCARBON DATES

Salts Cave:

Vestibule:

710 BC ± 100 (GaK2622)
990 BC ± 120 (GaK 2765)
1460 BC ± 120 (GaK 2766)
1540 BC ± 110 (GaK 2767)
(all dates on charcoal)
1410 BC ± 220 (GaK 2764)

Cave Interior:

290 BC ± 200 (M 1573)
(squash seeds)
320 BC ± M 1777)
400 BC ± 140 (M 1577)
(squash pollen)
620 BC ± 140 (M 1574)
(gourd seeds)
710 BC ± 140 (M 1770) (sunflower)
(The above 5 dates are on paleo-fecal material)

480 BC ± 140 (M 1585)
560 BC ± 140 (M 1584)
570 BC ± 140 (M 1587)
770 BC ± 140 (M 1588)
890 BC ± 150 (M 1586)
1190 BC ± 150 (M 1589)
(The above 6 dates are on wood or bark)

1125 BC ± 140 (I 256)
(The above date is on soot)

Little Al Interior:

30 AD ± 160 (M 2259)
10 BC ± 160 (M 2258)
(The above 2 dates on internal tissue from the Salts Cave mummy)

Mammoth Cave Interior:

280 BC ± 40 (X-8)(This date is on a slipper fragment)
420 BC ± 60 (X-9) (This date is on cane fragments)
2150 BC ± (UCLA-1730A)
1030 BC ± (UCLA-1730B)

Wyandotte Cave Interior:

260 AD ± 80 (UCLA-1731A)
890 BC ± 60 (UCLA-1731B)

PROGRAM IN HISTORY AND ECONOMICS

History of the Peoples and Caves of Flint Ridge, Kentucky

Stanley D. Sides

An active field program has been initiated in an attempt to systematically record names and dates written in the caves of Flint Ridge. Unknown Cave and Salts Cave have been examined in part, and the Overlook area of Floyd Collins Crystal Cave was studied to better understand the history of exploration which occurred during the 1950's. A bibliography of references to cave exploration and development in Flint Ridge is being compiled, and several interviews were conducted with residents of the Cave region.

The oldest name recorded in Salts Cave is that of John West, who wrote his name in the cave on several occasions in the summer of 1809. William West, perhaps his father, first patented 200 acres of land near Salts Cave on August 8, 1799. Bennett Young wrote that William West was the first white man to see the cave, and patented land in the area of the cave as early as 1794. In 1802, the Warren County Court granted a patent to William West which included the cave entrance. This land was surveyed on March 18, 1804, and was found to consist of 109 acres. Salts Cave was called West Cave until approximately the 1830's, when it was renamed Salts after two men became lost in the cave.

Several years of work and collaboration with Mammoth Cave Historian Harold Meloy resulted in the publication of "The Pursuit of Health in the Mammoth Cave". The article documents the conditions and thought which led to having people afflicted with tuberculosis reside in Mammoth Cave in 1842 in an attempt to cure their disease. Widely acclaimed by the Medical profession initially, the death of the patients caused the experiment to be denounced by scientists and laymen alike.

ADVISORY ACTIVITIES

WILDERNESS RESOURCES OF MAMMOTH CAVE NATIONAL PARK

J.K. Davidson and W.P. Bishop

The publication in early 1971 of the final report on Wilderness Resources in Mammoth Cave National Park culminated a detailed three-year study of the caves, their wilderness potential, the relation of the caves to the surface, the potential for surface wilderness, and the future development of the Park. The recommendations emphasized regional planning with a large role to be played by private citizens in supplying the needs of the large tourist population attracted by the National Park. A passage classification scheme was evolved to assist the planners in the difficult task of extending land management practices underground.

STRIP MINING NEAR RUSSELL CAVE NATIONAL MONUMENT

F. Benington and W.B. White

A coal company has commenced strip mining operations in lands adjacent to Russell Cave National Monument in northern Alabama. The Foundation was asked for an opinion as to whether the mining activities constituted a safety hazard to tourists and Park personnel in the archeological area just inside the cave entrance and whether there was a possibility of damage to the cave itself.

The investigation included a site visit to the monument and to the mining operation. Based on the visit, on an examination of the local geology including the stratigraphic separation of the cavernous limestones and the coal measures, and on previous experience with caves in and near active quarries, it is the opinion of the investigators that no serious hazard exists. The entrance area is in a zone of weathering and some rock fall is expected naturally. There is the possibility that heavy blasting might trigger some of these blocks that would soon fall anyway.

INTERPRETATION AT MAMMOTH CAVE NATIONAL PARK

Training Session

T.L. Poulson, P.J. Watson and W.B. White

A one-day training session for the guides and seasonal employees at Mammoth Cave National Park was held again this year. It included a half day lecture and a half day field trip through the Historical Section of Mammoth Cave

Trail Guides

T.L. Poulson

The draft manuscript for the underground trail guide for the self-guided tour in Mammoth Cave was extensively revised during the year and is now about ready for press.

MANAGEMENT OF THE CAVE RESEARCH FOUNDATION

THE DIRECTORATE

At the annual Directors' meeting in November 1971, Dr. John P. Wilcox was elected a Director, replacing Dr. Richard A. Watson, who has resigned. Dr. Watson has been instrumental in Foundation affairs for many years and served as its second President from 1965 to 1967. Dr. Wilcox is Chief Cartographer of CRF.

FIELD OPERATIONS MANAGER AT MAMMOTH CAVE NATIONAL PARK

A new position has been created to manage all field activity at Mammoth Cave National Park. This important post has been filled by Dr. Phillip Gary Eller who has just completed requirements for the PhD in Chemistry at the Ohio State University and has taken up residence as a Research Associate at the Georgia Institute of Technology in Atlanta.

PERSONNEL

During the past year, October 1970 through September 1971, the total number of participants in our field program grew by 7% and now stands at 281. The level of data-gathering activity over the past three years by Foundation personnel at Mammoth Cave National Park is shown in the following tables:

MAN-DAYS AT MCNP

	in cave	on surface
Oct.'68 to Sept. 1969	624	165
Oct.'69 to Sept. 1970	442	167
Oct.'70 to Sept. 1971	539	141

MAN-HOURS UNDERGROUND AT MCNP

1969, calendar year		7305
1970, calendar year		4908
1971, Jan. to Sept.	5045	
plus Oct. to Dec. 1970	1123	
ADJUSTED TOTAL, 1971		6168

One can show by dividing MAN-HOURS UNDERGROUND in a given year by MAN-DAYS in the caves that the average length of a caver's day is consistently about 11 1/2 hours.

PUBLICATIONS IN 1971

BOOKS

A number of books have been published in the past several years in which the Foundation research program has had some influence.

Archeology

EXPLANATION IN ARCHEOLOGY by Patty Jo Watson, Steven A. LeBlanc, and Charles L. Redman (Columbia University Press, 1971) is based in part on the archeological research in Salts Cave and specifically on C.L. Redman's thesis which was conducted under National Geographic-CRF sponsorship.

History

Richard A. Watson is general editor for a series of reprint volumes of historical interest issued by Johnson Reprint Corporation under the title CLASSICS IN SPELEOLOGY. Four volumes have been published each with a new introduction written by a current authority. They are:

Edwin S. Balch, GLACIERES OR FREEZING CAVERNS (1900)
Introduction by William R. Halliday.

Horace C. Hovey, CELEBRATED AMERICAN CAVERNS (1896)
Introduction by William R. Halliday.

Luella A. Owen, CAVE REGIONS OF THE OZARKS AND BLACK HILLS (1898)
Introduction by Jerry D. Vineyard.

Ralph S. Thompson, THE SUCKERS VISIT TO MAMMOTH CAVE (1879)
Introduction by John F. Bridge.

Poetry

ANSWER BACK by Donald Finkel, Poet-in-Residence at Washington University (Atheneum, New York, 1968) is a long poem that takes its theme from cave exploration and its section titles, Indian Avenue, Mummy Valley, Wow Shaft, The Corkscrew, Angel Hair, and Blue Arrow Passage from the passage names in the Flint Ridge Cave System.

JOURNAL ARTICLES

Contributed Papers

24. Elizabeth L. White and William B. White. PROCESSES OF CAVERN BREAKDOWN. Bull. Natl. Speleol. Soc. 31, 83-96 (1969).

25. William B. White and Elizabeth L. White. CHANNEL HYDRAULICS OF FREE-SURFACE STREAMS IN CAVES. Caves and Karst 12, 41-48 (1970).

Supported Papers

16. David C. Culver. ANALYSIS OF SIMPLE CAVE COMMUNITIES: NICHE SEPARATION AND SPECIES PACKING. Ecology 51, 949-958 (1970).

17. David C. Culver and Thomas L. Poulson. COMMUNITY BOUNDARIES: FAUNAL DIVERSITY AROUND A CAVE ENTRANCE. Ann. Speleol. 25, 853-860 (1970).

18. David C. Culver. CAVES AS ARCHIPELAGOES. Natl. Speleol. Soc. Bull. 33, 97-100 (1971).

19. David C. Culver. ANALYSIS OF SIMPLE CAVE COMMUNITIES: III. CONTROL OF ABUNDANCE. Amer. Midland Nat. 85, 173-187 (1971).

20. David C. Culver and Thomas L. Poulson. OXYGEN CONSUMPTION AND ACTIVITY IN CLOSELY RELATED AMPHIPOD POPULATIONS FROM CAVE AND SURFACE HABITATS. Amer. Midland Nat. 85, 74-84 (1971).

21. Thomas L. Poulson. BIOLOGY OF CAVE AND DEEP SEA ORGANISMS: A COMPARISON. Natl. Speleol. Soc. Bull. 33, 51-61 (1971).

22. Thomas L. Poulson and William B. White. A REPLY TO "BIOGEOGRAPHY OF TROGLOBITES." Natl. Speleol. Soc. Bull. 33, 119-122 (1971).

23. Louise M. Robbins. A WOODLAND "MUMMY" FROM SALTS CAVE, KENTUCKY. Amer. Antiquity 36, 200-206 (1971).

24. Stanley D. Sides and Harold Meloy. THE PURSUIT OF HEALTH IN THE MAMMOTH CAVE. Bull. Hist. Medicine 45, 367-379 (1971).

Advisory Reports

9. Joseph K. Davidson and William P. Bishop. WILDERNESS RESOURCES IN MAMMOTH CAVE NATIONAL PARK: A REGIONAL APPROACH. Cave Research Foundation, Columbus, Ohio, 34 pp. (1971).

PAPERS AT PROFESSIONAL MEETINGS

National Speleological Society (Blacksburg, Va., June)

John P. Wilcox, William B. White, Thomas L. Poulson, and William R. Crowther, "Geological and Biological Reconnaissance of New Discovery, Mammoth Cave National Park, Kentucky."

John W. Hess and William B. White, "Cave Conduits as Components of Surface Stream Channels: Meander Bend Cut-Offs."

William B. White and James J. VanGundy, "Geological Reconnaissance of Timpanogos Cave, Utah."

International Symposium on Karst Denudation (Oxford, England, Sept.)

Russell S. Harmon, John W. Hess, Evan T. Shuster, Roger Jacobson, Cricket Haygood, and William B. White, "Denudation Processes in Carbonate Terrains of North America."

Cave Research Associates Meeting (McMaster University, Ontario, Oct.)

Arthur N. Palmer, "Hydrodynamic Aspects of Cavern Development by Floodwater."

Thomas E. Wolfe, "Classification of Cave Sediments."

Geological Society of America (Washington DC, Nov.)

William B. White, "Hydrogeology and Geochemistry of Fractured Carbonate Rocks."

American Association for the Advancement of Science (Philadelphia, Pa. December)

William B. White, "Mineral Stability in the Cavern Environment."

TALKS, SEMINARS AND SYMPOSIA

Horton H. Hobbs III:

"Population studies of the Cave Crayfishes and Their Entocytherid Ostracods from Pless Cave, Lawrence County, Indiana," Limnology Seminar, Indiana University.

Thomas L. Poulson:

"Caves as Evolutionary and Ecological Laboratories," Seminar at Southern Illinois University and at Bradley University.

"Amblyopsid Cave Fish and the Evolution of Species Diversity" Seminars at Indiana State University and at University of Cincinnati.

Stanley D. Sides:

"Cave Research Foundation and the Central Kentucky Karst," Mississippi Valley-Ozark Regional Convention of the National Speleological Society.

ANALYSIS OF SIMPLE CAVE COMMUNITIES: NICHE SEPARATION AND SPECIES PACKING[1]

DAVID C. CULVER[2]

Department of Biology, Yale University, New Haven, Connecticut 06520

Abstract. This paper considers various ecological relationships of three gammarid amphipods (*Gammarus minus, Stygonectes emarginatus,* and *Stygonectes spinatus*) and one asellid isopod (*Asellus holsingeri*) in cave streams of the Greenbrier Valley in West Virginia. Two clear-cut cases of reduction of realized niche due to the presence of other species were found: *S. emarginatus* is limited to small trickles of water when *G. minus* is present in the stream and *A. holsingeri* is limited to gravel-bottomed pools when *G minus* is present in riffles. *S. spinatus* prefers smaller rocks than do the larger amphipod species. All four species maintained weight equally well on rotting leaves or mud, so feeding differences appear to be minimal. Using Levins' matrix of competition coefficients as a framework, interference and exploitation competition were quantified and separated. From these data, it is indicated that the community is closed to immigration by similar species into the microhabitats occupied by the four crustacean species. Field evidence supports this. Some unused microhabitats may be available, but the aquatic insects that might potentially use them are not present.

Analysis of Simple Cave Communities III. Control of Abundance

DAVID C. CULVER[1]

Department of Biology, Yale University, New Haven, Connecticut 06520

ABSTRACT: In several cave-stream populations of *Stygonectes spinatus* and *Gammarus minus,* but not *Asellus holsingeri,* there was a large drop in abundance during spring high water. A long-lasting rather than short-term distributional change, this drop in abundance occurred despite the fact that the amount of food available is greatest during spring high water. *Stygonectes* species are less abundant than *G. minus,* largely because of the former's higher washout rate. This explains the rather difficult-to-grasp fact that the older cave species are less common. Experiments in an artificial stream indicate that washout rate is density-dependent, at least in *G. minus,* with some density-independent washout occurring under extreme environmental conditions. Washout is increased by increasing current velocity, increasing density, decreasing the size of the animals, or reducing the amount of available food.

Caves as Archipelagoes

By David C. Culver °

ABSTRACT

An analogy is drawn between caves and archipelagoes. Using the formal theory developed for the number of populations of a species present in an archipelago, it was possible to obtain estimates of migration and extinction rates for crustaceans in caves of the Greenbrier Valley of West Virginia. In general, these estimates agreed with what is known about the species' biology.

COMMUNITY BOUNDARIES : FAUNAL DIVERSITY AROUND A CAVE ENTRANCE,

by David C. CULVER (1) and Thomas L. POULSON (2).

Department of Biology, Yale University, New Haven, Connecticut, 06520.

Analyse.

Les caractères de la biocénose de la zone de l'entrée à la grotte de la Cathédrale, Kentucky, étaient établis en se référant aux théories admises. On propose une règle nouvelle pour la similarité de collection. Nous avons établi que le nombre d'espèces et la similarité de leur abondance sont plus grands dans la zone de l'entrée que dans la grotte ou en surface. Il se peut que ce soit un phénomène caractéristique des « ecotones » (frontières écologiques) en général.

The nature of the entrance zone community in Cathedral Cave, Kentucky, was investigated using information theory as a frame of reference. A new measure for similarity of collection is proposed. We found some evidence that the number of species and their evenness of abundance is higher in the entrance zone than in the cave or on the surface. This may be a phenomenon characteristic of ecotones in general.

Oxygen Consumption and Activity in Closely Related Amphipod Populations from Cave and Surface Habitats

DAVID C. CULVER[1] and THOMAS L. POULSON[2]

Department of Biology, Yale University, New Haven, Connecticut 06520

ABSTRACT: In contrast to other cave animals, metabolic rate of amphipods was not reduced in cave populations as compared to surface populations. In the genus *Stygonectes* the cave-limited *S. emarginatus* and *S. spinatus* had no lower standard metabolic rate than a surface seep population of *S. tenuis potamacus*. Cave ecotypes of *Gammarus minus* showed no lower standard or routine metabolic rate and no higher activity level or locomotor efficiency than surface spring ecotypes. One possible reason for these results is that the caves in which these amphipods were found are probably not food limited.

Biology of Cave and Deep Sea Organisms: a Comparison

By Thomas L. Poulson *

ABSTRACT

A panel discussion held at the 1969 AAAS meeting is summarized. The cave and deep sea environments have many similarities for the organisms which have adapted to life in them. The similarities and differences in these adaptations are examined for insight into evolutionary ecology and community structure in the two environments. The characteristics of life history and age distribution, sensory adaptation, and metabolic efficiency are discussed. The effects of geographic isolation and Pleistocene invasions are contrasted. Species diversity and the factors influencing it are discussed.

A WOODLAND "MUMMY" FROM SALTS CAVE, KENTUCKY

LOUISE M. ROBBINS

ABSTRACT

A mummy, or rather, a dessicated body, from Salts Cave, Kentucky, has been subjected to a comprehensive analysis. Radiocarbon analysis of internal body tissue placed the individual in the Woodland cultural period. A careful dissection of the body cavity revealed the presence of all internal organs but, due to dehydration, in a collapsed form. The diet of the individual, and indirectly of the population, was determined from the contents of the fecal material in the lower intestine and colon. Examination of the external side of the body revealed the individual to be a male, and radiographic and dental evidence indicated that he was around nine years of age. Blood group studies are still somewhat inconclusive, but tests are being conducted to clarify that problem. This paper was originally presented at the 35th Annual Meeting of the Society for American Archaeology, Museo Nacional de Antropologia, Mexico, D.F.

Processes of Cavern Breakdown

By Elizabeth L. White and William B. White

ABSTRACT

Breakdown occurrences have been studied extensively in the large cavern systems of the Central Kentucky Karst and in caves elsewhere in folded limestones. Rosettes of straight breakdown block edges show strong preferred orientation suggesting that fracturing occurs along pre-existing zones of weakness. Wide-span ceilings have a measurable sag.

Some processes activating cavern breakdown are: (1) loss of buoyant support by draining of galleries (2) undercutting of banks by floodwater stoping at the base level (3) removal of support by free surface stream action (4) crystal wedging and attack by sulfate mineralization (5) frost wedging (6) undercutting by later cavern development (7) undercutting and removal of material by vertical shafts and shaft drains (8) weakening of ceiling beds through attack by acid surface water.

One or more of the mechanisms of cavern breakdown are operative during all stages of development. Thus breakdown takes place continuously and plays an important role both in the initial enlargement of the cavern system and in its final degradation.

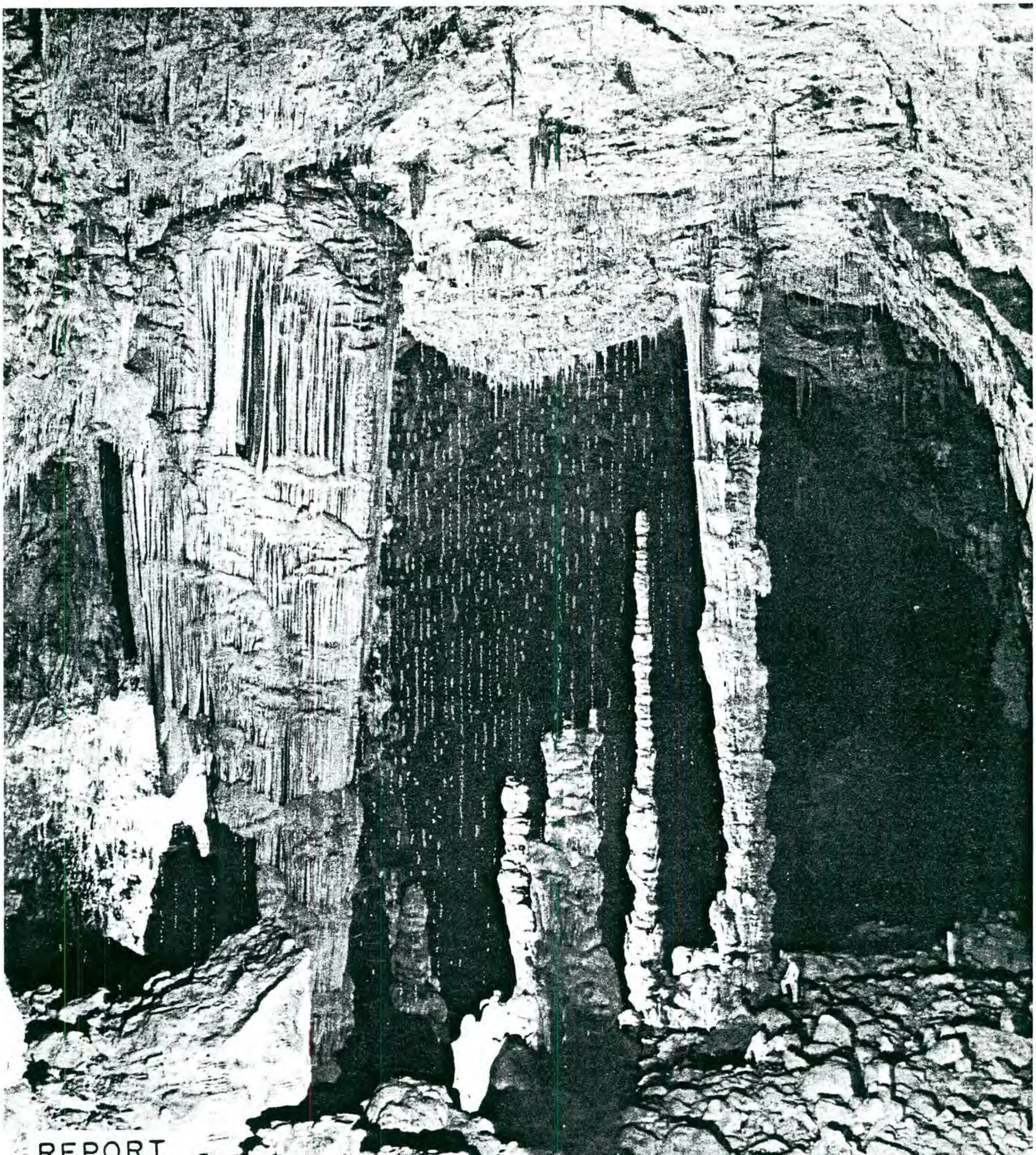
CHANNEL HYDRAULICS OF FREE-SURFACE STREAMS IN CAVES*

by WILLIAM B. WHITE** and ELIZABETH L. WHITE***

Abstract

Elementary fluid mechanics is applied to cave conduits in which the generating stream had a free air surface. These are mainly passages with canyon-like cross-sections. Examples are taken from the central Kentucky karst. Estimation of Reynolds and Froude numbers for typical water flows in caves predicts that most cave streams flow in a sub-critical turbulent regime. Channel widths vary systematically with both velocity and discharge. Slopes of channels calculated from the Manning equation agree with measured values for small canyons. Large canyons have very flat gradients and are interpreted as high points in an undulating conduit which lies near the ground-water level.

CAVE RESEARCH FOUNDATION



REPORT
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1972

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Cover Photo: Main passage in Ogle Cave, Slaughter Canyon, Guadalupe Escarpment, New Mexico. Photo by R. Pete Lindsley.

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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.

Dr. Miotke's work on the geomorphology of the Central Kentucky Karst was supported by a fellowship from the Deutsche Forschungsgemeinschaft.

The work of Mr. Hess and Dr. White on the hydrology of the 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.

HIGHLIGHTS OF 1972

In early September a long term goal of the exploration effort was achieved: The Flint Ridge Cave System was connected with Mammoth Cave unifying a grand agglomerate of passages whose presently surveyed length exceeds 144 miles. Key to the connection was the forcing of an exceedingly tight canyon which lead eventually to the discovery of Pete Hansen's Lost River--a mile long passage that passed completely under Mammoth Cave Ridge and the overlying dry passages in the Ganter Avenue Complex to connect with Echo River at Cascade Hall.

Dr. Franz-Dieter Miotke and his assistant Mr. Hans Papenberg completed their 10 month stay on Flint Ridge. The first fruits of their concentrated attack on the problems of the geomorphic history of the region have appeared in print as the monograph Genetic Relationship Between Caves and Landforms in the Mammoth Cave National Park Area, by F.-D. Miotke and A.N. Palmer. Dr. Miotke's efforts have also broadened our perspectives on the extent of the Central Kentucky Karst particularly to the south and west where his spore tracing experiments and those of Steve Wells have outlined the Graham Spring drainage basin.

The Foundation was host to Professor Alfred Bögli for a ten day period in June. Dr. Bögli was concerned with the measurement of joints and their influence on passage development.

Explorations of the Sinkhole Plain by Steve Wells and associates have produced a new cave system in the Graham Spring drainage with major trunk passage beneath the Sinkhole Plain.

The Foundation's annual graduate student fellowship for 1972 was awarded to Mr. Russell S. Harmon of McMaster University for support of his PhD dissertation on ages and paleoclimates of karst areas based on isotope distributions in speleothems. Mr. Harmon's field work will span areas in Canada, Mexico, and Western United States as well as in the Central Kentucky Karst.

COMMENTS BY THE RETIRING PRESIDENT

Joseph K. Davidson

Yes, I have retired as CRF President after five years. And Stan Sides is our fourth President. In recently reflecting on events of the past five years I was surprised at just how much has happened:

1. Funding for cave related research really got underway in 1969 with a series of grants from the National Geographic Society for Pat Watson's archeological work. It totaled over $10,000. In 1971 a Federal grant of about $23,000 was made to Pennsylvania State University to support Jack Hess and Will White's hydrology project in the Central Kentucky Karst.

2. Our interpretive program was really boosted in 1970 when we operated a one-day training session for the MCNP staff. It has continued each year right up to the present. CRF sends three scientists to the park to discuss the important aspects of the geology, biology and archeology of the caves and the region. Tom Poulson has nearly finished the preparation of an interpretive booklet for the self-guiding trip in Mammoth Cave.

3. Through Dr. Dean Merchant, CRF cooperated with the Ohio State University to conduct an aerial survey of the southeast part of MCNP. With it we have important closures between entrances including elevations and we will now be able to accurately place all the caves in that area on one map. We now have the framework for more major cave connections.

4. About Thanksgiving of 1968 Gordon and Judy Smith discovered Lee Cave on Joppa Ridge with characteristics just like Mammoth Cave and the Flint Ridge Cave System. It even had pre-Columbian Indian artifacts in Marshall Avenue (the main passageway). Today it has 7 1/2 miles of surveyed passage and extends under a major part of Joppa Ridge.

5. In 1970 work began in Mammoth Cave. Much of the work has involved rediscovering passages that were known by early explorers and then forgotten. But an increasing amount has been in Virgin areas. The archeology, geology, and biology projects are involving an increasing amount of field work in Mammoth Cave. The potential for more work seems as limitless as in the FRCS and Joppa Ridge.

6. Our average climbing capabilities have increased tremendously. Five years ago we had only about two people with a wide experience in rope climbing and caving techniques. Now there are many so that it is almost routine to field parties into areas that require technical capabilities.

7. The number of scientists carrying on research at MCNP has grown considerably in recent years and we have more researchers from foreign lands doing research at MCNP. Whereas research operated at a steady plateau level for several years, it is now clearly increasing in intensity. No end is in sight.

8. The Field Station at MCNP has seen much-needed improvement. CRF has invested in a new water system, heating system, and summer shelter. And the NPS has added another building to our Use Permit. These improvements boost considerably our ability to support research. We now can house a researcher longer than a few days and we can do it in the winter. In just one year the improved Field Station has been so used for Dr. Franz-Dieter Miotke, Hans Papenberg, Professor Alfred Bögli, and Jack Hess.

9. In the autumn of 1969 CRF promised the NPS to prepare a report on the resources of MCNP. In mid-1971, after a full man year of work, the Foundation released the fifth in its series of studies: the 34-page Wilderness Resources of Mammoth Cave National Park: A Regional Approach.

10. The Guadalupe Cave Survey has merged with the Cave Research Foundation. The Guadalupe Cave Survey is a group of approximately 30 active people that has been working in Carlsbad Caverns National Park and the surrounding area for the past eight years. The interests and goals of the GCS have been largely the same as CRF's so that considerable cooperation has occurred between the two groups for the past two years. In fact many of the westerners are Joint Venturers of both CRF and GCS. Pete Lindsley, as GCS Director, has become the CRF Operations Manager for the Guadalupe Escarpment Area.

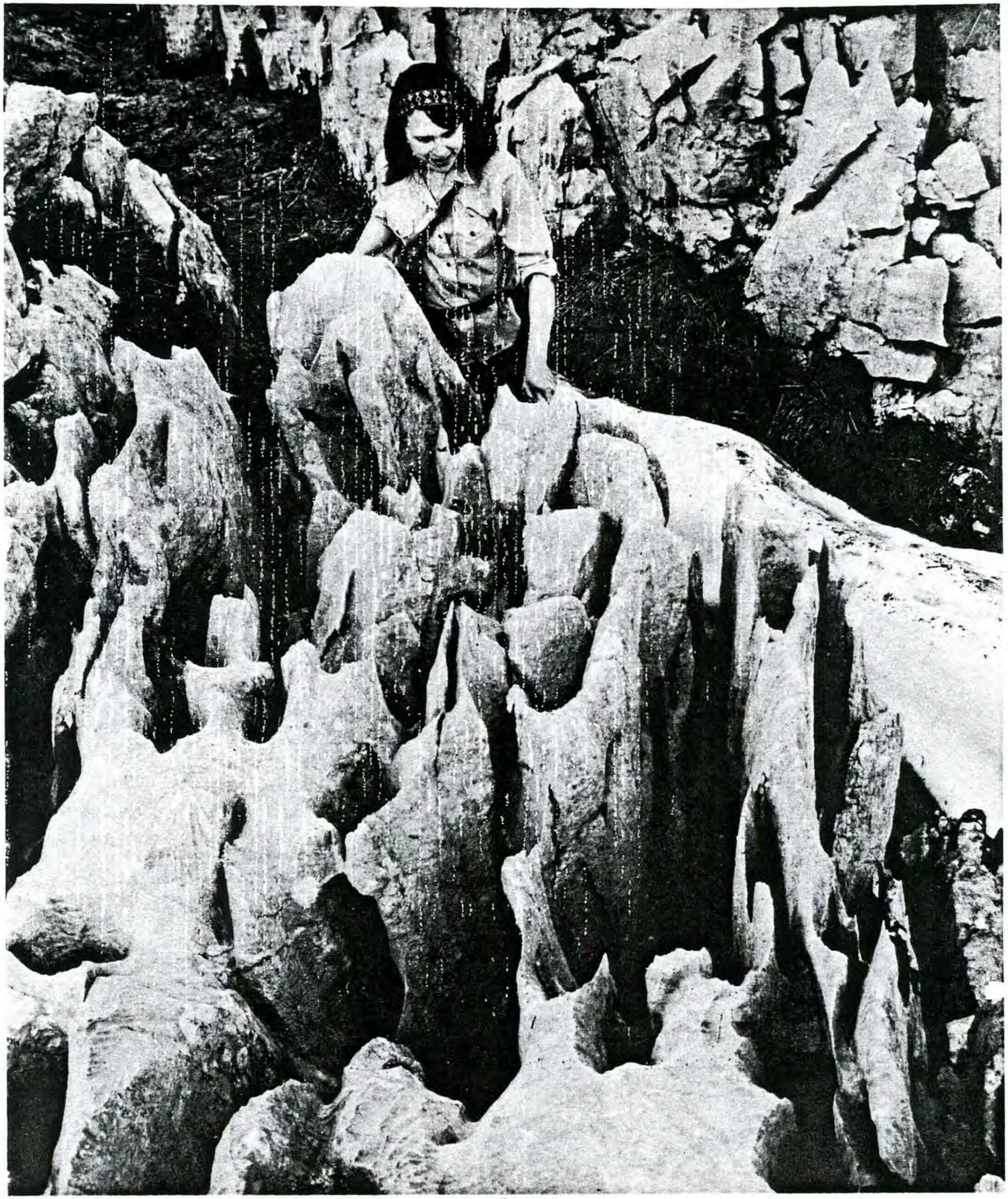
CRF's primary impact in the West will likely be to increase the research output and to promote the use of those results in interpretation and land management. Already the amount of research is on the rise in the Guadalupe Escarpment Area. And the past two years have seen considerable interest in park planning at CCNP and Guadalupe Mountains National Park.

As I have been writing all this I've been trying to think of an accurate way to describe the feeling one has being President of CRF. My thoughts keep returning to that November night in 1965 when we conducted our first practice rescue at MCNP. We rescuers had just eaten a hearty evening meal and had collected the stretcher, blankets, etc. In getting these materials to the Austin Entrance, we transported them by stationwagon to the point of the hill where the road turns sharply left and down. Fred Morrison asked me to lead the group to the Austin Entrance. I grabbed some piece of necessary gear in order to feel more needed than just as a guide, the others hefted the stretcher and off we went. In two minutes we realized we were in the sticks!! No trail!! I had been so busy trying to keep ahead of those 12 people that I had forgotten the left turn and had led them right off the end of the hill into the brush. Traversing left solved the problem, and the remainder of the practice rescue went smoothly.

But being CRF President is a little like being guide that night in 1965. The organization is made up of so many people with great energy, motivation, and initiative that one's eyes must always be forward in order to keep the resources just behind usefully deployed and out of the brush. And let me tell you that's what makes running CRF fun. It is not a one man show. Everyone has enthusiasm and ideas. And most have little hesitation communicating their ideas to the President in short order.

So I want to thank you all for your efforts in working with me, providing ideas, giving me something to guide. It has made by five years as President very enjoyable. I now ask that we all give our new President, Stan Sides, support in the same way. Let's give him lots to guide and direct.

THE SCIENTIFIC PROGRAMS



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Karren topography over Hölloch, Switzerland: The surface overlying the cave is a forested karst containing numerous deep pits in the Seewer limestone (Cretaceous) which overlies the Schratten limestone in which Hölloch is developed. Due to a steepening of the dip southeastward in the updip direction toward the crest of the Drusberg Nappe, the Schratten limestone crops out in the headwater areas of the cave in a high, barren region of karren topography. Attempts to explore Hölloch upstream beneath the barren plateau shown here have so far proved futile although most of the recharge to the cave apparently takes place through this surface.

Photo and commentary by Arthur N. Palmer

CARTOGRAPHY

CARTOGRAPHY AND EXPLORATION AT MAMMOTH CAVE NATIONAL PARK

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

Again in 1972, the total footage recorded by survey parties in Mammoth Cave National Park was greater than in any previous year. 21.12 miles of passage were surveyed during the twelve-month period ending November 1, 1972, 96 percent of it previously unsurveyed by the Foundation. The surveyed length of Mammoth Cave was increased by 19.4 percent this year.

A breakthrough in the Candlelight River area of Flint Ridge led to a new river passage at a lower level than the previously known passages there. In September downstream exploration in the new river yielded the long sought connection with Mammoth Cave. The Flint-Mammoth Cave System thus established contains 144.9 miles of surveyed passageway.

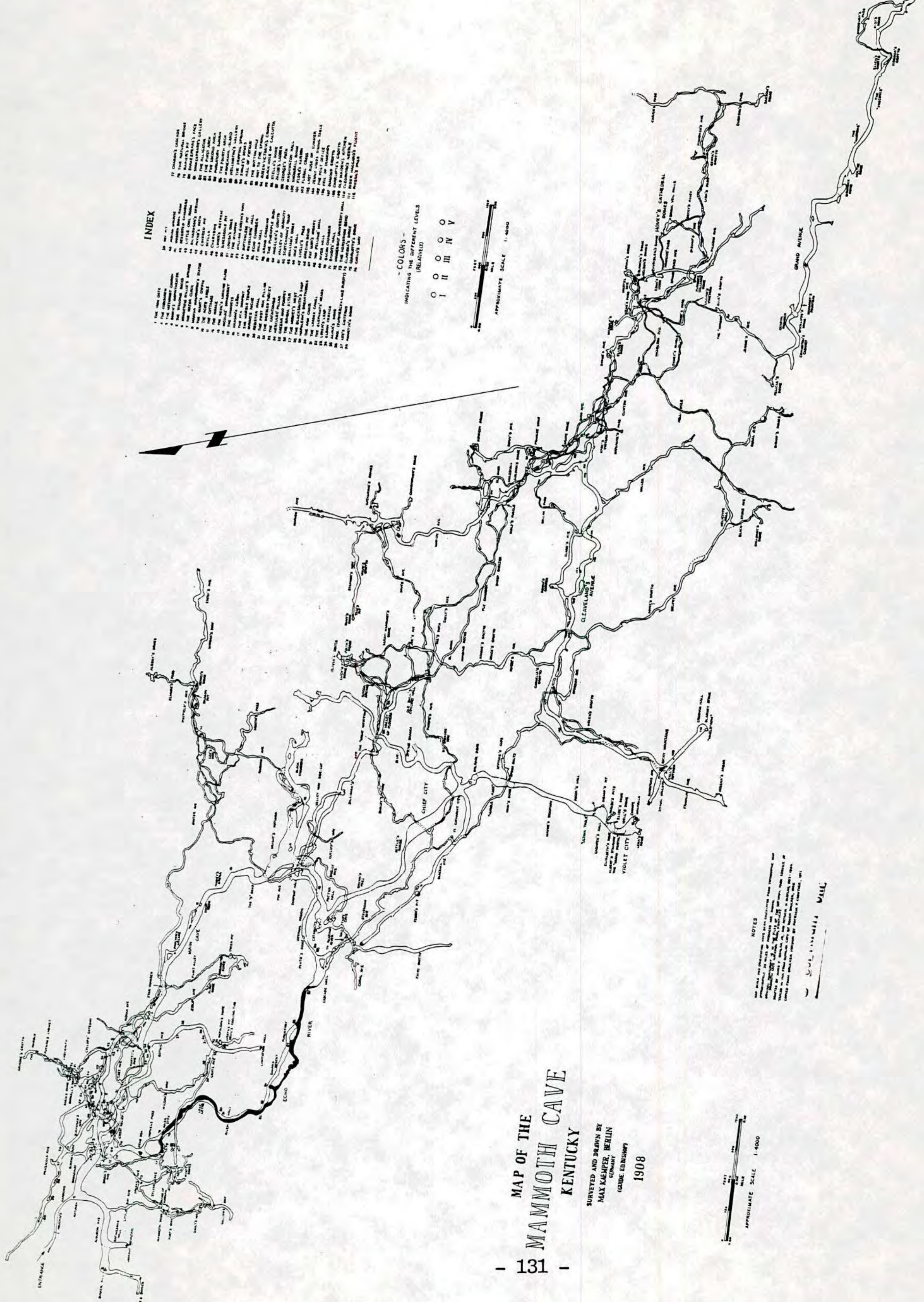
Map production has been speeded by the computerized processing of all survey data. The program, developed by Will and Pat Crowther, generates rectangular coordinates, draws large-scale Calcomp plots of individual survey lines to which passage detail may be added by hand, and draws small-scale plots of entire areas with the walls shown instead of the survey lines. The latter mode is illustrated by Figure 2, which shows a computer drawn map of CRF and Walker surveys in Mammoth Cave. Place names and titles were added manually. Since they may be produced to any desired scale, these computer drawn maps are useful as topo map overlays and as the basis for illustrations for technical papers. Their quick availability makes them valuable in the direction of the field effort.

Entrance locations have been improved by data from the aerial photography project. Radio equipment developed by Frank Reid is being used for accurate locations of points on the surface that are vertically above points in the caves.

Exploration and Survey in Flint Ridge

Decreasing amounts of new footage from Flint Ridge reflect a maturing of our knowledge of the presently integrated portions of the cave system. There remain, however, large areas of the ridge that must be underlain by cave to which access has not yet been found. The year has been one of rechecking localities that have potential for breakthrough into areas of new cave.

In July, such a recheck of a previously surveyed passage in the Candlelight River area led to a major breakthrough into a lower level


MAP OF THE
MAMMOTH CAVE
KENTUCKY
SURVEYED AND DRAWN BY
MAX KAEMPER, BERLIN
GERMANY
(GUIDE ED BISHOP)
1908
APPROXIMATE SCALE 1:4000
INDEX
-COLORS-
INDICATING THE DIFFERENT LEVELS
(RELATIVELY)
NOTES
ENTRANCE
ECHO
RIVER
CHIEF CITY
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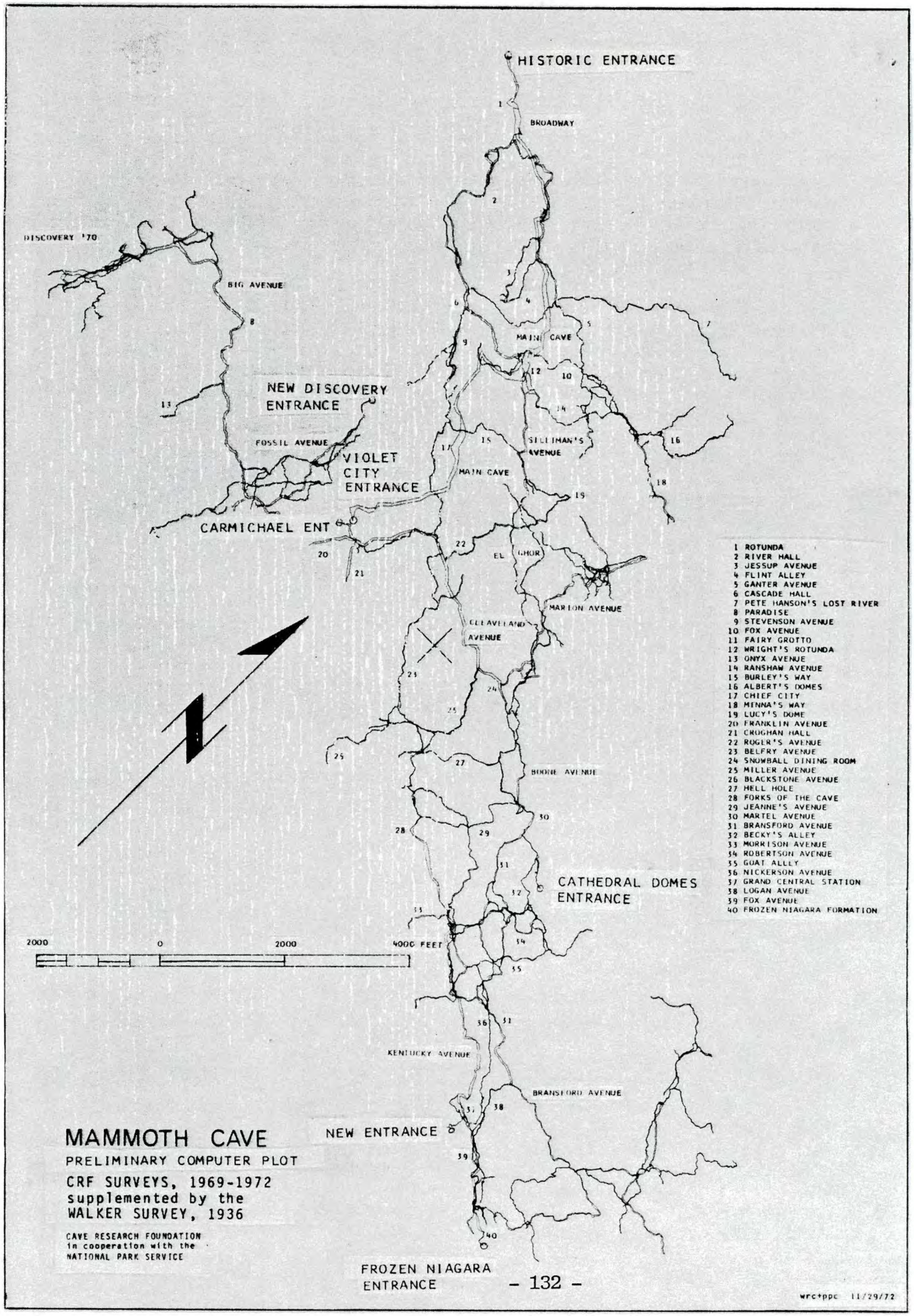
CLEVELAND AVENUE
GRAND AVENUE
HOVEY'S CATHEDRAL
MAIN CAVE


HISTORIC ENTRANCE
BROADWAY
DISCOVERY '70
BIG AVENUE
MAIN CAVE
NEW DISCOVERY
ENTRANCE
FOSSIL AVENUE
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AVENUE
MAIN CAVE
CARMICHAEL ENT
EL GHOR
MARION AVENUE
CLEAVELAND
AVENUE
BOONE AVENUE
CATHEDRAL DOMES
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2000
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BRANSFORD AVENUE
NEW ENTRANCE
FROZEN NIAGARA
ENTRANCE
1 ROTUNDA
2 RIVER HALL
3 JESSUP AVENUE
4 FLINT ALLEY
5 GANTER AVENUE
6 CASCADE HALL
7 PETE HANSON'S LOST RIVER
8 PARADISE
9 STEVENSON AVENUE
10 FOX AVENUE
11 FAIRY GROTTO
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13 ONYX AVENUE
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15 BURLEY'S WAY
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18 MINNA'S WAY
19 LUCY'S DOME
20 FRANKLIN AVENUE
21 CROGHAN HALL
22 ROGER'S AVENUE
23 BELFRY AVENUE
24 SNOWBALL DINING ROOM
25 MILLER AVENUE
26 BLACKSTONE AVENUE
27 HELL HOLE
28 FORKS OF THE CAVE
29 JEANNE'S AVENUE
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31 BRANSFORD AVENUE
32 BECKY'S ALLEY
33 MORRISON AVENUE
34 ROBERTSON AVENUE
35 GOAT ALLEY
36 NICKERSON AVENUE
37 GRAND CENTRAL STATION
38 LOGAN AVENUE
39 FOX AVENUE
40 FROZEN NIAGARA FORMATION
MAMMOTH CAVE
PRELIMINARY COMPUTER PLOT
CRF SURVEYS, 1969-1972
supplemented by the
WALKER SURVEY, 1936
CAVE RESEARCH FOUNDATION
in cooperation with the
NATIONAL PARK SERVICE
wrc+ppc 11/29/72

drainage system. More than 1000 feet were surveyed there in August, most of it in a walking river passage that is the largest to be found in Flint Ridge since the discovery of the Northwest Passage in 1966. Access is through a very tight canyon that has aborted two parties. Exploring ahead, the survey team found the signature of Pete Hanson, a guide who explored in Mammoth Cave in the 1930's, and an arrow pointing in the direction they were going.

On September 9 a six-member assault team returned to the passage. Splitting into two survey crews, they worked simultaneously, alternately leading, trending always to the southwest. After 5000 feet of surveying, often in waist deep water, they emerged through a near siphon into the Echo River tourist passage of Mammoth Cave, tied their survey to a CRF survey in Cascade Hall, and left the cave via the Snowball Dining Room elevator.

Several promising leads remain in the new river system, one of them extending northward for more than 1500 feet under known parts of the Flint Ridge Cave System. The current surveyed length of the FRCS is 86.56 miles.

Exploration and Survey in Mammoth Cave

As the survey of known passages in Mammoth Cave has progressed, CRF teams have been spending an increasing portion of their time in exploration. Of the 18 miles surveyed there this year, 9.5 miles have been in passage not on the Kämper or Nelson maps. The greatest activity has been in the east end of the cave. Black Kettle Avenue was extended to the southeast beyond previous surveys to a point where it junctions with Bransford Avenue, which continues eastward as a major trunk passage, passing to the north of the Cocklebur Avenue region. Martel, Nickerson, Robertson, Fox, Logan, and Cocklebur Avenues have been surveyed. From Bransford Avenue the boundaries of the cave have been pushed northward more than half a mile toward Strawberry Valley. The entire region from Cathedral Domes to the Frozen Niagara Entrance is still in the initial exploration stage.

The Marion Avenue area has been surveyed and has yielded 0.7 miles of new cave. There are pits yet to be descended. A survey line has been completed from Pinson's Pass through Emily's Avenue and Sit Greaves Way to Stevenson Avenue.

The upstream end of Roaring River has been surveyed, also yielding 0.7 miles of new cave. The end of the passage is under Joppa Ridge, but the potential for continuing is poor.

The current status of surveys in Mammoth Cave is shown in Figures 1 and 2. Figure 1 is a reproduction of the map drawn by Max Kämper in 1908 after an intensive period of compass-and-pace surveying. It shows approximately 35 miles of passages, many of them not yet surveyed by the CRF. The Kämper map is still the most detailed available of the west end of the cave. It does not show New Discovery or the Frozen Niagara Section, since these were first entered after Kämper's work.

Figure 2 is a computer plot of CRF surveys in Mammoth Cave, with the addition of Walker data for some passages not yet surveyed by the CRF. The Walker Survey was a series of transit traverses run through some of the larger passages during the 1930's. The data from the Walker Survey has never been presented in the form of a detailed map. Figure 2 includes numerous passages in New Discovery and in the east end of the cave that were virgin or were visited by perhaps one party before the explorations of the last two years. Hanson's Lost River, the connection route to Flint Ridge, may be seen joining Echo River just to the west of Cascade Hall. CRF survey currently totals 37.4 miles, of which 13.9 miles are in previously unsurveyed passage. The surveyed length of Mammoth Cave, including earlier surveys by Kämper, Walker, and others as compiled by J.F. Quinlan in 1969, is approximately 58.4 miles.

Small Caves

Activity north of the Green River included the survey of Ganter Cave, 0.83 miles long, and Wilson Cave, 1300 feet. There are still leads in Ganter. Owl Cave and Hickory Flat Cave were surveyed. Both are very short.

CARTOGRAPHY AND EXPLORATION AT CARLSBAD CAVERNS NATIONAL PARK

John Corcoran and James Hardy

This is the seventh year of operation for the Cartography Program in the Guadalupes. The major caves being surveyed are Carlsbad Caverns, New Cave, Ogle Cave, Goat Cave, Spider Cave, and Chimney Cave in Carlsbad Caverns National Park. Cottonwood Cave and Hidden Cave are being surveyed in Lincoln National Forest. Caves being surveyed on Bureau of Land Management property include Dry Cave and Ft. Stanton Cave.

Carlsbad Caverns

The survey of Carlsbad Caverns consists of two major packages--the base line survey and the secondary surveys. The base line survey uses data from both theodolite and transit surveys which are leveled and connected to USGS brasscaps. Secondary surveys are performed with tripod-mounted Brunton compass and tape. Extensive use of computer data processing provides an exact correlation between all surveys and the result is one of the highest accuracies of three dimensional cave surveying known today.

During 1972 over 4,000 feet of transit survey was completed both on the surface and in the cave. Approximately 1000 points were established over Carlsbad Caverns as part of the Gravity Measurement Program which incorporated a Plane Table survey. Approximately 1900 feet of level survey was performed in the cave with emphasis on the New Section. Over 2000 feet of Brunton survey was completed in Carlsbad Caverns--primarily in the Cave Pearl Section, the New Section and the Left Hand Tunnel. The Cave Pearl Room is a very delicate section of Carlsbad Caverns that exhibits some excellent examples of calcite cave pearls. Although this area is essentially off limits to all visitors, survey of the passage will relate its importance to the other portions of the cave. Drafting of several Left Hand Tunnel and New Section quadrangles was started this year and additional Brunton surveys were completed in these areas in order to clarify existing information.

Summary of 1972 Carlsbad Caverns Surveys

Control surveys - transit (Big Room)	921. ft. = .17 mi.
Level surveys - Palmer Pole (New Section)	1900. ft. = .36 mi.
Brunton surveys - New	1915. ft. = .36 mi.
Brunton surveys - Re-survey	389. ft. = .07 mi.
Total cave surveys	5125. ft. = .96 mi.
Surface surveys - transit	3252. ft. = .62 mi.
Surface surveys - plane table	Approx. 1000 points established.

New Cave

New Cave is one of the larger caves of Carlsbad Caverns National Park and is perhaps the second best known of the caves. Located just within the entrance of Slaughter Canyon, New Cave offers a wilderness cave experience to its few visitors. Survey of New Cave was initiated in 1972 in conjunction with the planning for guided tours of the cave by the Park Service. A transit survey base line was carried from the entrance to the rear of the cave and tripod-mounted Brunton surveys connected the walls and smaller passages to the base line. The majority of the cave was surveyed during 1972, and the maps will be drafted during 1973. Formation and guano-mining detail will be provided as well as the "tourist" trail route.

Summary of 1972 New Cave (Slaughter Canyon) Surveys

Control surveys - transit	1178. ft. = .22 mi.
Brunton surveys - new	11695. ft. = 2.22 mi.
Brunton surveys - Re-survey	619. ft. = .12 mi.
Total cave surveys	13493. ft. = 2.56 mi.

Ogle-Rainbow Cave

Also located in Slaughter Canyon, "Rainbogle" Cave is on the opposite wall of the canyon from New Cave. A geological reconnaissance was made of Ogle Cave and the area above the cave with emphasis on geological mapping of the area. Both the Ogle entrance and the Rainbow Cave entrance were tied to recently established brasscaps. A second survey line was established down the main corridor for the purpose of tying to historical survey points and to increase the accuracy of our past surveys. A newly discovered passage was also surveyed and tied to previous surveys.

Summary of 1972 Ogle-Rainbow Cave (Slaughter Canyon) Surveys

Brunton surveys - New	577. ft. = .11 mi.
Brunton surveys - Re-survey and tie-in	1694. ft. = .32 mi.
Total cave surveys	2271. ft. = .43 mi.
Surface surveys - Brunton	2071. ft. = .39 mi.

Goat Cave

Goat Cave is also located in Slaughter Canyon in Carlsbad Caverns National Park. The cave consists of one large corridor with two side passages. Although the cave is very dry and dusty, it is quite impressive and presents the visitor with a true wilderness experience due to the remoteness of the entrance. The cave was surveyed with tripod-mounted Brunton and the map was drafted during 1972.

Summary of 1972 Goat Cave (Slaughter Canyon) Surveys

Brunton surveys - New	1558. ft. = .29 mi.

Able Goat Cave

Able Goat Cave is typical of numerous smaller caves of Carlsbad Caverns National Park. Consisting essentially of one medium sized room with one smaller room to one side, the cave location is quite remote. This is a typical "dead" cave since most of the formations are now quite dry. Survey was by tripod-mounted Brunton.

Summary of 1972 Able Goat Cave Survey

Brunton surveys - New	470. ft. = .09 mi.

HYDROLOGY

HYDROLOGY OF THE CENTRAL KENTUCKY KARST

John W. Hess and William B. White
(MACA-N-12)

The present problems are concerned with spring hydrograph analysis in order to investigate the flow system of the Central Kentucky Karst and with the seasonal changes in the water chemistry of the various waters of the area. This past summer Pike Spring and Owl Cave were instrumented to record water velocity, temperature, and electrical conductivity. The water chemistry sampling program includes the Haney Springs, the sinking streams of the Sinkhole Plain, and the springs along the Green River. The rain gage network using private observers has been enlarged this year to include areas of Mammoth Cave National Park. A spring survey of the Barren River was carried out in conjunction with Steve Wells. Twenty-five springs were located and described between Polkville and Bowling Green.

The continuously recording instruments were installed in Pike Spring on 8 July 1972 and in Owl Cave on 13 July 1972. The data since then have varied in quality as various bugs were worked out of the system. Several good pulses were picked up on the recorders and at least one example of Pike Spring back flooding was recorded. Figure 1 shows the early parts of a pulse through Owl Cave during 28 - 30 July 1972. It is in response to 2.5" to 5.5" of rain 27 through 30 July 1972. The heaviest rain was on the night of the 28th. In general the Spc (specific conductance) of the water, which is proportional to its hardness, decreased and the temperature of the water increased as the pulse went through. The early small decreases in the Spc might be due to the early arrival of a low conductance water with inputs close to Owl Cave such as vertical shaft inputs of water off of the clastic ridge tops, water falling directly onto Cedar Sink and Mill Hole and surface drainage. The increases in conductance can be explained by the pulse flushing water out of storage in front of it as it moves through the system. The water in storage would be expected to have a higher than average Spc, since it has had a longer resident time within the flow system. The increase in temperature as the pulse goes through is caused by the fact that the summer rain water has a higher temperature than the ground water.

Figure 2 shows a back flooding of Pike Spring during 28 - 30 September 1972. The springs will back flood when the hydrostatic head due to the increase in the level of the Green River is greater than the head due to the input waters to the spring. Both the temperature and Spc increased because the temperature and Spc of the Green River were greater than those of Pike Spring. The dashed portions of the curves denote that the temperature went off scale, and the Spc is dependent on the temperature.

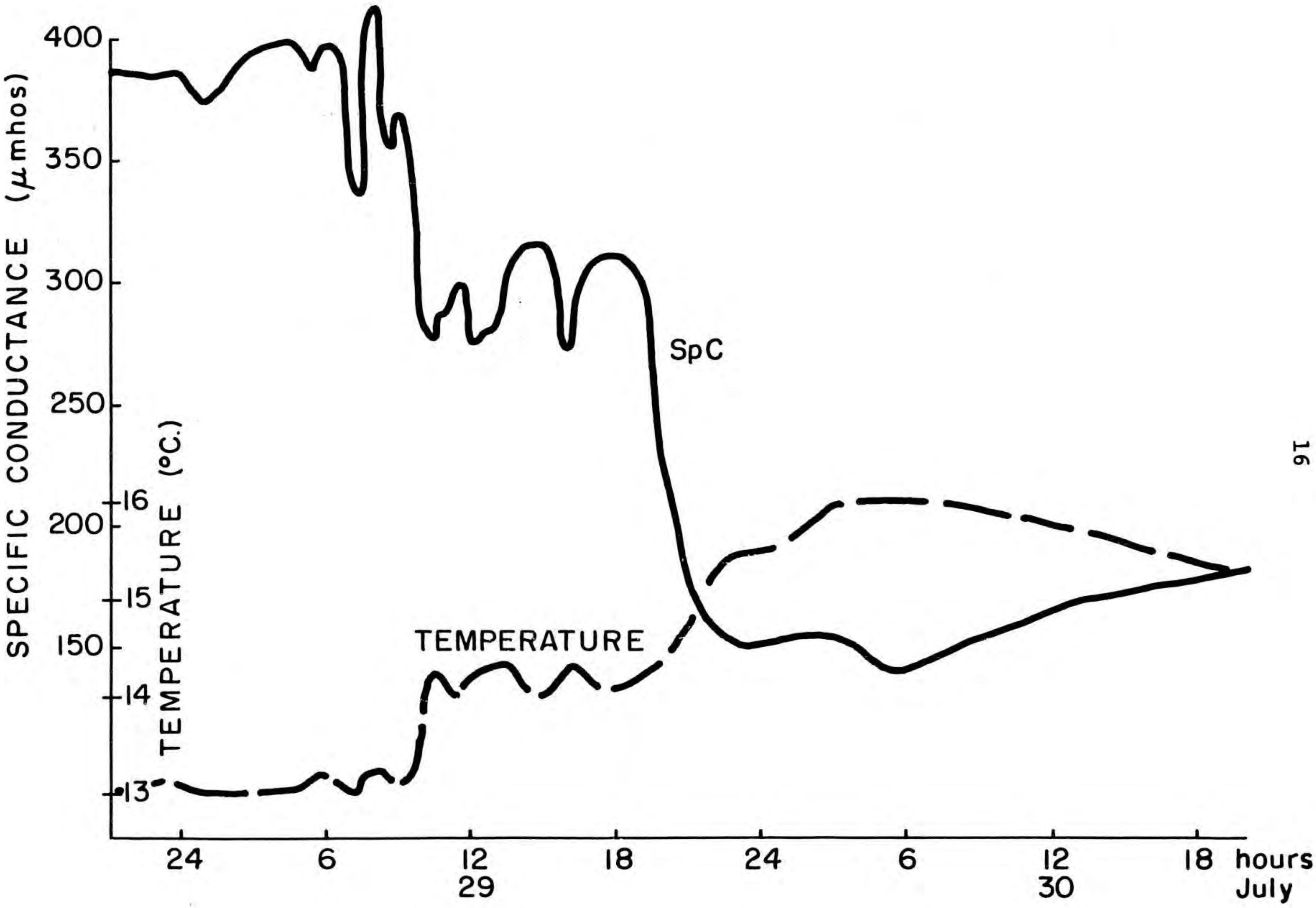


Fig. 1. The leading edge of a pulse through Owl Cave
28 to 30 July, 1972.

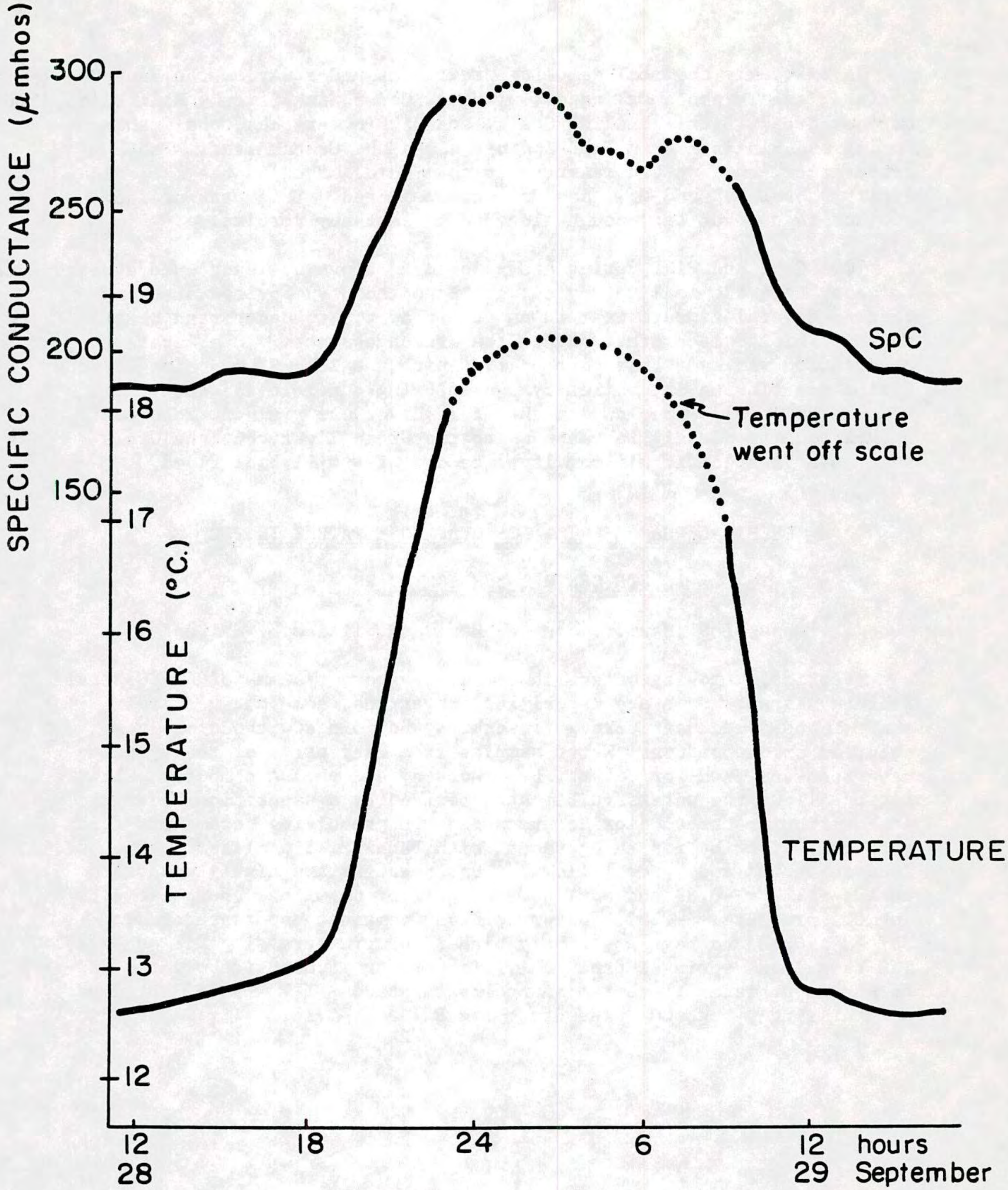


Fig. 2. Backflooding of Pike Spring, 28 to 29 September, 1972.

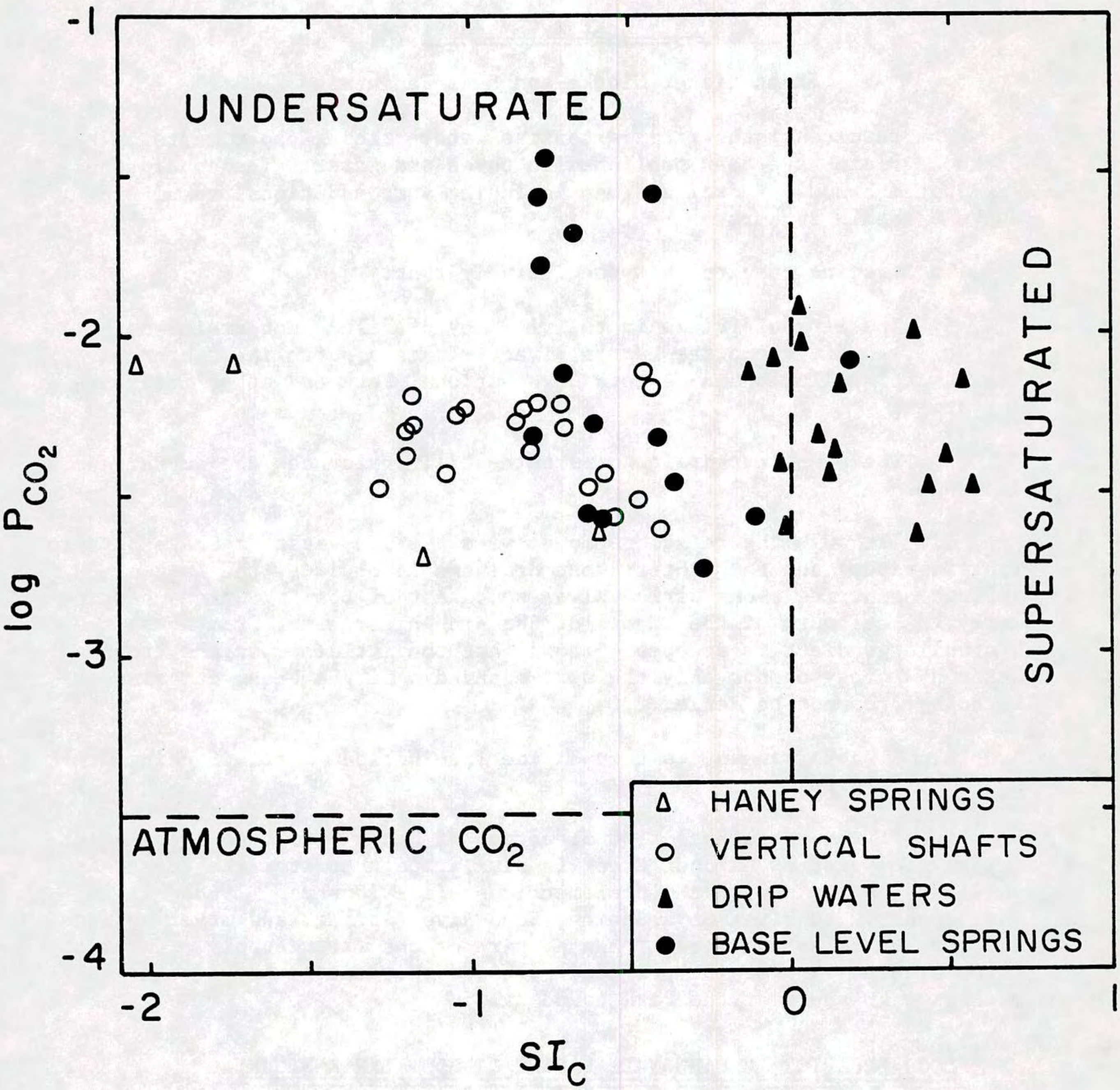
A bi-weekly chemical sampling program is under way on the Haney Springs, the Turnhole Drainage (Owl Cave, Ceder Sink Stream, Mill Hole, Gardner Creek, Little Sinking Creek, and Sinking Branch), the Graham Spring and Sinking Creek, and springs along the Green River. The pH, temperature, and Spc are measured in the field. Back in the lab, alkalinity, total Ca^{2+} and Mg^{2+} and Ca^{2+} are measured. This part of the project is not yet far enough along to present any results.

Owl Cave and Pike Spring are sampled as above at least once a week to generate a chemical rating curve. Echo and Styx Springs are also checked several times a week in an effort to try to understand their relationship to each other and to the drainage system. One interesting observation was made this year dealing with the Echo-Styx drainage. Echo Spring was flowing in, while Styx was flowing out. It was at a time when water levels were low and the Green River was rising. Echo can back flood immediately in response to the Green River, but the Green must be at a specific minimum level before Styx will back flood.

CHEMICAL CHARACTERIZATION OF VADOSE WATERS IN THE SOUTH CENTRAL KENTUCKY KARST

Russell S. Harmon, John W. Hess and William B. White

Vertically moving waters intersect the cave systems of the Central Kentucky Karst. Some are depositing travertine, some cut vertical shafts, and some enter through fractures and joints without obvious solution or deposition. Water samples from many parts of the system have been analyzed for Ca, Mg, bicarbonate, and pH. A computer calculation allows the waters to be characterized by a saturation index and an equilibrium carbon dioxide pressure. The resulting parameters form a bimodal distribution in agreement with Thrailkill's classification of "vadose seeps" and "vadose flows." Shaft waters are highly undersaturated, $<SI_c> = -0.83$ and would be in equilibrium with a gas phase with log CO_2 pressure = -2.33. Dripwaters are somewhat supersaturated, $<SI_c> = +0.18$ and have a slightly higher CO_2 pressure $<\log P_{CO_2}> = -2.29$. The base level springs, presumably discharging a composite of the different input water types remain undersaturated, $<SI_c> = -0.58$ but have a surprisingly high CO_2 pressure, $<\log P_{CO_2}> = -2.14$.


UNDERSATURATED
SUPERSATURATED
ATMOSPHERIC CO_2
HANEY SPRINGS
VERTICAL SHAFTS
DRIP WATERS
BASE LEVEL SPRINGS
log P_{CO_2}
SI_C
-1
-2
-3
-4
-2
-1
0
1

GEOMORPHOLOGY AND HYDROLOGY OF THE SINKHOLE PLAIN AND GLASGOW UPLAND, CENTRAL KENTUCKY KARST

Franz-Dieter Miotke and Hans Papenberg

The results of the first extensive water tracing experiments on the Sinkhole Plain have been published in Caves and Karst. The conclusions are quoted below. A drainage map including some additional results by Steve G. Wells appears on Page 32.

The tracing results show conclusively that:

1. The Sinkhole Plain in the vicinity of Pilot Knob drains both to the Green River and the Barren River. It is a potential source of groundwater pollution in Mammoth Cave National Park and other intervening areas.

2. The pre-karst drainage pattern still influences the subterranean drainage.

3. Although the relationship between the pre-karst drainage pattern (physiography) and the subterranean drainage is obvious, the lack of springs occurring along Barren River southeast of Bowling Green--particularly to the south of the ponors of the sinking streams, from where the hydraulic gradient is steepest--shows that the influence on the groundwater hydrology of not only the strike and dip of the beds, but also the lithology, cannot be denied.

4. A subterranean drainage divide lies between Little Sinking Creek and Sinking Creek.

5. If the subsurface flow direction of water from the several sinking streams east of Gardner Creek is similar to that from the Creek--as suggested by the map of the piezometric surface (Cushman, 1968)--it is most probably to River Styx Spring, Echo River Spring, and other springs east of Turnhole Bend Spring; hence, part of the water supply of Mammoth Cave National Park may be polluted by water that enters the aquifer as much as 6 km south of the Park boundary.

FLOOD BEHAVIOR IN CARBONATE BASINS OF SOUTHERN KENTUCKY

Elizabeth L. White

Most of the storm enters the underground storage and does not appear as runoff. Thus the usual peaked flood hydrograph is not present in limestone areas.

The mean annual flood was found to be inversely proportional to the basin area underlain by limestone. A Pennsylvania basin with about 80% limestone (Area = 87.2 square miles) had a mean annual flood of 8 csm, whereas most basins in Pennsylvania and surrounding states between 2 and 200 square miles in area have a mean annual flood of approximately 30 csm.

A basin about 70 miles south of Mammoth Cave, Kentucky, is underlain by carbonates. The West Fork of Drakes Creek (USGS #3-3137) drains 110 square miles and contains 17 square miles that is drained completely underground. This basin is unique in that most of the basin is underlain by a homogeneous clay-rich-limestone-derived soil of Silurian age. The limestones of Pennsylvania are Cambrian and Ordovician age. The surface clay-rich soils keep the water from draining into the ground; thus about one-half the sinkholes in this basin were filled with water in March 1972.

Bacon Creek, near Priceville, Kentucky (USGS #3-3104) has an area of 85.4 square miles containing 31 square miles of underground drainage. The soils here also appear to be more homogeneous than is usually expected. The surface soils here contain more sand than the lower soils. The ratio of sinkholes with water vs those without water is less than that for West Drakes Creek. This is due to the ability of sandy soils to drain more easily than the clay-rich soils. A summary of some soil observations is given below:

	March 1972 With water / Without water	Mottling	Surface soils	B-horiz	ls area	Total area
W. Drakes	1:1	None	Clay-rich	Clay-rich	17	110
Bacon Creek	1:4	Some	Sandy	Clay-rich	31	85.4

Note: Soil mottling is due to a fluctuating water table resulting from alternating oxidation and reduction. Mottling was present only on Bacon Creek watershed. The clay soils of West Drakes Creek keep most of the water perched on the surface.

Flood records from these and other carbonate basins in South Central Kentucky are being compiled to quantitatively investigate the effects of the basin parameters, local stratigraphy, and soil type on flood response in carbonate aquifers in flat-lying limestones.

SEDIMENTATION & MINERALOGY

PLEISTOCENE PALEOCLIMATE INVESTIGATIONS IN THE CENTRAL KENTUCKY KARST

Russell S. Harmon

During the latter half of 1972 a study of the Late Pleistocene paleoclimatology of the Central Kentucky karst region was begun as a portion of a PhD program. Absolute ages of secondary calcium carbonate deposits from the caves of Mammoth and Flint Ridges will be determined by the Th^{230}/U^{234} method and depositional temperatures from the O^{18}/O^{16} ratio of the carbonate and D/H ratio of trapped interstitial pore waters.

Initially, two small stalactite specimens from the Flint-Mammoth Cave System were obtained from W.B. White to determine the concentration of U and Th in speleothems from the region and assess the possibility of dating such materials. The samples were found to contain a sufficiently high concentration of the radioisotopes (0.1 to 0.3 ppm) to undertake a more extensive sampling program. The one specimen from the Frozen Niagara section of Mammoth Cave was dated at 6000 ± 100 years before present.

Late this year a number of carefully selected stalactite and/or flowstone specimens from Flint Ridge, Cathedral Cave, and Great Onyx were collected for both age dating and stable isotope work. The tips of six active soda straws and the associated drip waters were also sampled to study the conditions under which speleothems are presently being deposited and to check the validity of the stable isotope "thermometers" in the region.

POLLEN STUDY OF CAVE SEDIMENTS

Gilbert Peterson

Pollen has often been recovered from sediments of Pleistocene and recent age and used to identify floral assemblages and hence climatic conditions at the time of deposition. Most pollen studies deal with ponds, lakes, bogs, or small rock shelters, i.e. the pollen is precipitated directly from the atmosphere. In this study the chief transporting agent was moving water, from shaft drains and from backflooding of the Green River. The purpose of the study was two-fold. First, ancient sediments in upper passage levels were examined to see if any identifiable pollen has been preserved. Second, the present-day transport of pollen by shaft drains and Green River backflooding was examined to see what types of pollen are being brought into the cave and whether this mechanism favors certain pollen types to the exclusion of others. This second question has potential value in the interpretation of the ancient pollen record, not only in Central Kentucky, but in other similar geographic areas.

Field work was begun in July and largely completed by the end of the summer. Small sediment samples of 10 cc each were taken from upper levels of Mammoth, Great Onyx, and Salts Caves. Modern sediments were sampled in Echo River, Columbian Avenue and Eyeless Fish Trail, and from shaft drains in Colossal Cave. A few samples of surface sediment were taken for comparison. Samples were processed in the palynology laboratory at the University of Wisconsin.

Preliminary results indicate that, although pollen is now being deposited in the cave system, it has not been preserved in the older cave sediments. A detailed pollen count is now in progress.

MINERALOGY OF CARLSBAD CAVERNS

Carol A. Hill, Harvey R. DuChene and David H. Jagnow

In the past year two new speleothems were recognized and three (with a possible fourth) new minerals were discovered in Carlsbad Caverns National Park. Calcite blades were found on the wall of the main trail in the Boneyard and tabular gypsum was found in the Mystery Room (see GCS Mineralogical Report, April 7, 1972). Two phosphate minerals were discovered in the bat guanos of New Cave and Ogle Cave. Brushite, $CaHPO_4 \cdot H_2O$, occurs as a leached product on top of bat guano in Ogle Cave. Fluorapatite, $Ca(PO_4) \cdot F$, occurs in New Cave as a blue-green layer in a suite of layered phosphates in the mined bat guanos. The other layers are being x-rayed at the present time. Thenardite, $NaSO_4$, a dehydration product of mirabilite, $NaSO_4 \cdot 10H_2O$, was found occurring along the trail near the Pump Room. This soluble salt probably initially forms as mirabilite and at least partially dehydrates to thenardite within the cave. Epsomite is a possible fourth new mineral discovered in Carlsbad Caverns National Park this year. Although not x-rayed, a bitter tasting mineral was found along the trail in the Big Room. Similar to the mirabilite, it formed as a fluffy "cotton" on top of cave soils. The presence of epsomite would certainly be likely, considering the other sulfates present.

An extensive amount of work was continued on the huntite flowstone ("crinkle blisters") of the Left Hand Tunnel area. This new occurrence of huntite will be published soon in a forthcoming report. Aragonite cave pearls were analyzed from Able Goat Cave, a small cave recently surveyed in the Park. These pearls are different from ordinary cave pearls in that they were not radially layered but were composed of moonmilk.

The primary objective of the mineralogical program is to determine the mineralogy of various speleothems and deposits in the caves of the Guadalupe Mountains. Some of the long range goals and study areas of the project are listed below:

1. Detailed investigations of the growth of helictites
2. Gypsum blocks in the Big Room of Carlsbad Caverns and other caves of the Guadalupe Mountains
3. Interrelationships and genesis of the carbonate system in Carlsbad Caverns

4. Disintegration (old age) of speleothems
5. Deflected stalactites
6. Popcorn lines in Carlsbad Caverns
7. Canopy growth
8. Halloysite genesis

KARST GEOMORPHOLOGY

GENETIC RELATIONS BETWEEN CAVES AND LANDFORMS IN THE MAMMOTH CAVE NATIONAL PARK AREA

Franz-Dieter Miotke and Arthur N. Palmer

Some results of a ten month intensive study of the landforms and caves in South-Central Kentucky have already been published in monograph form. The conclusions reached in this monograph are quoted below, and the proposed geomorphic history of the region is presented in Table 1.

Field work carried out by both authors indicates that cave development in Mammoth Cave National Park has been closely governed by the erosional and depositional history of the region, with large cave passages having formed at grade with the Green River at times when the river lay at base level. Major cave levels are therefore correlative with any surface features that also owe their development to pauses in the dissection or aggradation of the river, such as terrace remnants and erosion surfaces. By determining the ages of surface features of this type, it is possible to establish the ages and developmental history of the corresponding cave levels.

The following observations from this paper support the validity of this correlation:

1. The elevations, morphology, and (to some extent) the sediments in the cave passages of Floyd Collins' Crystal Cave agree closely with those of surface valley features.

2. The gentle, uniform gradients of trunk passages in the cave suggest that the majority of their enlargement has taken place near the top of the phreatic zone. Although the discharge in accessible trunk passages was greater than that of the smaller canyon passages, the flow velocity was less in the trunk passages (generally less than 10 cm/sec). Attainment of a large passage width has consequently required a long period of groundwater stability at or near base level.

3. Variations in stratigraphy and geologic structure influence the trends and gradients of cave passages, but not their elevations.

4. Chemistry data indicate that most solution in caves of the national park takes place in lateral passages at or near base level, rather than where water descends vertically in shafts and at canyon heads.

Despite the limited areal extent of the cavern data, the genetic relationship between passages in Crystal Cave and erosional-depositional

CORRELATION BETWEEN GEOMORPHIC HISTORY AND CAVE DEVELOPMENT (Simplified Schematic)

AGE	GEOMORPHIC EVENTS	GREEN RIVER TERRACE LEVELS AT MAMMOTH CAVE (ELEV. IN FEET)	CAVE LEVELS (ELEV. IN FEET)	CAVE PASSAGES
Holocene	Development of floodplain and present river pool; soil development; erosion due to deforestation; deposition of silt	420 - 440	Active levels mainly at 420 - 460	Lowest levels flooded; local canyon entrenchment
Wisconsin glaciation (late)	Beginning of loess erosion and silt accumulation; filling of Ohio valley with outwash: southern tributaries ponded and filled with silt	455 - 460	450 - 480	Pohl Ave., Columbian Ave., Mud Ave.
Wisconsin glaciation (early)		465 - 470		
Sangamonian interglacial	Erosion to base of present Wisconsin valley fill; soil development	420(?) - 450		
Illinoian glaciation	Filling of Ohio valley with outwash; ponded southern tributaries filled with sand and silt; thin gravel deposits at Mammoth Cave	520 - 550	500 520 550	Deposition of sand and gravel in Lost Passage (?)
Yarmouthian interglacial	Yarmouthian deep stage; entrenchment followed by long period at nearly static base level; relatively wide valleys	500 - 520 530 - 550	500 520 550	Lost Passage Flat Room "L Survey"
Kansan glaciation	Filling of Ohio valley with outwash; sand and silt fill in ponded southern tributaries	520 - 600	600	Clastic fill in Thomas Avenue (?)
Aftonian interglacial	Aftonian deep stage; "new" Ohio cut deep channel due to larger headwater area and steeper flow gradient; narrow canyon cut 150-200 feet below present river level in lower Ohio valley, 30 feet below present river level at Mammoth Cave	approx. 390	——	Development of canyons below 600-foot level
Nebraskan glaciation	Teays valley buried by till and outwash; Nebraskan marginal "outwash valley" formed "new", long Ohio	520 - 600	——	
Pliocene and early Pleistocene (pre-Aftonian?)	Erosion in several stages 150-200 feet into Lexington peneplain; wide, shallow valleys ("Parker strath"); formation of Chester escarpment; deposition of gravels in clay matrix; Ohio River head at Madison, Ind.	590 - 650 700 - 715	600 - 630 670 - 690	Wide canyons formed; maximum width at 620 feet (Dyer Ave., Thomas Ave., Collins Ave.) Top of Collins Ave.
Miocene (?)	Lexington peneplain; very gentle relief; cherty gravels deposited	800 - 950	——	——

levels in the Green River valley cannot be an isolated example. Because the geomorphic history of the Green River valley is related to that of the entire Ohio River basin, it should be possible to extend the correlation of cave levels well beyond the small area studied here. A similar relationship between cave development and erosion levels has been suggested for the Indiana karst by Powell (1968) and Palmer (1969, p. 112-114). Taking into account local variations in geologic setting and geomorphic history, it should be possible in a similar way to determine the developmental history of caves throughout the entire midwestern United States.

GEOLOGIC STUDY OF FLOYD COLLINS' CRYSTAL CAVE

Arthur N. Palmer and Margaret V. Palmer

The leveling and geologic mapping program in Crystal Cave was continued in 1972 and is nearing completion. Several major passages were leveled, including Flint Crawl, the route to the bottom of Bottomless Pit and the remainder of the former Commercial section. Shaft systems near Camp II were surveyed to provide a more complete picture of the present drainage patterns in the cave. A surface survey, which linked the datum at the Crystal Cave entrance with the level of Green River, showed that the entrance is about 700 feet in elevation, 280 feet above the river. The present maximum depth of the cave is 260 feet below the entrance.

Future plans include leveling to the Overlook area in order to provide a link with passages accessible from the Austin entrance. Minor passages will also be leveled to provide detail for the hydrologic interpretation of the cave. Preliminary results from the project have been outlined in a recent publication by Arthur N. Palmer and Franz-Dieter Miotke.

A GEOMORPHIC INVESTIGATION OF THE KARST PLAIN
(PENNYROYAL PLATEAU OF SOUTH CENTRAL KENTUCKY)

Steve G. Wells

The morphology of surface karst features and their interrelationship to the subterranean features was investigated in the sinkhole plain of south central Kentucky. The area of investigation is situated on a low relief plateau developed on 430 foot (130m) thick sequence of limestones of Meremac Age (Upper Mississippian), southwest of Mammoth Cave National Park. This area was chosen because of the large lateral extent of the plain which affords the maximum possibility for the surface and subsurface integration. Genetic relations between relief processes and structural and stratigraphic variations are examined to illustrate the degree to which these factors control the landscape in the study area.

Controversy over the genesis of karst plains in humid, temperate climates is centered around the effects of structure and stratigraphy versus the effects of baselevel on the karst landscape. It has been suggested that the karst plain of the Pennyroyal Plateau in Kentucky is a stripped, structural surface developed on resistant lithologic units. However, studies in the sinkhole plain of southern Indiana (Mitchell Plain) reveal erosional levels which support fluvial erosion of the carbonate terrain. Recent investigations in the Mammoth Cave region (Chester Cuesta or Mammoth Plateau) suggest important relations betweel fluvial terraces and cave elevations. It is the undertaking of this study to determine the controls of the karst landscape for this section of the Pennyroyal Plateau.

A major portion of the study area is comprised of a large, single drainage basin which encompasses a total area of 140 square miles (364 km^2). This was determined by subterranean dye tracings conducted by Franz-Dieter Miotke and the author in the spring and summer of 1972 (see Figure 6). The resurgence for the watershed is a spring complex, known as Graham Springs, situated on the Barren River near the edge of the Chester Cuesta. The Graham Springs system has a surface channel over 1500 feet (457.5m) long, along which four springs are located. The fact that there is only one outlet system which has remained horizontally stationary over an extended period of time is indicated by two terraces at elevations of 430 feet (130m) and 440 feet (134.2m) and by associated abandoned spring alcoves. This evidence, along with the karst ground-water flow times, suggests an integrated system (limited number of master conduits) whose hydraulic gradient has remained high enough to maintain a grade to the master drainage, the Barren River.

Approximately thirty-two square miles (83.6 km^2) of the headwater region of the Graham Springs watershed is characterized by several sinking streams. A new method was devised to determine whether any fluvial erosion could be detected on the karst plain by means of the sinking stream morphology. A mathematical equation was used to model the slopes (longitudinal profiles) of the sinking streams. The exponential curve defined by the equation:

$$Y = Ae^{Bx}$$

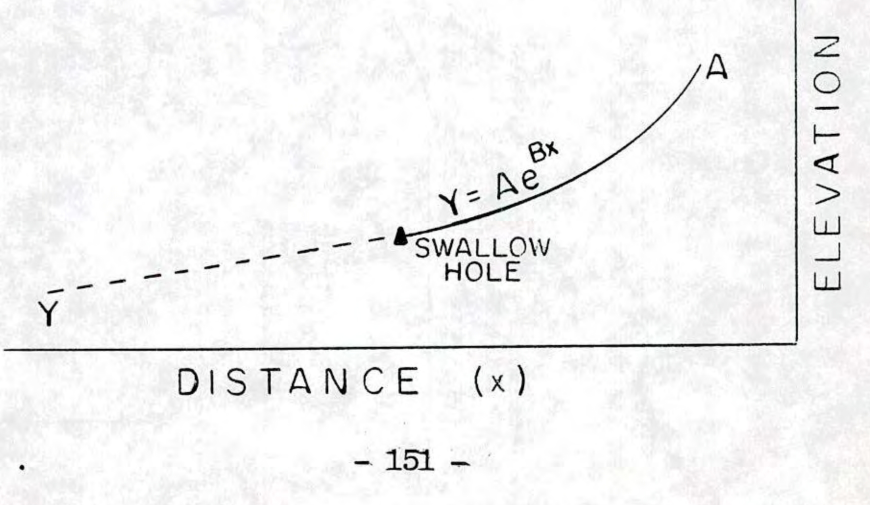
where Y is the elevation of the local baselevel, A represents the elevation of the headwaters, B is the wear-coefficient, and x is the distance downstream, has a remarkable correlation with the actual stream profiles (Table 2). All correlation coefficients for the best fit curve to the actual stream slope are greater than 0.95. Projection of the sinking stream slopes beyond the terminal ponor have an average baselevel elevation (Y value) of 460 feet (140.3m), nearly 100 feet below the surface of the karst plain. Results suggest that the sinking streams are graded to the karst ground-water level, which is a function of the cave systems' elevation and discharge. Variations in the values for Y may be due to the fact that the terminus of a sinking stream will vary with discharge (during high discharge they sink at the terminal swallow hole, but during low discharge they will sink several hundred feet upstream). Another plausible explanation for variations in Y values could be related to the drainage basin sizes, where higher Y values occur with the larger drainage basins. However, changes in the karst ground-water elevation will

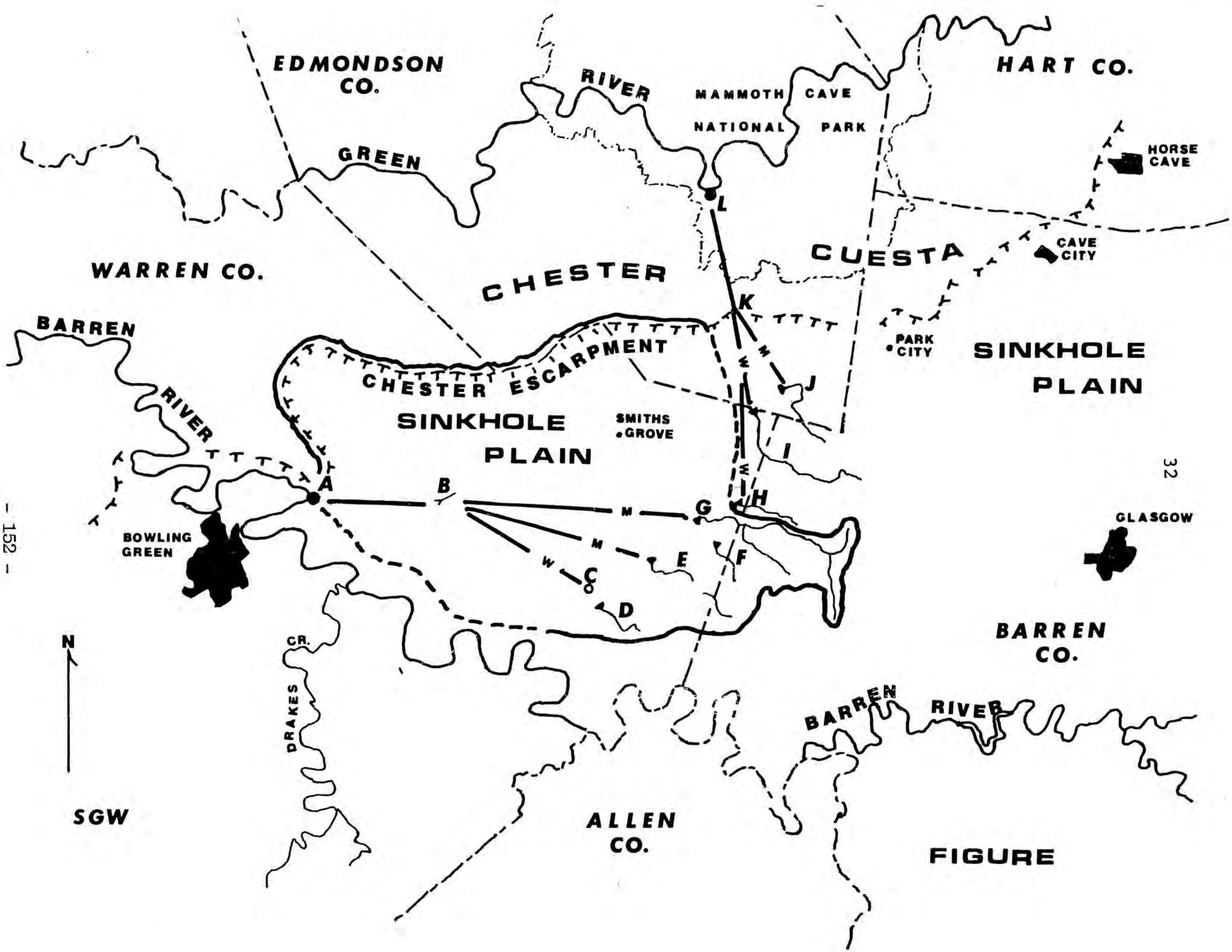
TABLE 2

Exponential Equations for Best Fit Curves of the Sinking Streams in Karst Plain

DOTY CREEK	$486' = 671.23e^{-.0525x}$	r = -.982
PONDSVILLE CREEK	$444' = 677.95e^{-.0631x}$	r = -.999
SINKING CREEK	$512' = 726.36e^{-.0287x}$	r = -.984
MOISER SINKING CR.	$437' = 621.24e^{-.091x}$	r = -.972
KEPLER (4) S. CR.	$451' = 580.76e^{-.101x}$	r = -.993
GARDNER CREEK	$445' = 692.89e^{-.064x}$	r = -.992
LITTLE SINKING CR.	$529' = 729.49e^{-.029x}$	r = -.989
SINKING BRANCH	$416' = 705.33e^{-.068x}$	r = -.955

The exponential equations are in the form of $Y=Ae^{Bx}$, where Y is point which represents baselevel of sinking streams, A is the elevation of the stream's head, x is miles downstream)x=0 at A), and the correlation coefficient is represented by r.




EDMONDSON CO.
RIVER
GREEN
MAMMOTH CAVE NATIONAL PARK
HART CO.
HORSE CAVE
L
WARREN CO.
CHESTER
CUESTA
CAVE CITY
K
BARREN
PARK CITY
SINKHOLE PLAIN
CHESTER ESCARPMENT
J
RIVER
SINKHOLE PLAIN
SMITHS GROVE
I
A
B
M
G
H
W
BOWLING GREEN
GLASGOW
E
F
C
D
N
CR.
DRAKES
BARREN CO.
BARREN RIVER
SGW
ALLEN CO.
FIGURE
32

LEGEND FOR FIGURE

A - Graham Springs

B - Graham Springs Cave

C - Elk Spring

D - Moiser Sinking Creek

E - Doty Sinking Creek

F - Pondsville Sinking Creek

G - Sinking Creek

H - Sinking Branch

I - Little Sinking Creek

J - Gardner Creek

K - Mill Hole Karst Window

L - Turnhole Bend Spring

Subterranean Flow Paths,
M = Miotke dye tracing
W = Wells dye tracing

Graham Springs Drainage Basin boundary, solid line represents topographic divide, and dashed line is a karst ground water divide.

affect the hydraulic gradients of the sinking streams. The elevation of the ground-water in the karst plain is related in part to the discharge of the Barren River where the average level of the ground water is increased approximately (6.1m) 20 feet during periods of moderately high discharge.

Results show little relation between cave passage trends, elongate sinkhole orientations, and fracture patterns in the study area. Elongate sinkhole orientations don't coincide with the orientation of measured joints, nor do they show close correlation to major cave passage trends, suggesting little major collapse into the cave systems. Further evidence for this is cited by the fast ground-water flow times which indicate that the sinkholes do not penetrate the vadose portion of the karst groundwater. Two major cave systems (Graham Springs and Smith Grove caves) are used as field evidence, which combined have a total of nearly 10,000 feet of survey. There also appears to be little correlation between fractures and cave passage trends suggest the major ground-water systems are oriented to maintain grade with the master surface drainage. The preferred orientation of the cave passages are along the strike (no stratigraphic implications since strike is an arbitrary orientation in space) and oblique to the dip of the strata. Further evidence for lack of stratigraphic controls is illustrated by the mere fact that the karst ground-water system originates in the St. Louis limestone (lower stratigraphically) and resurges in the Ste. Genevieve limestone (higher stratigraphically). Very little evidence has thus been observed in the field for any major type of structural and stratigraphic controls on the karst plain landforms.

GRAVITY MEASUREMENT AT CARLSBAD CAVERNS

John McLean

The purpose of the gravity measurement program is to investigate the correlation of gravity anomalies with the existence of cave passages below. In order to establish the density gradient in the area, a gravity profile was run down the elevator shaft at Carlsbad Caverns. The mean density is about 2.37 grams per cubic centimeter. Approximately 1000 surface survey points have been established during 1972 using plane table surveying techniques. These stations are being set on a 100 foot interval with supplemental stations for topographic control. To date, approximately three quadrangles have been completed and gravity measurements will be made at the stations before the next quadrangles are mapped. A 20 x 30 inch quadrangle represents an area 1000 x 1500 feet at the scale of 1" = 50' and is established on the same grid system on which the cave map of Carlsbad Caverns is to be published.

GEOLOGIC INVESTIGATIONS OF OGLE CAVE, NEW MEXICO

Harvey R. DuChene, Dwight E. Deal, David H. Jagnow, John McLean

A comprehensive geological study is being made of Ogle Cave, Carlsbad Caverns National Park. Ogle Cave is located in Slaughter Canyon, approximately 500 feet above the canyon floor. The cave is strongly joint controlled and was connected to Rainbow Cave via a "joint" passage in 1966 by the Guadalupe Cave Survey. Particular areas of interest are the structure, stratigraphy and mineralogy of Ogle Cave and the adjoining area. Carol A. Hill is working on the mineralogy and distribution of speleothems in Ogle Cave. Harvey R. DuChene, John McLean and Dwight Deal are working on the stratigraphic and structural features of the cave and surrounding area. A long range goal of this project is a thorough stratigraphic study of the rocks in Slaughter Canyon including several measured sections beginning at the Guadalupe Escarpment and going back to the point where the Capitan Limestone is no longer exposed.

SPELEOGENESIS IN THE GUADALUPE MOUNTAINS

David H. Jagnow

The goal of this project is to piece together the most comprehensive picture of speleogenesis in the Guadalupe Mountains to date. The work will be published as an MS thesis during 1973 and is entitled "Factors Controlling Speleogenesis in the Guadalupe Mountains, New Mexico and Texas." In the past much has been published on Carlsbad Caverns, but the hundreds of other caves in the Guadalupe Mountains have largely been ignored. Only an estimated 3% of the known Guadalupe caves have had geologic reports published on them. This project will study 30 to 40 caves throughout the Guadalupes, analyzing structural controls, lithologic controls and base level controls on each of the caves. To date joints have been mapped in the Left Hand Tunnel, the Mystery Room and the New Mexico Room of Carlsbad Caverns.

PROGRAM IN ECOLOGY

THE DISTRIBUTION AND POPULATION DYNAMICS OF THE CAVE CRAYFISHES OF SOUTHERN INDIANA

H. H. Hobbs III

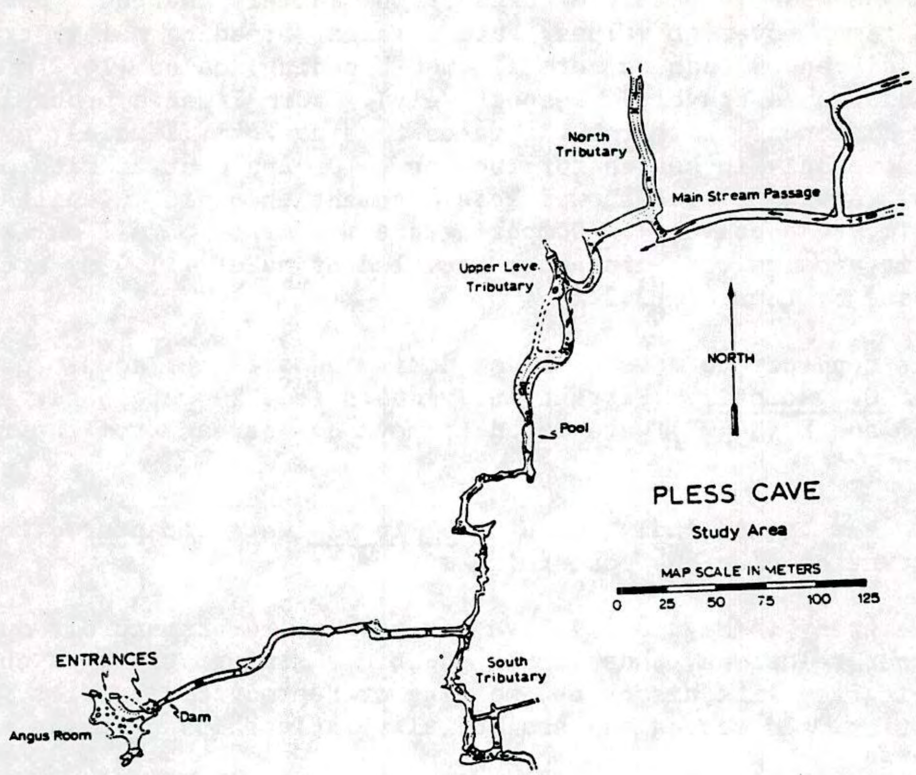
Five species of crayfishes are known to occur within the subterranean waters of Indiana caves. Orconectes inermis inermis (Fig. 1), a troglobite, occurs in 39 caves in Crawford, Greene, Harrison, Lawrence, Martin, Orange, and Washington Counties. Orconectes inermis testii, also a troglobite, is restricted to the caves of Monroe County (13). Cambarus (Erebicambarus) laevis, a troglophile, has been observed in 46 caves in Crawford, Decatur, Dubois, Greene, Harrison, Lawrence, Monroe, Orange, Owen, and Washington Counties. Two trogloxenes (?), Orconectes propinquus and Orconectes immunis, have been observed in the waters of one and two caves, respectively, in Lawrence County. Very few caves developed in Silurian limestones in the southeast portion of the state have been visited. However, no troglobitic forms are known to occur within these, and to date, only one cave in Decatur County has yielded a single specimen of C. laevis.

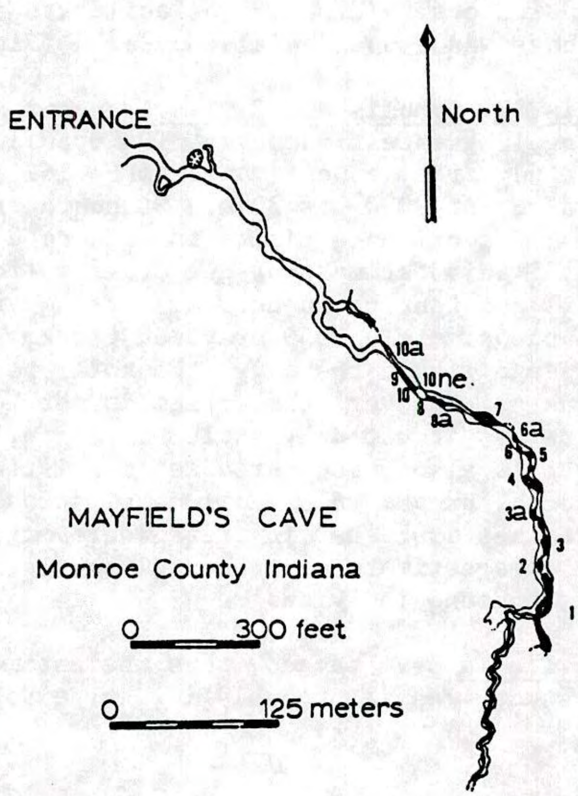
An attempt to determine the population dynamics of O.i. testii and C. laevis in Mayfield's Cave began September, 1969. The cave (Fig. 2), 4.8 km northwest of Bloomington, Monroe County, is developed in the Ste. Genevieve limestone and is approximately 550 m long. A stream with alternating riffle-pool areas flows from the rear of the cave and sumps approximately 230 m from the entrance. During the seven-month study period, 49 O.i. testii and 19 C. laevis were individually tagged with fingernail polish. Twenty-five of the tagged individuals were observed at least once after marking, for a 42.3% recovery rate (40.9% O.i. testii and 20% C. laevis). Using the Peterson index, the population of O.i. testii was estimated to be 128 over the 300 m study area; one crayfish per 2.3 m, or 13 per 30 m. The standard error was calculated to be 16.75, thus the 95% confidence limits for the population are 115 and 161.

The population of C. laevis was estimated to be 13 (this is well underestimated due to small sample size), one crayfish per 23.1 m, or 1.3 per 30 m. Standard error was 1.36, thus the 95% confidence limits for the population are 10.3 and 15.7.

Minimum and maximum distances moved by individual O.i. testii are 0 m and 42 m; however, 73.9% of the individuals moved up to 10.5 meters away from their original marking site. It is apparent from these few data that most individuals restrict their activity to a specific area ranging up to 10.5 m ("familiar home range").

The range of movements of O.i. testii does not appear to be related to the size of the animals. However, there is an apparent correlation


North Tributary
Main Stream Passage
Upper Leve. Tributary
NORTH
Pool
PLESS CAVE
Study Area
MAP SCALE IN METERS
0 25 50 75 100 125
ENTRANCES
Dam
Angus Room
South Tributary


North
ENTRANCE
10a
9
10ne.
10
8
8a
7
6a
6
5
4
3a
3
2
1
MAYFIELD'S CAVE
Monroe County Indiana
0 300 feet
0 125 meters

that can be made between the sexes of the animals and their home ranges. Using maximum movement values, Form I males (breeding males) travel greater distances than do Form II (non-breeding) males (14.2 m and 2.9 m - mean distances traveled, respectively). Form I males probably travel greater distances in search for mates than do Form II males, which most likely move only in search for food or to escape contact with other individuals. Adult females showed less movement than did juveniles (2.2 m and 5.1 m, respectively). Comparing the movements of all males and females, it appears that distances traveled by males (11.4 m) are greater than those by females (3.2 m).

The tendency to move upstream dominated over the downstream movements of O.i. testii. Fifteen individuals (65.2%) were observed to move upstream and 8 (34.8%) were found to move downstream from their tagged location.

Too few tagged individuals of C. laevis were recaptured to draw any significant conclusions concerning movements.

The study in Mayfield's Cave was terminated prematurely due to poor land-owner relations, thus little additional information was obtained concerning the life histories, molting or reproductive cycles, behavior, competition, and ecological and social relationships of these two cave crayfishes.

Pless Cave, developed in the Salem and St. Louis limestone formations in Lawrence County, was chosen as an alternate cave in which to conduct studies of cave crayfishes. Nearly 5 km of passages have been mapped, through which a stream(s) flows, varying in depth (normal flow) from several centimeters to 2.5 m. To facilitate study, a particular section of the cave was chosen as a study area (Fig. 3).

O.i. inermis, O. immunis and C. laevis occur in the cave, with O.i. inermis occurring in greatest numbers. The population size of O.i. inermis in the study area was estimated to be 1623 over 540 meters; one crayfish per 0.33 m, or 90.0 per 30 m. Standard error was calculated to be 110. The 95% confidence limits for the population are therefore 1407 and 1839. If this estimate of one crayfish for every 0.33 m of stream passage is constant throughout all stream areas of the cave, there would be approximately 3030 crayfish per km. If one assumes three km of stream passage within the cave, the total population in Pless Cave is 9090 individuals. However, the stream is not homologous throughout its entire course, as it not only varies in depth, flow, and gradient, but the substrate is also quite variable, consisting of silt, sand, gravel, small rocks, breakdown and all combinations thereof. Also the density of crayfishes is higher in areas where organic debris has accumulated. Thus, this estimate of the total cave population is undoubtedly high by several thousand individuals.

Only 13 C. laevis were tagged, thus the estimate of 70 individuals over the 540 m study area is probably low. The 95% confidence limits are 23 and 117.

All three species of crayfishes were internally (permanent - ink injection) and externally (temporary - fingernail polish) tagged when captured and then released. To date, 226 crayfishes have been permanently tagged, 211 O.i. testii, 2 O. immunis, and 13 C. laevis. Thirty-two additional small (less than 17 mm) O.i. inermis were temporarily marked (numbers painted on mid-dorsal region of carapace).

During the two year study, 96 tagged individual O.i. inermis were recaptured at least once for a 45.5% recovery rate. One marked O. immunis and 5 tagged C. laevis were recovered, for a recapture rate of 50% and 38%, respectively.

Minimum and maximum distances moved by individual O.i. inermis are 0 m and 571 m. Separating the population by sex, the minimum and maximum distances moved by males are 0 m and 204 m. The mean distances moved downstream by males is 39.24 m and upstream 22.61 m. Minimum and maximum distances moved by females is 1.5 and 571 m. Mean distances moved are 81.13 m downstream and 32.09 m upstream. In both sexes, downstream movements are greater than those against the current, thus demonstrating the strong influence flooding exerts upon the population. Size of individuals and length of time between recaptures does not significantly affect the movement of individuals.

With 13 individual C. laevis tagged and only 5 recaptured, data are too few to make interpretations of their movements. Individual females demonstrated a maximum movement of 15 m downstream and 12 m upstream. Males moved 30 m downstream and 38 m upstream.

The size distribution of O.i. inermis varied from 17.0 mm (carapace length) to 34.0 mm (♂) and 15.9 mm to 32.0 mm (♀). These measurements represent those animals tagged. However, numerous smaller (less than 15 mm were observed. C. laevis ranged in length for males from 19.6 mm to 40.0 mm and females ranged from 24.5 mm to 50.2 mm. The few observed individual O. immunis ranged from 24.6 mm to 27.5 mm.

The study of growth of crayfishes is simplified, as they increase in size only after molting occurs. Individuals equal to or larger than 20 mm increased only 1.0 mm (mean for males). Females showed a mean increase of 1.8 mm per molt. Those specimens tagged that were less than 20 mm in length were not recaptured frequently enough subsequent to molting to evaluate their growth rates. Only three (2♂, 1♀) crayfish were recorded and values ranged from 0.7 mm to 2.9 mm increased length. Without additional data, no additional comments can be made concerning the growth rates of juvenile crayfishes.

Two major periods of molting for O.i. inermis occurred from March to April and from August to September, both sexes following this pattern during the study. The population of breeding males is lowest during the spring and early summer months (March to July) and rises during August and September to a peak in late October and early November. The non-breeding male population is lowest at this time and increases to a high during the month of June. These changes in male form are closely correlated with the observed major molting periods.

The adult females follow a similar molt cycle to that of the adult males. There is some variation in the fall molt period as the ovigerous females observed during the spring and early summer months molted at a slightly later date (October, November) than non-ovigerous females. This "lag" in ecdysis is most probably attributed to the reproductive cycle, as an individual bearing eggs or young would not only loose the exuivae at ecdysis, but also cast off the developing embryos.

The reproductive cycle of the troglobitic crayfishes is relatively easy to trace, as the translucent carapace enables one to observe directly the changes in size and shape of the gonads of males and females, and particularly the formation and growth of oocytes in the females.

Many environmental parameters were measured each visit to the cave. Deep within the cave ("constant temperature zone") the air temperature remained relatively constant, varying only 2.9°C during the study. Water temperatures were affected greatest during periods of flood and during snow or ice melt. Even during these periods the temperature never varied more than 3.1°C within the cave.

Water chemistry data also indicated the cave environment to be relatively predictable. The extremes shown below are related primarily to floods during the spring and winter months. Oxygen levels were high, varying from 9.62 ppm (89% saturation) to 12.39 ppm (113% saturation). Methyl orange alkalinity ranged from 65.0 ppm to 256 ppm. pH values ranged from 7.39 to 8.21.

Current velocity varied considerably throughout the study period, revealing a summer low of 0.67 cfs to a spring high of 109.74 cfs. This increased volume of flow, no doubt, has tremendous effects on the fauna in the cave and certainly can explain some of the great distances individuals moved downstream after spring flooding.

PREY-PREDATOR INTERACTION: HADENOECUS EGGS EATEN BY NEAPHAENOPS

Thomas C. Kane and Thomas L. Poulson
(MACA-N-14 and N-15)

Detailed analysis of species or interactions between species is needed to provide comparisons with the larger body of knowledge of aquatic species and to characterize the evolutionary strategies of species from different parts of the ecosystem. Russell Norton has reported on aspects of this interaction in past annual reports; he is now concentrating on the cricket's reproductive and behavioral strategies that minimize predation on its eggs by the beetle. Thomas Kane is concentrating on the beetle's foraging strategy when eating only cricket eggs so that he can predict differences in diet when Neaphaenops competes with Pseudanophthalmus species.

Schoener has proposed a model of optimal feeding strategy in solitary predators, that is, predators that exist in the absence of closely related competing species and monopolize a more or less discrete energy source. This type of model is appealing in that it allows one to construct a baseline energy cost budget of the various parameters of predation (e.g., cost of searching, cost of handling, etc.) in the abscence of competitors and predict which of these parameters will change if a competitor is present. These predictions can then be tested by introducing a competitor or by manipulating the system in such a way as to mimic competition.

Unfortunately, the model has so far only been tested using very special types of vertebrate predators, namely pursuers like raptorial birds and island lizards. Because of its general value, the model will be extended to invertebrate predators by testing it using the cave trechine beetle Neaphaenops tellkampfii which is a searching predator.

The principal work done so far has involved establishing that Neaphaenops is in fact a solitary predator. Previous work (Barr and Kuehne, 1972) has shown that Neaphaenops preys on the eggs of the common cave cricket, Hadenoecus subterraneus, which are deposited primarily in the upper level sandy passages of caves or in other areas of loosely packed substrate.

To meet Schoener's criteria for a solitary predator, two requirements had to be met:

1. No other cricket egg predator could be present. This first criterion was easily met, since no other beetle in the sandy cave passages of Mammoth Cave National Park shows the appropriate digging behavior required of a cricket egg predator.

2. Neaphaenops must prey solely on cricket eggs, at least in sandy areas. A number of pieces of experimental data indicate that this second requirement is also met.

A. N.t. density is much greater in sandy areas than on any other type of substrate, yet species diversity and organic content are lower in sand indicating that other potential food items are more abundant in non-sandy substrates.

B. A study of mean free path, the mean rectilinear distance moved by an organism per unit time, indicates that it is lower on sand than on any other substrate for N.t. This implies that N.t. searches more thoroughly on sand and spends more time in a sandy patch than in an equal sized patch of any other substrate.

C. Bait trapping studies indicate that N.t. does not come to bait readily in sand areas, although it is captured in fairly large numbers in bait traps in non-sandy substrates.

D. Perhaps the most conclusive evidence comes from N.t. substrate choice. Four 1 m^2 plots of substrate were set up in the Natural Bridge area of Mammoth Cave, an area of highly compacted, relatively dry substrate. The four plots were treated as follows: 1 contained only sand; 1 mud; 1 rocks;

and 1 a randomly distributed equal amount of all three. The plots were trapped for 15 weeks and the contents analyzed for presence of N.t. If the beetles showed no preference, approximately equal numbers should have been captured in each plot. However, a Chi-square value of $p<.005$ shows that this is not the case and that the beetles preferentially choose sand.

E. A final bit of evidence involves behavior within a sand patch using hole digging as an assay. For this study $1m^2$ plots were set up in cave areas representing the three types of substrate previously mentioned. The m^2 plots were divided into 25 subsquares, checkerboard fashion, and half were randomly assigned sand treatment, the other half mud. In every case a Chi-square test indicated significantly greater hole digging in sand than in mud.

Having now established N.t. as a solitary predator in sandy areas, the next phase of the study will involve detailed studies of the various energetic costs of various predation parameters. Subsequent to this the system will be manipulated in such a way as to introduce competition and test for predicted changes in N.t. predation strategy.

CAVE VERSUS SURFACE POPULATIONS OF THE SNAIL CARYCHIUM

Richard W. Greene
(MACA-N-15)

Studies on these snails are of interest in understanding the evolutionary transition from troglophile to troglobite, since this is one of few situations where surface and cave populatins of any organism are found in the same local area.

At the present time specimens from cricket guano slopes in Little Beauty Cave and White's Cave are being compared to specimens of an epigean Carychium sp. from Mammoth Dome Sink, especially with regard to eye development. Preliminary results show that eyes of cave-dwelling specimens are rather well developed when compared with surface forms. This is consistent with an earlier report (Harry, 1951; thesis, U. of Michigan, Ann Arbor) which stated that C. stygium was not blind. Observations are being made in Little Beauty Cave on the size distribution of the snails throughout the year in order to better understand their life history.

COMMUNITY ANALYSIS

Thomas L. Poulson
(MACA-N-14 and N-15)

Is there seasonal reproduction?

Since January we have done size-frequency distributions of species with indeterminate growth and teneral frequencies for beetles in different areas of Flint-Mammoth Cave. So far we see no changes which suggest a seasonal pulse of reproduction in any species. If many of the organisms live a long time and reproduce slowly, as in many aquatic species, then it will take several years of data to discern the times when the young are present.

Species diversity in relation to evolutionary strategy

Pitfall and bait trapping are compared to see if those species attracted to bait are those from communities of low diversity and are those with the higher rates of reproduction as determined from "A" and egg number and size (dissection studies once season of reproduction has been determined).

Pitfall trapping and visual census both show that many species have a very high mobility and that there is a higher species diversity when food is scarce. Diversity in and around bait traps is lower because of a differential attraction of "crickets", diplurans, catopid beetles, and tomocerine collembola with some avoidance of bait by trechine beetles and other presumed predators.

Trapping and census in areas of loose substrate, especially sand, show that the community in these "cricket"-beetle areas is more complex than heretofore suspected. The Hadenoecus and Neaphaenops are still overwhelmingly abundant, giving a low equitability and so lower species diversity than in mud-debris areas, but there is a definite sub food web probably based on cricket feces. This sub web includes diplurans, two types of collembola (Arrhopalites and Folsomia?), and three presumed predators (a spider, Anthrobia; a mite, Rhagidia; and a pseudoscorpion, Kleptochtonius).

There is no difference in relative humidity (or desiccation problems as indexed by saturation deficit) along a transect through Great Onyx Cave even though there are striking differences in occurrence and abundance of sulfate minerals and animal life. This suggests that differences in species diversity are due rather to some combination of distance from entrances accessible to crickets, substrate moisture, substrate texture, and perhaps substrate sulfate minerals. This will be an interesting area for cooperative research between mineralogists and ecologists.

Experimental manipulation of substrate and food

The aim is to test alternate, multiple hypotheses concerning the control of species diversity.

1. Substrate diversity: Earlier studies have shown a correlation of substrate diversity with species diversity but we felt this was spurious, because many areas of high substrate diversity also have steady food input and relatively invariant microclimate. Replicate 1 m^2 plots in an area with even food input and steady microclimate, of all sand, all mud, dirt and rock, and sand-mud-dirt-rock substrate show that the correlation of species diversity with substrate diversity is real.

2. Food: Experiments have been designed to test the effect of aggregation around concentrations of food of uniform composition and the effect of food quality, principally rate of possible utilization, on species diversity in different areas of and kinds of caves.

a. Food dispersion: Use of dead leaves of uniform food quality shows that clumped food vs dispersed food has the same general effect as bait vs non-bait traps except that the difference in diversity is not as great and the equitabilities are never as low as with bait traps using liver and limburger cheese.

b. Food quality: The effect of calories available per time is being studied by following microsuccession of species composition and diversity with time on a heterogeneous food source, namely horse manure. It is already clear that more frequent census will be necessary in the early stages as the most available calories are consumed quickly. In the first week crickets, phorid flies, and catopid beetles predominate and as the most available calories are used in the first month the species diversity increases as sciarid flies and collembola arrive and dominate the bait station.

BIOGEOGRAPHY OF CKK AS COMPARED TO APPALACHIAN VALLEY CAVES

Thomas L. Poulson, Thomas C. Kane, and James Keith

Absolute counts on all the fauna in randomly selected CKK sinkhole plain caves have been made to compare to the best fauna caves in the Appalachian Valley and randomly selected caves censused by John Holsinger and David Culver. Kane and Poulson have visited the Appalachian Valley caves to insure that the results are not due to difference in census methods.

Sinkhole Plain vs Mammoth Cave Plateau Caves

The overall fauna of the large plateau caves, such as Flint-Mammoth, does not differ from that of small caves on the plateau, such as Little Beauty, or small caves on the sinkhole plain, such as Parker's, Hanson's or 70 Sinks. The fauna in these small, relatively disconnected (in geological time), and relatively rigorous (in terms of flooding and seasonal change in microclimate) caves are in fact more diverse than in the most diverse areas of equal extent in the large plateau caves.

Sinkhole Plain vs Appalachian Valley Caves

Based on 4 caves from each region the species diversity, abundance of animals, continuity of fauna between seasons, and overlap of fauna between caves are all greater in the Central Kentucky Karst. The reason for this is not differing diversities of the possible ancestral faunas; there is none. It does appear to relate to greater cave interconnectivity and cave longevity in the CKK with associated differences in the time available for cave adaptation or rates of cave adaptation.

THE NEAPHAENOPS-HADENOECUS PREDATOR-PREY SYSTEM

Russell M. Norton

Research on this problem, begun in 1968-69, was inactive during 1970-71, but has now been resumed. For a discussion of previous results, refer to the Eleventh Annual Report of the CRF (1969).

Current work centers on the impact of egg predation on Hadenoecus (cave cricket) populations. In the Pennyroyal plateau of western Kentucky, the predator is the trechine beetle Neaphaenops, and in the edge of the Cumberland plateau in eastern Kentucky, the predator is the trechine beetle Darlingtonea. Both predator-prey associations are found in a rather large number of caves, and both associations appear to be highly coevolved since:

1. Neaphaenops searching behavior is related to Hadenoecus oviposition behavior. Especially, Neaphaenops avoids digging for eggs when they encounter the type of puncture hole made when Hadenoecus is testing the substrate with its ovipositor prior to oviposition. The controls for this experiment consisted of both a similar hole produced with a toothpick and untreated squares.

2. It has been shown that egg production by Darlingtonea in winter is highly correlated with egg production by Hadenoecus (Marsh, 1969).

3. I have found Hadenoecus ovipositors are consistently longer in caves which have a predator, although adult body sizes are the same.

Therefore, current research is aimed at four evolutionary aspects of these predator-prey associations:

1. How far does the convergence between Neaphaenops and Darlingtonea extend?

2. How do the demographic parameters of Hadenoecus compensate for the impact of predation?

3. Does the predation lead to a seasonal adjustment on the part of the prey?

4. What adaptive responses are present in the oviposition patterns of predated Hadenoecus?

BIOLOGY OF THE GUADALUPE CAVE AREA

William R. Elliott and Sigurd Szerlip

Biological studies during 1972 were carried out in New Cave, Able Goat Cave, Ogle Cave, and in the Bat Cave section of Carlsbad Caverns. Two species observed, *Brackenridgia* and *Ceuthophilus* are of particular interest.

One female of the species *Brackenridgia*, an isopod, was collected in New Cave. James Reddell collected the only other *Brackenridgia* (also female) observed in Carlsbad Caverns. There is no record of this species being found in New Mexico prior to the above two. It is still necessary to collect some males for complete identification.

Of ecological interest is the now established fact that there are three species of *Ceuthophilus* in Able Goat Cave. This is the first such cave in the Guadalupes with this many species. An ecological study could well be done here in the future, since one of the species is an entrance dwelling trogloxene, another is a twilight, entrance and dark zone troglophile, and the third is a twilight and dark zone troglobite.

Work that could be done in the future would include a supplement to the record of species found in the Guadalupes published by Barr and Reddell in 1967. Also, a comparison of the fauna from entrance sinks and entrance areas of the Guadalupe caves to the troglobites which are able to adapt completely to the cave could be of value in determining distribution patterns and evolutionary trends of cave dwelling arthropods in the Guadalupes and New Mexico.

ARCHEOLOGY

ARCHEOLOGICAL ACTIVITIES IN MAMMOTH CAVE AND VICINITY

Patty Jo Watson
(MACA-N-24)

Archeological work in and around Mammoth Cave National Park in 1972 began with reconnaissance of several Green River shellmounds in the vicinity of Morgantown and Rochester, Kentucky, and test excavation of one of these: the Carlston Annis site in Butler County. It was thought that these Archaic shellmounds should overlap in time with aboriginal use of the MCNP caves and would provide subsistence and other data comparable to that from our excavations in Salts Cave Vestibule. Two radiocarbon dates just released (October 1972) by the UCLA Institute of Geophysics and Planetary Physics indicate that at least this one shellmound -- Carlston Annis -- was contemporary with some of the prehistoric caving activity in MCNP (see Summary Sheet of Radiocarbon Dates). Flotation samples, animal bone, and mussel shell from Carlston Annis are being analyzed by Richard Yarnell, Lathel Duffield, and David Stansbery, respectively. All of these experts have worked on Salts Cave Materials. The shellmound work was supported by a Washington University research grant.

During May, 1972, archeological observation and recording trips were made to the K and E surveys in Mammoth Cave's Ganter Avenue area, and through the Violet City to Historic Entrance commercial route. Surprising quantities of relatively well preserved material were noted and further work is planned in Mammoth Cave for the future in order to ensure thorough documentation of these remains.

Robert Stewart, ethnobotanist, has completed a quantitative analysis of the food contents in 23 paleofecal specimens from Mammoth Cave. His results plus the work of Yarnell (plant remains), Duffield (animal bone), Robbins (human remains), Stansbery (mussel shell), Schoenwetter (pollen), and Dusseau (parasites in the paleofeces) on material from the Salts Cave Vestibule excavations will be included in a volume now being assembled by P. Watson: ARCHEOLOGY OF THE MAMMOTH CAVE AREA. This book is a sequel to the 1969 Illinois State Museum publication on Salts Cave and will contain accounts of all archeological work done since 1969 in MCNP by the CRF project. It will be published by Seminar Press in New York.

Since 1969, the archeological project of the CRF has been partially supported by a National Geographic Society Research grant.

TABLE

Summary of Available Radiocarbon Dates* 1972

Salts Cave

Vestibule

710 B.C. ± 100 (GaK 2622)
990 B.C. ± 120 (GaK 2765)
1410 B.C. ± 220 (GaK 2764)
1460 B.C. ± 220 (GaK 2766)
1540 B.C. ± 110 (GaK 2767)

(all dates on charcoal)

Cave Interior

290 B.C. ± 200 (M 1573) (squash seeds)
320 B.C. ± 140 (M 1777)
400 B.C. ± 140 (M 1577) (squash pollen)
620 B.C. ± 140 (M 1574) (gourd seeds)
710 B.C. ± 140 (M 1770) (sunflower)
(The above 5 dates are on paleofecal material)

480 B.C. ± 140 (M 1585)
560 B.C. ± 140 (M 1584)
570 B.C. ± 140 (M 1587)
770 B.C. ± 140 (M 1588)
890 B.C. ± 150 (M 1586)
1190 B.C. ± 150 (M 1589)
(The above 6 dates are on wood or bark)

1125 B.C. ± 140 (I 256)
(The above date is on soot)

Little Al Interior

A.D. 30 ± 160 (M 2259)
10 B.C. ± 160 (M 2258)
(The above 2 dates are on internal tissue from the Salts Cave mummy)

Mammoth Cave Interior

280 B.C. ± 40 (X-8) (This date is on a slipper fragment)
420 B.C. ± 60 (X-9) (This date is on cane fragments)
1050 B.C. ± 70 (UCLA 1730B) (wood)
2170 B.C. ± 70 (UCLA 1730A) (dried, weed stalks)

Lee Cave Interior

2250 B.C. ± 65 (UCLA 1729A)(cane)
4100 B.C. ± 60 (UCLA 1729B)(log fragments)

Wyandotte Cave, Indiana Interior

910 B.C. ± 60 (UCLA 1731B) (Bark and sticks from under Fallen Rock in Washington Hall)
A.D. 240 ± 80 (UCLA 1731A) (Bark and wood from Rugged Mountain)

Carlston Annis Shellmound, Bt-5 (Butler County, Kentucky)

2090 B.C. ± 180 (UCLA 1845B) (charcoal from level 8)
2300 B.C. ± 80 (UCLA 1845A) (charcoal from level 10)

November, 1972

*All calculated on the basis of the Libby half-life and with 1950 base date.

HISTORY AND ECONOMICS

HISTORY OF THE PEOPLES AND CAVES OF FLINT RIDGE, KENTUCKY

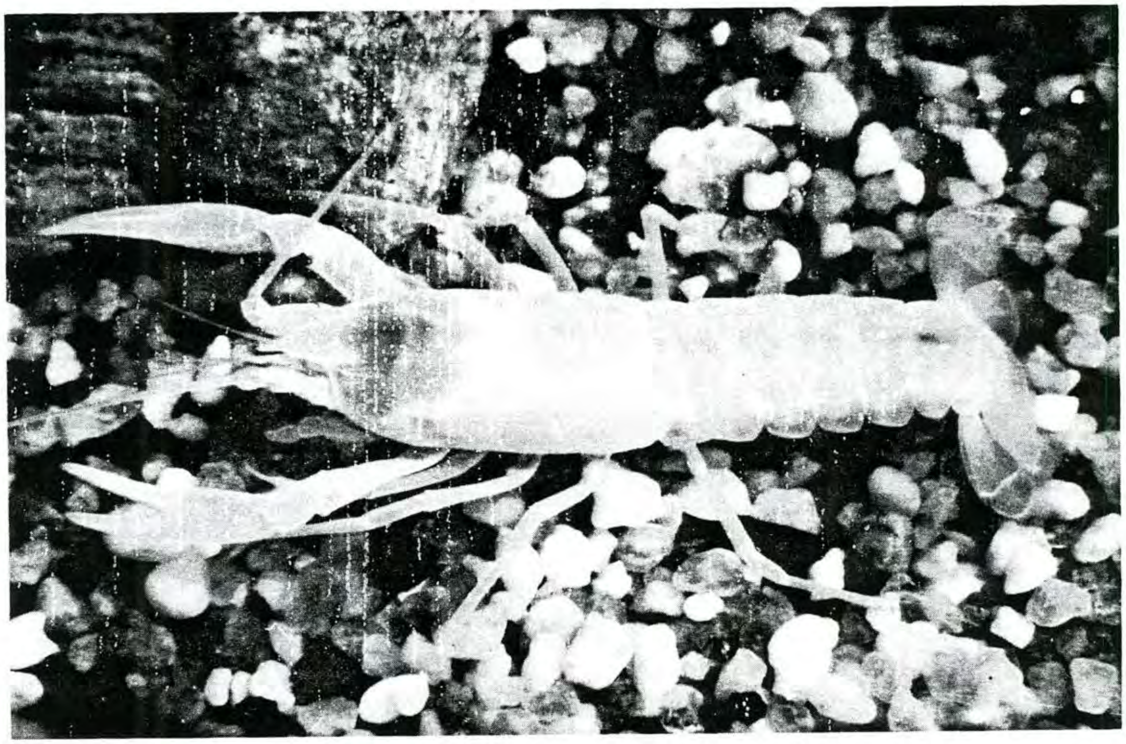
Stanley D. Sides
(MACA-H-1)

The field program initiated in 1971 was continued in 1972 with more passages of Upper Salts Cave being examined and names recorded. An area of special interest in Salts Cave is the "Neville Bedroom" where the Russell T. Neville party spent the night of July 12, 1927 in the cave. An interesting photograph of the party "asleep" in the cave may be found in the Saturday Evening Post in an article by Clay Perry entitled "Come, Let Us Go Spelunking," July 12, 1941, p. 15.

Reconnaissance of the Bedquilt area of Colossal Cave revealed several Lee names in the "1871" passage dating back to that year. Few dates are then found until 1896, the year Colossal Cave was commercialized by the Louisville and Nashville Railroad. Several names and dates of a limited group of local cave explorers are present up until the turn of the century. Extensive visitation of the Bedquilt area ceased with commercial development of Colossal Cave and only rare dates are found after 1900.

During 1973 attention will be focused on the passages in Middle Salts and the passages between Dismal Valley and Salts Cave Entrance. In 1912 Edmund Turner and Floyd Collins explored extensively in Salts Cave. The distribution of their names is being plotted to attempt to determine where they concentrated their activity in the cave.

ADVISORY MANAGEMENT PUBLICATIONS



Orconectes inermis inermis from Pless Cave,
Lawrence County, Indiana.

Photo by Horton H. Hobbs III

ADVISORY ACTIVITIES

CRITIQUE OF THE MASTER PLAN FOR MAMMOTH CAVE NATIONAL PARK

Richard A. Watson

Following is a summary of a critique of the Master Plan and Wilderness Study for Mammoth Cave National Park that appears in National Parks and Conservation Magazine. The master plan is analyzed and its eight basic principles are abstracted and presented as exemplary for future National Park Service planning. The plan is without question extraordinarily farsighted and it may be of revolutionary significance for the national park system.

The basic principles exemplified in the Mammoth Cave National Park preliminary master plan are these:

1. Move all facilities except those absolutely essential to observing the park's features to the periphery of the park. This includes all Park Service headquarters buildings, museums, and housing; and all concessioner-operated overnight accommodations, restaurants, and shops.

2. Eliminate all private automobile traffic to the major attractions in the park, and remove automobile parking lots at these locations.

3. Provide concessioner-operated transit service to all major attractions in the park.

4. Expand facilities for hiking, primitive camping, hand-powered boating, and other outdoor recreational activities appropriate to the natural surroundings.

5. Cooperate with regional organizations in planning the development of, and publicity for, regional recreational and tourist accommodations outside the park.

6. Provide for the public only those activities, facilities, and services essential to visiting the park, so as to protect its unique features for the enjoyment of future generations.

7. Continue ecologically oriented research to aid in the management and interpretation of the park.

8. Keep foremost the goal of managing and developing the park in ways that will best preserve, protect, and exhibit the unique natural features on the basis of which the park was established.

Although it is urged that the Master Plan be adopted, the Plan and the Wilderness Study are criticized on the grounds that NPS criteria for excluding areas from wilderness designation are idealistic and unrealistic, that the location of the new staging center should be on Mammoth Cave Ridge rather than on Joppa Ridge, that the NPS should not build a bridge across Green River, and, finally, that the designation of underground wilderness should be applied in Mammoth Cave National Park.

UNDERGROUND WILDERNESS IN THE GUADALUPE ESCARPMENT: A CONCEPT APPLIED

Robert R. Stitt and William P. Bishop

The concept of underground wilderness is not new to the discussions of protection of caves and karst features and has occurred regularly since before the Wilderness Act of 1964 became law. Those who have experienced the cave wilderness have never doubted its existence, but land managers have been slow to accept it. Here we discuss the definition of underground wilderness in terms of the value of the resource, its impact on an observer, and its defensible boundaries. We explore the utility of the concept in management of the cave resource and the overlaying lands and apply it explicitly to the Guadalupe Escarpment of New Mexico and Texas. From the considerations of underground wilderness and its application to the Guadalupe Escarpment we arrive at concrete recomemdations for underground wilderness in the Guadalupe Escarpment area.

WORKSHOP ON UNDERGROUND WILDERNESS

William P. Bishop

On 27-28 October 1972 a "Wilderness Workshop" was held in El Paso, Texas under the sponsorship of the El Paso Centennial Museum with support of a number of environmental and conservation organizations from the Texas-New Mexico area. Dr. William P. Bishop, a Foundation Director, was invited to chair a seminar and discussion of the concept of "underground wilderness" and its application to areas of interest to the group in attendance.

Approximately thirty individuals--including members of conservation organizations, private citizens and land managers--attended the hour-long "group session" on 28 October. Among the topics of discussion were 1) the concept of underground wilderness, 2) the applicability of the 1964 Wilderness Act to the underground, 3) the idea of three-dimensional land management, 4) interactions of surface and underground usage, and 5) the application of the concept to areas in Texas and New Mexico.

SPELOLOGY: AN EDUCATIONAL TOOL FOR LOW ACHIEVERS

Sarah G. Bishop

For students who have not known better than average academic accomplishment it is often useful to demonstrate to them that their learning capability is indeed significant--something they have had little opportunity to observe. In order to draw attention to their unknown capabilities, students must be presented with a learning experience different from the ones which have failed to teach them in the past. Furthermore, so that a student clearly realizes he has learned something from the particular lesson, the subject must be quite unfamiliar to him. With this in mind a presentation on speleology was delivered to Developmental Academic Program students in an orientation session at the University of Albuquerque.

The 90 minute learning experience was comprised of four parts: a lecture on the fundamentals of speleology, reading of a few pages in a model "case study," a visual presentation of slides covering the several aspects of cave studies, and a taped excerpt of a narrative sequence read by a trained speaker. A fifth learning technique was discussed by the group, that of a field trip to an actual locale, a cave.

Formal lecture material of the fundamentals included discussion of the scope of speleology and the several classical disciplines involved. Geology was divided into three areas: petrology, geomorphology/hydrology and mineralogy. Stress was placed on the formation of the limestone deposits, the results of the action of water upon those deposits and the deposition of minerals and the types of minerals found in caves. Biology was limited to the animal species most apparent, their ecological community, and the evolution of the troglobites from terrestrial forms. The final few minutes were devoted to man in caves including pre-Columbian Indian usage, 19th century guano miners and present day use and abuse of caves. The mystery and allure of caves was not omitted.

The case study selected was the Central Kentucky Karst. The reading material distributed was selected from "Wilderness Resources in Mammoth Cave National Park: A Regional Approach" by Davidson and Bishop. The passages chosen were a brief review of the scientific findings in the CKK on the drainage basin, the caves, the cave fauna, the influence of human activities and archeology. A short glossary was supplied to augment understanding of the unfamiliar terms.

The visual presentation was pictures taken mostly from the book Life of the Cave by Mohr and Poulson with a selection of scenic and activity slides taken from private collections. The presentation was made on two screens in order to show relationships between a number of the illustrations.

A taped reading from The Caves Beyond by Brucker and Lawrence illustrated the psychology of the caver and the excitement in the study of caves. While the subject matter was not scholarly (in the usual sense), the impact was one of adventure and searching for new understanding in one particular cave.

In discussions following the four parts of the presentation, it became clear that the students had developed and maintained an interest in the material, had learned a great deal, and were impressed with the possibilities for learning from several different sources of material. Little encouragement was needed to elicit a suggestion of a fifth possible means of learning about caves, namely a field trip.

MANAGEMENT

THE DIRECTORATE

Changes in the Officers and Board of Directors were made at both Spring and Fall meetings of the Board. The final arrangement of responsibilities is reported here.

Mrs. Jacque Austin retired as Treasurer and Board Member after many years of service. The new Treasurer is Dr. William P. Bishop, who will be assisted by Dennis Drum acting in the newly created position of Controller.

Dr. Thomas L. Poulson retired from the Board of Directors. He will continue to have an active role as Chairman of the Committee for Interpretation and Information. His replacement on the Board is Dr. P. Gary Eller, the Area Operations Manager for Mammoth Cave.

Dr. Joseph K. Davidson retired from the Presidency after five years of service. He remains on the Board of Directors and will be in charge of Park Service and Conservation Organization relations. Dr. Stanley D. Sides of the University of Kentucky Medical Center becomes the fourth President of the Cave Research Foundation.

Dr. Denver P. Burns is the new Secretary of the Foundation, replacing Dr. Bishop.

MERGER OF GUADALUPE CAVE SURVEY WITH CAVE RESEARCH FOUNDATION

The Guadalupe Cave Survey, which has been operating as a research organization in Carlsbad Caverns National Park since 1966 has merged with the Cave Research Foundation. The purpose of the Guadalupe Cave Survey, now the western arm of the Cave Research Foundation, is to make a scientific study of the features of the caves in the area of the Guadalupe Mountains in Southeastern New Mexico and other adjoining areas. Emphasis will continue to be placed on cartography, geology and biology programs in the Guadalupes.

FIELD OPERATIONS AT MAMMOTH CAVE

Major rearrangements have been made on the Flint Ridge Field Station. The Austin House now serves the dual role of residence for on-site researchers and as commissary for the expedition personnel. The Old Ticket Office is now Expedition Headquarters and supplies and rescue equipment are stored there. The Collins House and the back Bunkhouse retain their primary purpose of providing sleeping space for expedition personnel. The Speleo-Hut is now used only for long term storage. The new water system is working well.

FIELD OPERATIONS AT CARLSBAD CAVERNS NATIONAL PARK

Field Operations Manager at Carlsbad Caverns is Pete Lindsley, previously Director of the Guadalupe Cave Survey. Mr. Lindsley is a member of the Technical Staff of the Equipment Research and Development Laboratory of Texas Instruments in Dallas. Approximately six expeditions are fielded each year in the Guadalupes and are supported by approximately 45 Joint Venturers from Arizona, New Mexico and Texas.

PERSONNEL

CRF Joint Venturers have decreased slightly in number during the past year and now stand at 274. These and other statistics on the following pages do not include approximately 23 Guadalupe Escarpment Area personnel who have not yet signed CRF Joint Venture Agreements:

Number of JV's as of November 6, 1971	280
Attrition through death, discontinuance, etc.	-57
New JV agreements since November 6, 1971	+51
Number of JV's as of November 11, 1972	274

This modest decrease in our numbers should not be taken as reflective of any decrease in activity in the Mammoth Cave area. Our facilities were used to near capacity on most scheduled expeditions. Throughout the rest of the year much activity was evident from nonscheduled parties working on special projects and by the almost continuous occupancy of the Field Station by resident researchers. It is also reflected in the 5979 hours spent underground by expedition members.

The conclusion then is that we are working more intensively these days than in the recent past, accomplishing more work with no net increase in numbers. As long as the projects to which we have committed ourselves do not suffer from inattention, this situation of relatively static manpower has decided advantages for us:

1. Facilities adequate (with proper upkeep and minor improvements).
2. No shortage of leadership for cave parties or expeditions.
3. Persons returning after several months absence see a large number of familiar faces; Red Watson's oft-mentioned objective of preserving "human values" in CRF is fulfilled.

During the past year, no special effort was made to restrict the influx of new personnel, aside from the usual screening for maturity, continuing availability, and serious intent. The job may not be so straightforward in the coming year. The surge of national publicity is likely to make an increasing number of cavers aware of us, asking to participate in the exploration-survey project. More trained speleo-specialists and their field assistants will be attracted to the CKK by the scientific papers coming off the presses.

Easter weekend, March 39 to April 2, saw a large turnout for what had been planned as an opportunity for party leaders to interact with a few of our key scientists. As planning progressed, the weekend's intent was broadened to provide a semi-symposium atmosphere.

Table 4

Central Kentucky Operations
GEOGRAPHICAL DISTRIBUTION OF JOINT VENTURERS

	Nov. 1972		Aug. 1968	
Near to MCNP				
Ohio	48		77	
Indiana	24		9	
Missouri	21	139	10	137
Kentucky	18	(51%)	14	(55%)
Illinois	12		5	
Tennessee	10		18	
West Virginia	6		4	
Mid-Distant				
Pennsylvania	18		22	
Michigan	6		4	
Minnesota	4		4	
Georgia	4		3	
Wisconsin	3	41	0	44
Arkansas	3	(15%)	0	(17%)
Alabama	1		6	
Virginia	1		5	
Mississippi	1		0	
Far Away				
Canada	15		11	
New York	12		4	
Texas	11		6	
New Mexico	11		2	
Dist. of Columbia	8		8	
Massachusetts	6		2	
Connecticut	4		6	
California	4		1	
North Carolina	1		11	
Maryland	2		3	
Nebraska	2	94	2	70
Florida	2	(34%)	1	(28%)
Alaska	2		0	
Louisiana	2		0	
Utah	2		0	
West Germany	2		0	
Washington	1		4	
Arizona	1		2	
New Jersey	1		2	
Maine	1		0	
New Zealand	1		0	
Peace Corps, Army	1		3	
New Hampshire	0		1	
United Kingdom	0		1	
TOTAL:	274		251	

Nov. 1972: 33 States, D.C.; 3 Foreign countries

Aug. 1968: 27 States, D.C.; 2 Foreign countries

Of the 51 new Joint Venturers during the past year, the majority, 55%, were from the three states of Ohio (11), Indiana (11), and Kentucky (6). The remaining personnel (45%) resided in the following: Canada (3), Connecticut (3), Missouri (3), D.C. (2), Maryland (2), and one each from Georgia, Germany, Illinois, Massachusetts, New York, Pennsylvania, Tennessee, Virginia, West Virginia, and Wisconsin.

PUBLICATIONS IN 1972

JOURNAL ARTICLES

Supported Papers

25. Franz-Dieter Miotke and Arthur N. Palmer. GENETIC RELATIONSHIP BETWEEN CAVES AND LANDFORMS IN THE MAMMOTH CAVE NATIONAL PARK AREA. Böhler Press, Würzburg, 69 pp. (1972).

26. Franz-Dieter Miotke and Hans Papenberg. GEOMORPHOLOGY AND HYDROLOGY OF THE SINKHOLE PLAIN AND GLASGOW UPLAND, CENTRAL KENTUCKY KARST: PRELIMINARY REPORT. Caves and Karst 14, 25-32 (1972).

27. Stanley D. Sides. EARLY CAVE EXPLORATION IN FLINT RIDGE, KENTUCKY: COLOSSAL CAVE AND THE COLOSSAL CAVERN COMPANY. Jour. Spelean History 4, 63-69 (1971).

28. Stanley D. Sides. EARLY HART COUNTY TRAVEL BY MAMMOTH CAVE VISITORS. Hart County Historical Quat. 4 [2] 6-10 (1972).

Scientific Reports

1. Carol A. Hill, Harvey R. DuChene and David H. Jagnow. "Preliminary Geological and Mineralogical Investigations of the Lower Cave and Left Hand Tunnel Portions of Carlsbad Caverns," January 10, 1972, Guadalupe Cave Survey Report to the National Park Service, 18 pp (13 photos).

2. Carol A. Hill, David H. Jagnow and Dwight E. Deal, "Guadalupe Cave Survey Mineralogical Report for the Geologic Field Trip of 12 February, 1972," April 7, 1972, Guadalupe Cave Survey Report to the National Park Service, 7 pp (2 photos).

3. Carol A. Hill, "Lithographic Controls on Speleothem Development in Carlsbad Caverns," January 10, 1972, Guadalupe Cave Survey Report to the National Park Service, 20 pp (3 photos).

4. Harvey R. DuChene, "A Survey of Cave Sediment Studies with Special Emphasis on the Sediments in the Lower Cave Portion of Carlsbad Caverns," January 10, 1972, Guadalupe Cave Survey Report to the National Park Service, 23 pp.

Advisory Reports

10. Horton H. Hobbs III and Steve G. Wells. The Lost River Karst: PROBLEMS IN CONSERVATION AND LAND MANAGEMENT. Natl. Speleol. Soc. News 30, 123-128 (1972).

PAPERS AT PROFESSIONAL MEETINGS

American Association for the Advancement of Science (Philadelphia, December, 1971)

Thomas L. Poulson and John E. Cooper, "A new genus and species of amblyosid cave fish and its relation to evolution and cave adaptation in the group"

Thomas L. Poulson, "Experimental analysis of species diversity in terrestrial cave ecosystems"

Thomas L. Poulson, "Bat guano ecosystems"

Society for American Archeology (Bal Harbour, Florida, May, 1972)

William H. Marquardt, "Recent investigations in a Western Kentucky Shellmount"

Patty Jo Watson, "Archeology of the Mammoth Cave Area"

American Association of Physical Anthropologists (Lawrence, Kansas, March, 1972)

Michael R. Zimmerman, "Preservation of blood cells in a 2000 year old mummy"

National Speleological Society (White Salmon, Washington, August, 1972)

Russell S. Harmon, John W. Hess and William B. White, "Chemical characterization of vadose waters in the South Central Kentucky Karst"

Indiana Academy of Science (South Bend, Indiana, November, 1972)

Thomas Kane, "Prey-predator interactions: behavior of *Neaphaenops* as a solitary predator on eggs of *Hadenoecus*"

Horton H. Hobbs III, "The distribution and ecology of cave crayfishes in Indiana"

TALKS, SEMINARS, AND SYMPOSIA

Arthur N. Palmer:

Slide lectures centering around the topic Geomorphology of Cave Regions of the U.S. were given at the following places:

Lancaster Univ. Speleological Soc., England, June 13, 1972.

Univ. of Leeds, England, Dept. of Geology/U. of Leeds Speleol.Assoc. June 15, 1972.

Cave Club of Ljubljana, Yugoslavia, July 21, 1972.

Annual Convention of Verein für Höhlenforschung in Österreich, Sierning, Austria, Aug. 13, 1972.

Horton H. Hobbs III:

"The Lost River Karst" at University of Wisconsin.

"Biospeleology" at Indiana University Spelunking Club.

Carol A. Hill:

"Mineralogy of Fort Stanton Cave" at Arizona Regional Meeting of NSS, Tucson.

William P. Bishop:

"Speleological Studies in the Mammoth Cave National Park Area" at the Southwest Region of the NSS, El Paso.

ABSTRACTS OF 1972 PAPERS

Franz-Dieter Miotke and Arthur N. Palmer

GENETIC RELATIONSHIP BETWEEN CAVES AND LANDFORMS

IN THE MAMMOTH CAVE NATIONAL PARK AREA

Cavern development in Mammoth Cave National Park has been controlled by the erosional and depositional history of the Ohio River drainage system during the late Tertiary and Pleistocene. Major cave levels were formed when the entrenching Green River stood at base level for long time periods, and therefore the largest cave passages correlate with terraces in the nearby river valley. Wide canyon passages at an elevation of roughly 620 feet correlate with the Pennyroyal plateau surface, part of an extensive erosion surface that developed when the former Teays River system drained most of what is today the Ohio River basin. Filling of the Teays valley by Nebraskan till and outwash diverted the headwaters of the Teays into the Ohio valley, causing deep and rapid entrenchment of river valleys during the Aftonian interglacial, with incision of narrow canyons in the caves. Kansan glaciation resulted in partial alluviation of surface valleys and filling of cave passages to roughly 600 feet. Terraces and several distinct cave levels were formed during the lengthy Yarmouthian interglacial at elevations of 500-550 feet, with thin gravel fill accumulating locally during the subsequent Illinoian glaciation. Terraces and cave levels below 500 feet are mainly of Sangamonian, Wisconsin, and Holocene age. The present Green River pool stands at 420 feet at Mammoth Cave.

Geologic structure and lithology influence passage trends, but not the elevation of major cave levels. Most cave passages have been generated by ground-water recharge from karst valleys, where infiltration is concentrated. Chemical data indicate that most infiltration into the caves reaches the phreatic zone while still unsaturated, with lowest dissolved carbonate content during wet seasons. Precipitation of travertine is consequently rare in caves of the national park. Coupled with the relatively long residence time for water within the phreatic zone, this solutional aggressiveness allows the development of lateral solution conduits near base level. During periods of high discharge, most ground water is still aggressive where it exits at springs.

GEOMORPHOLOGY AND HYDROLOGY OF THE SINKHOLE PLAIN AND GLASGOW UPLAND, CENTRAL KENTUCKY KARST: PRELIMINARY REPORT

By FRANZ-DIETER MIOTKE* & HANS PAPENBERG*

Abstract

Geomorphological studies supported by the tracing of subsurface flow of water from several sinking streams on the Sinkhole Plain near Mammoth Cave National Park, Kentucky prove that the initial fluvial drainage pattern of the Sinkhole Plain still influences the subterranean drainage system. Part of the Sinkhole Plain surface drainage in this area (Gardner Creek and Little Sinking Creek) flows via the subsurface to Green River, but part (Sinking Creek and Doty Creek) drains via the subsurface to Barren River at Graham Spring, northeast of Bowling Green. These subsurface flow paths are significant not only because they are proven by the first dye tests ever performed in the Sinkhole Plain, but also because they show the error of the traditionally accepted assumption that the Sinkhole Plain drains only to the Green River. Even more important is the very high probability that part of the water supply of Mammoth Cave National Park is derived from the Sinkhole Plain and that pollution of the aquifer in areas as much as 6km south of the Park boundary and surface water farther to the south could affect the Park. The average minimum velocity for the initial pulse of dyed spores is 29mm/sec (105 m/hr) and the highest average minimum velocity recorded is 49mm/sec (176 m/hr) over a distance of 21 km.

It is evident that the karst drainage system of the Sinkhole Plain is not chaotic but is well aligned and organized. The Sinkhole Plain is not formed by widespread subsoil solution of bedrock but instead has a complex fluvial-karstic origin. Structural influence cannot be denied but has only moderate importance.

APPENDIX

Addresses for Investigators Listed in this Report

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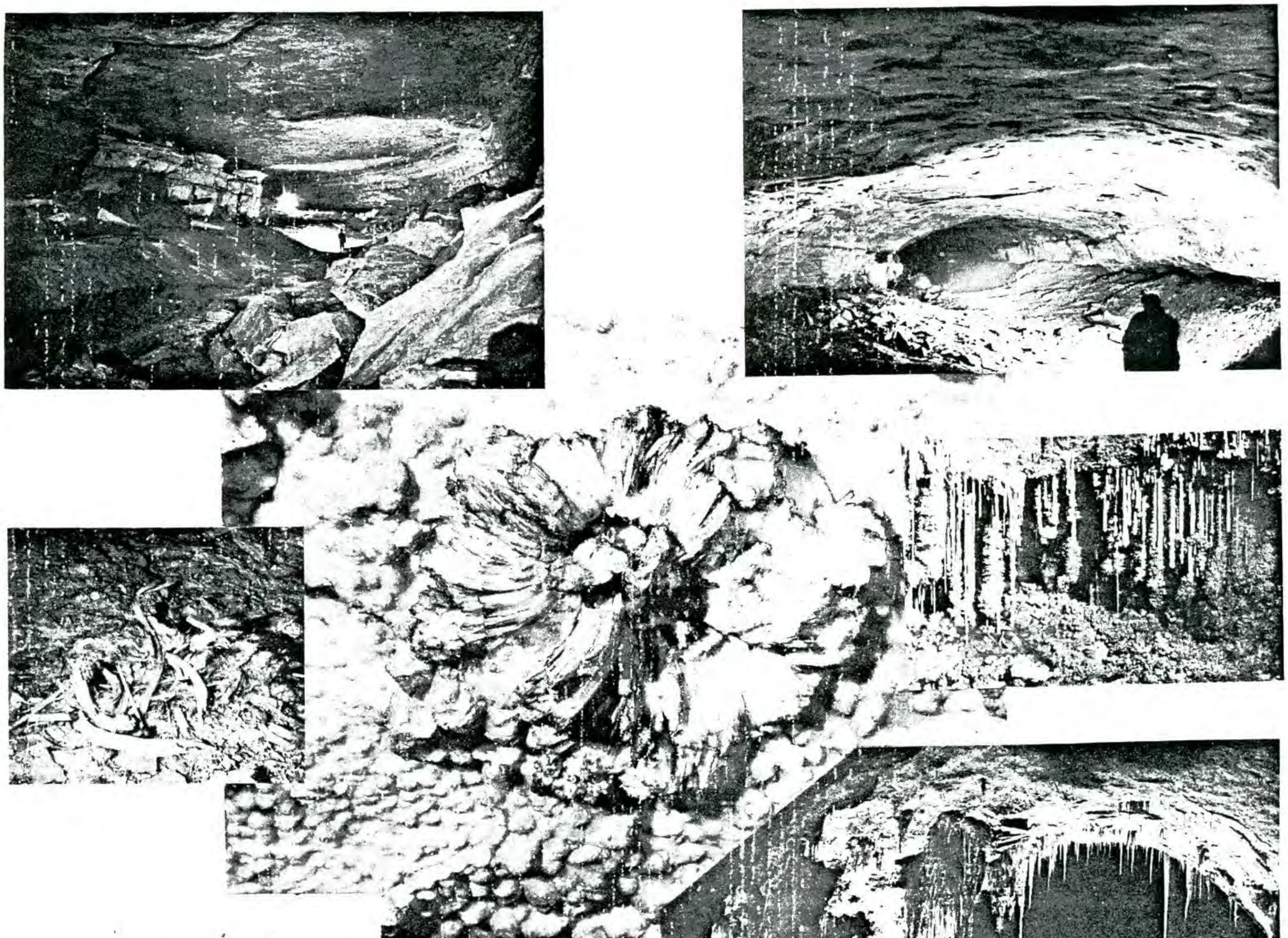
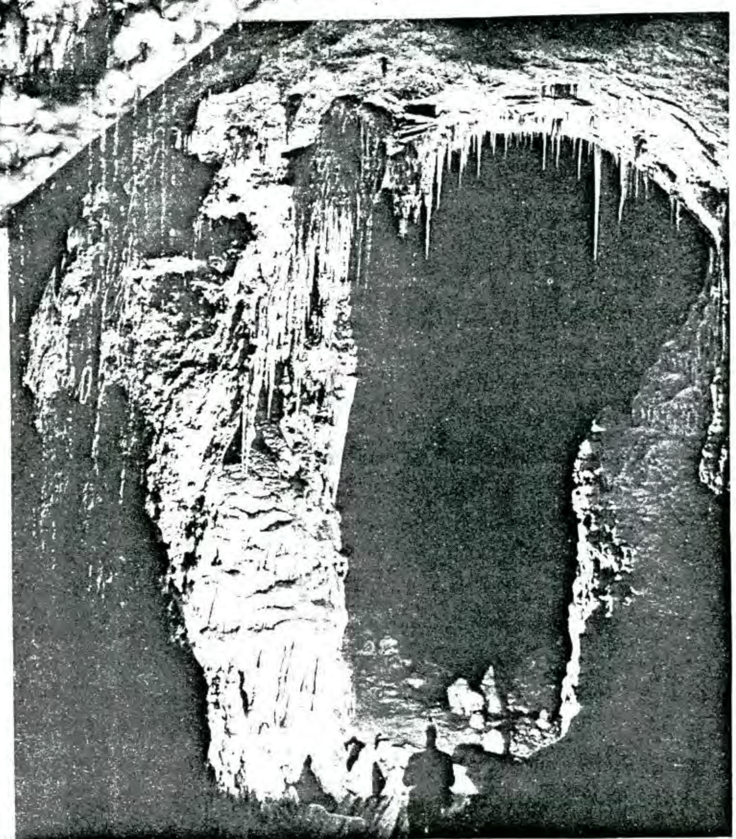
University Park, Pennsylvania 16802

Dr. John Wilcos
Battelle Memorial Institute
Columbus, Ohio

CAVE RESEARCH FOUNDATION





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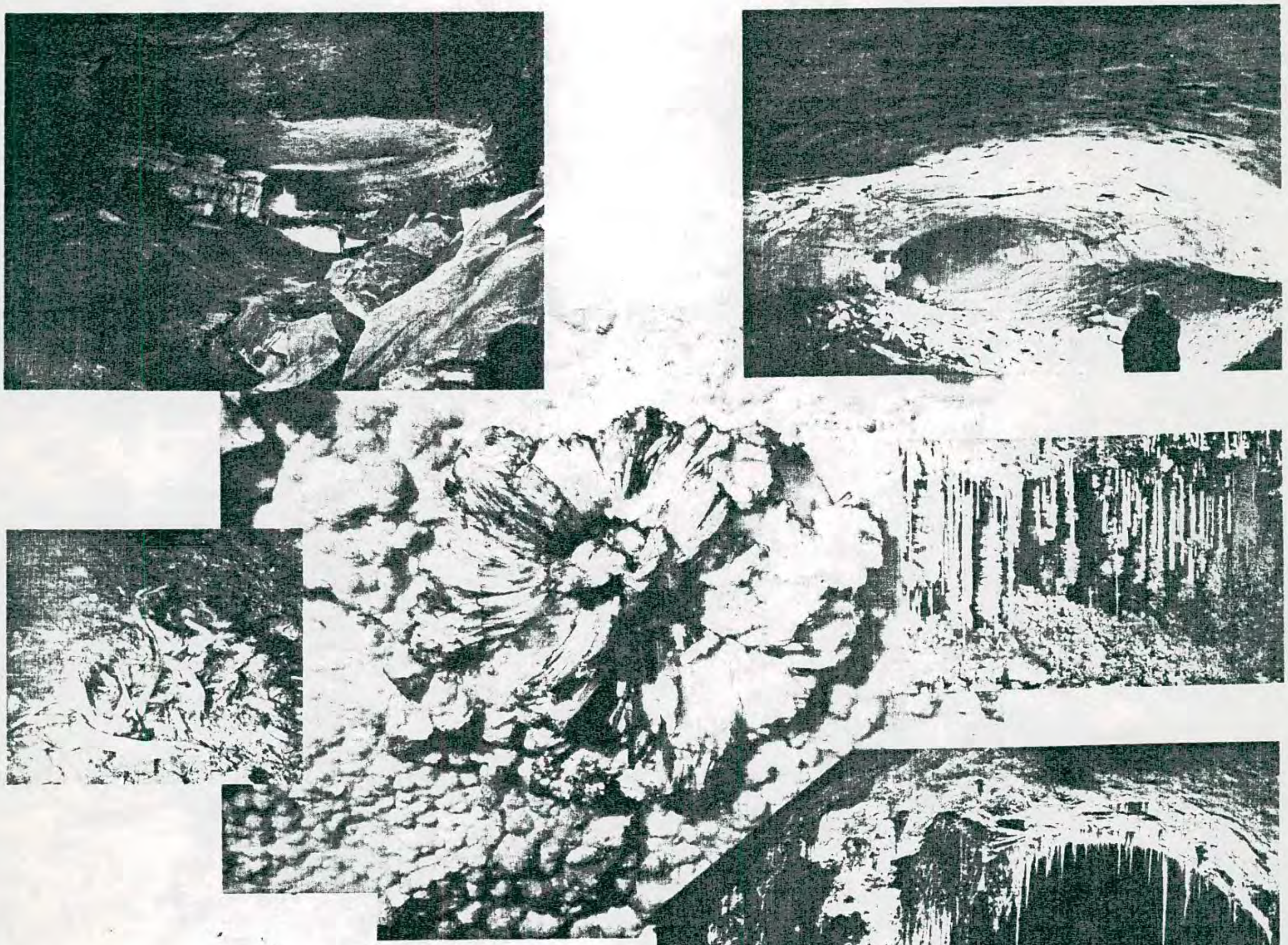
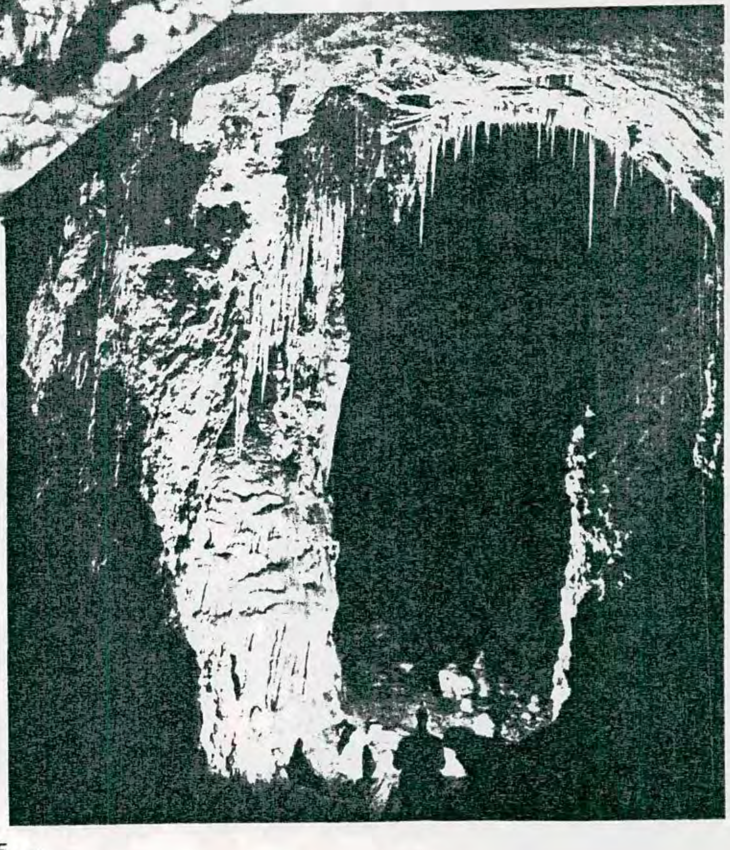
CAVE RESEARCH FOUNDATION





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Cover Photo: Some items of recent interest. Clockwise from upper left: Marshall Ave., Lee Cave; Turner Ave., Crystal Cave; aragonite overgrowths, Carlsbad Caverns; Ogle Cave; limestone pinnacle, Timpanogos Mountain; Mirabilite crystals, Crystal Cave. Central gypsum flower from Mammoth Cave. Photos by R.W. Brucker, R. Pete Lindsley, W.B. White and W. Ray Scott.

Table of Contents

Index to Authorized Projects, Mammoth Cave National Park

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.

HIGHLIGHTS OF 1973

Roger W. Brucker received an Honorary Life Membership in the National Speleological Society, the highest award made by the Society, in recognition of his many years of work at Flint Ridge. Mr. Brucker delivered the Banquet Address at the Society's annual convention on "Your Longest Cave and How it Grew," recounting the long tale of years from Stephen Bishop to Patty Crowther. The address received a standing ovation.

The Foundation issued three awards to graduate students in 1973: A fellowship to Mr. Thomas C. Kane to support his Ph.D. Dissertation research on "A Comparison of Foraging Strategies: Neaphaenops tellkampfii vs Pseudanophyhalmus menetriesii," a fellowship to Mr. Russell M. Norton to support his Ph.D. Dissertation research on "Convergent predator-prey systems in two Kentucky Plateau Karsts," and a grant to Mr. David Jagnow to support his M.S. thesis research on "Factors controlling speleogenesis in the Capitan Reef complex, New Mexico and Texas." Mr. Kane is in the Biology Department at Notre Dame University, Mr. Norton is in the Biology Department at Yale University, and Mr. Jagnow is in the Geology Department at the University of New Mexico.

New exploration continues unabated in the Central Kentucky Karst. New discoveries in Procter Cave have opened the long suspected major cave in Joppa Ridge. Likewise, Mammoth Cave yielded a new sequence of lower level trunks and passages.

The Foundation's geographical base was extended again this year. To a fast-growing research effort in the Guadalupe Escarpment Area has been added two regional studies. The first was an evaluation of the cave resources of the Current River Scenic Waterway. In cooperation with the National Park Service at Ozark National Scenic Riverways the Foundation fielded a team to inventory and classify caves visible from the river between Akers Ferry and Round Spring. A report is now in preparation and further investigations on the Current River are likely. The second regional study is International. At the invitation of the Costa Rican Government, a CRF team--in the field as this report is being written--is making an investigation of the cave resources of Barra Honda National Park.

SOME HINDSIGHTS, AN OVERVIEW, AND PERHAPS A BIT OF FORESIGHT

This report is number 15 in the series of annual documents through which the Foundation keeps the Park Service, its researchers, members, and other collaborators informed of its activities. Since the last ten of these have been edited by the undersigned, there is, perhaps, some point to reviewing the accomplishments of those years.

The fledgling Cave Research Foundation was founded in an auspicious year--1957. The classic period of American speleology was long over. Bretz's monograph saw print in 1942, the last of the famous cave-origin papers. In the 15-year hiatus that followed, little of consequence appeared in the North American literature. Professional geologists, perhaps glad to have heard the last of the "cave problem," turned their attention to other things. Cave and karst subjects all but disappeared from the professional journals. When the Foundation began its first tentative probings into scientific speleology, it found itself facing a monumental wall of professional indifference. As P.M. Smith remarked not long after, "...in the house of science, speleology has been relegated to the coal celler." Thus the Foundation was faced with the problem of not only creating a viable research program of its own, but of assisting in the restoration of professional recognition in the scientific community at large.

Fortunately CRF was not alone. Through the 15 empty years, the National Speleological Society had been growing and its publication, the Bulletin, had matured to the point where, under the editorship of W.E. Davies, it became a functional scientific journal. In the year 1957 Clifford Kaye published a classic paper on the effect of solvent motion on the kinetics of limestone solution. This was certainly one of the first attempts at constructing an analytical model for a cavern process, an analysis radically different from the descriptive and interpretive approach used in the classic period. One year later Rane Curl published his analysis of cave entrance distributions and the first of the statistical models had made its appearance. Cave science in those closing years of the 1950's was firmly attached to two names, both professionals from the U.S. Geological Survey, William E. Davies and George W. Moore. Cave biology followed a similar pattern except that the "middle period" of slow growth and retrenchment occupied the period from 1930 to 1955 according to T.C. Barr. In hindsight, it appears quite clear that modern cave science was born within a year or two of CRF's founding in 1957.

The problems that faced the Foundation in those early years were two-fold. First, cave science needed coherence. Much momentum was lost from each investigator carrying out his work in isolation and often trying to create the whole subject from first principles. Second, it was necessary to win back the professional status that cave-related studies had enjoyed in the 1930's. To tackle the first problem, the CRF policy makers focused their efforts at nucleating cave-related research in the universities. Professors instill their ideas, goals, and value systems into their students, some of whom in turn become professors and pass ideas on to more students. By encouraging dissertation research as the main mode of operation, CRF was assured of intensive and effective efforts since the results would have to meet the criticisms of university advisors and doctoral committees. There was also the side benefit of bringing the experience and insight of an established scientist, the advisor, whose long term interests in caves and karst might be minimal, to at least a momentary focus on the cave problems. The second problem was easy, at least in principle. It would be CRF policy that research results would be published in the most prestigious professional journals. The Foundation would support NSS publications but would not consider them its primary outlet. It would establish no journals or publications of its own. Both of these policies have been followed to the present day and both have been gratifyingly effective.

The first annual report was issued in 1959 when the Foundation began operations under agreement with the National Park Service. Two projects were listed: cartography and sulfate mineralogy. Fred Benington's analysis of the mirabilite stalactites in Turner Avenue was the Foundation's first scientific paper, and it was published in the prestigious journal Science. In 1973 the first scientific contribution from the Guadalupe Escarpment Area appeared, curiously enough also on mineralogy, and also published in Science.

Cave biology was rather quickly accepted by the community at large. In part this was because of the obvious relevance of the simplified cave environment as a means of testing evolutionary and ecological principles. And in part it may have been because the biologists from the start were less tainted with the flavor of exploration and amateurism that seemed to plague efforts at cave geology. Cave geology clearly needed a relevance link to the earth science community; the link was carbonate hydrology.

The International Hydrological Decade was launched in 1964 with much fanfare and bright promise. The promise, at least in the United States, quickly faded when it became apparent that no special funding for Decade would be forthcoming. But it was and is a major effort in Europe. Carbonate terrains received special attention because of the very real water supply problems of many of the circum-Mediterranean countries who depend on carbonate aquifers. This major emphasis on carbonates by the Europeans to some extent had an influence on this side of the Atlantic. Programs on carbonate terrain hydrology appeared in the U.S. Geological Survey, the Alabama Geological Survey, and Nevada's Desert Research Institute among others. CRF's proposal that a major integrated attack on the hydrological problems of the Central Kentucky Karst was accepted as an official Decade project in 1965.

By the latter half of the 1960's the Foundation program in Central Kentucky had come up to full steam. There was active research on an array of topics including geomorphology, hydrology, ecology, archeology, and history. By the end of the decade, a steady stream of publications were appearing each year. The stream has continued unabated through the present year. The 1973 report requires four pages just to list the titles of all the journal articles, theses, meeting talks, and seminars

Carbonate terrains have caught the attention of the professional community in the past few years. New disciplines or interdisciplines are springing up. Terms such as "process geomorphology," "environmental geomorphology," "land use management," "water supply," and "pollution control" headline the scientific papers. Indeed, it is difficult to pick up a copy of Water Resources Research, Ground Water, or The Journal of Hydrology that does not contain an article about carbonates. The geomorphological aspects of the subject have even become respectable, and the word "karst" has reappeared after long banishment from the literature.

And so 15 years after the reawakening, the cave science has come of age. In a very real sense everybody is doing it. From this comes a tremendous challenge to CRF. To the everlasting credit of the group of people who have made a science of speleology under the CRF banner, they did it with next to nothing in the way of financial support. It is a demonstrable rule of thumb that the average fully supported published paper costs about $10,000 to produce. Where was the million dollars that should have been required to generate the output of the past 15 years? The very real impact of CRF programs on the cave related sciences was only possible because the competition was equally broke but not quite as dedicated. No longer is this true. Well funded efforts with strong organizational bases are springing up. If the Foundation hopes to even compete, let alone maintain a leadership role in the decade to come, it will have to devise sources of support and methods of management that will allow long range, highly competitive research. And try to do it without destroying the sense of community, camaraderie, and drive to a common purpose, that made possible the first 15 years without the million dollars. This challenge should make the latter half of the 1970's an exciting time.

-30-

William B. White
Chief Scientist
1961-1973

THE SCIENTIFIC PROGRAMS

6

Top of the Horse Cave member of the St. Louis limestone seen in a shaft drain beneath Waterfall Trail in Crystal Cave. A gently foreset oomicrite forms the base of the Ste. Genevieve (behind subject's head), underlain by resistant, fine-grained dolomite and shaly biomicrite of the Horse Cave unit. The lowest point seen here is approximately ten feet above the prominent Lost River Chert. This shaft drain, which is one of the very few joint-determined passages in the cave, drains to the southwest, against the dip, in the direction of the Overlook.

Photo and commentary by Arthur N. Palmer.

CARTOGRAPHY

EXPLORATION AND CARTOGRAPHY IN THE CENTRAL KENTUCKY KARST

John P. Wilcox, Patricia P. and William P. Crowther,
William Mann, and Richard Zopf
(MACA-N-9)

The field program has been unusually active this year, spurred on by excitement over the Flint-Mammoth connection and continued discoveries in Mammoth and Proctor Caves. Underground survey during the twelve-month period ending November 1 has totalled 26.49 miles, a 25 percent increase over last year. Ninety-five percent of the survey was in passage previously unsurveyed by the Foundation. The surveyed length of the Flint Mammoth Cave System has been increased to 160.5 miles.

In August, a breakthrough in a remote area of Proctor Cave gave access to over three miles of large, upper level trunk passages spanning the width of Joppa Ridge. Numerous leads remain. The full significance of this first penetration to the heart of the third ridge of the Central Kentucky Karst will be determined by months, or perhaps years, of further exploration.

An initial publication of the Flint Mammoth Cave System was made in the form of an 8 1/2 x 11 inch, three-color map card with a descriptive text by Richard Watson. It is a computer-drawn cave map showing over 150 miles of passage superimposed on topography.

Exploration and Survey in Flint Ridge

New survey in Flint Ridge this year was 2.5 times greater than last year, reflecting some return of exploration effort as Mammoth Cave becomes better known. The additional survey has come in scattered segments, the largest input being 4100 feet from Art Palmer's work in Crystal Cave. Tom Brucker led an effort in the upper levels of Unknown Cave, an area that had not been visited for some years, yielding 2400 feet of new survey and several promising leads. The headwaters of Hanson's Lost River yielded 2000 feet. A party led by Richard Zopf found a new route in from the Flint Ridge side, not quite so tight but much wetter. Will Crowther's cartographic reconnaissance of Pohl and Mallot Avenues yielded 1350 feet. Eleven hundred feet were surveyed in a tributary to the Link River. The current surveyed length of the Flint Ridge Cave System is 89.26 miles.

Level lines are complete from the Austin Entrance to Lower Lower Gravel Avenue and from Pohl Avenue through the Unknown Link and Lehrberger Avenue to a point in Austin Avenue. Five cave-to-surface radio correlations have been completed.

Exploration and Survey in Mammoth Cave

Again this year the bulk of the field effort has been in Mammoth Cave. Nearly two-thirds of the survey new to CRF is in passage that had never been surveyed before, and the surveyed length of Mammoth Cave is increasing very rapidly.

In the older section of the cave, this year's survey includes Solitary Cave, Blue Spring Branch, and Blackall, Gothic, and Gratz Avenues. Of the cave as shown by the Kämper and Nelson maps, only the Historic end and the main tourist routes remain to be surveyed.

In July a party led by Gary Eller followed a series of small crawlways below Emily's Avenue to discover a major base level trunk passage under the heart of Mammoth Cave. Over three miles have been surveyed in passage sometimes as large as 20 feet wide and 20 feet high. An active river carries much of the previously untraced drainage from sinks along the north side of Mammoth Cave Ridge and from the southeast end of the cave. A recently discovered tributary, not yet fully explored, goes south for approximately a mile. Downstream the passage siphons but is doubtless a tributary to Roaring River. Further exploration has yielded an easy route in. Based on detailed study of early accounts, it appears probable that this passage is the semilegendary Mystic River, visited by early explorers but unknown in recent years.

An extensive network of virgin passages, not yet fully explored, was found by ascending the wall of Lucy's Dome and proceeding north in a continuation of Rhoda's Arcade. Lower levels reached by this route also drain parts of the north flank of Mammoth Cave Ridge. One of these passages has been surveyed to the northeast, under the axis of Houchins Valley, to a point under the edge of the Flint Ridge caprock.

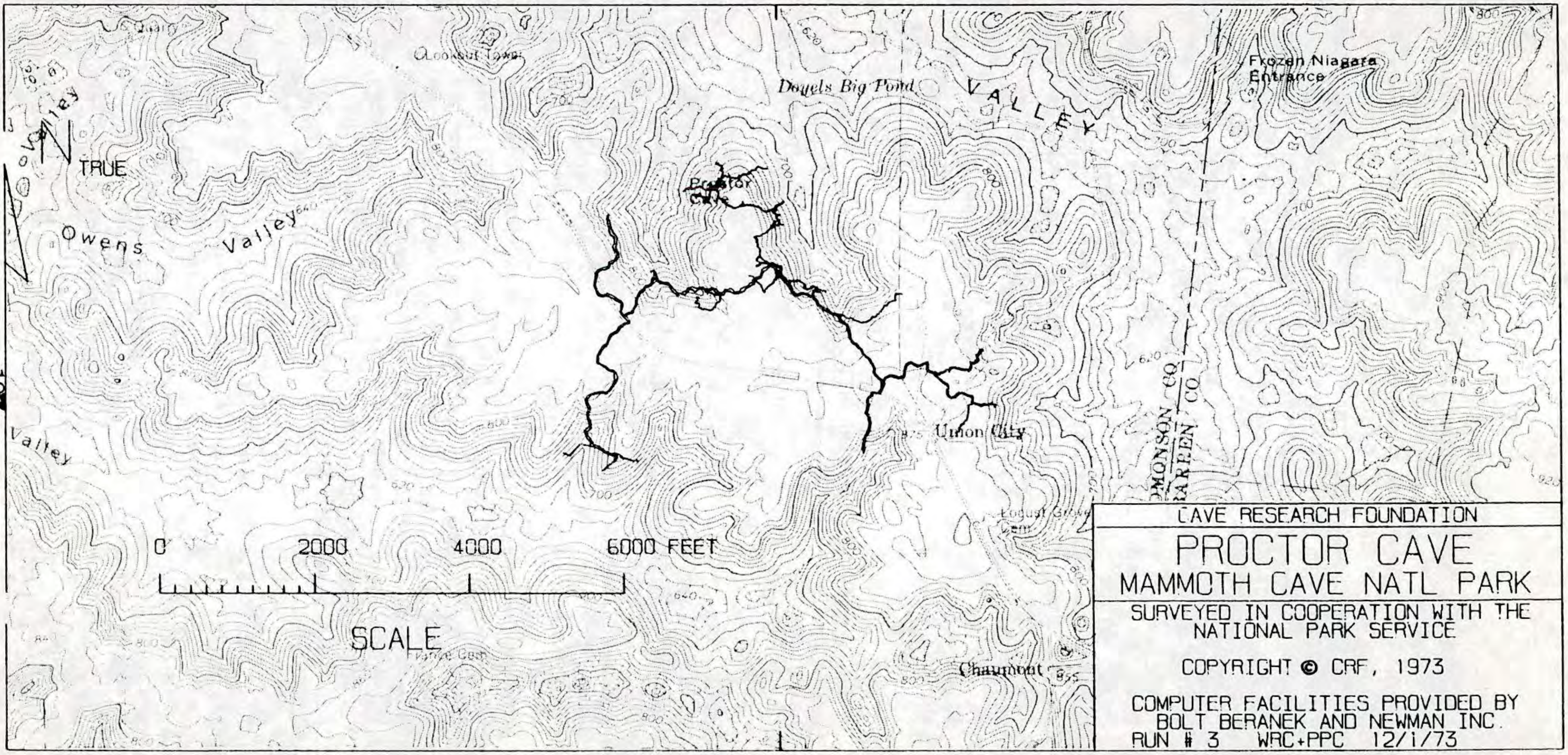
Another virgin area lying east of the Frozen Niagara Entrance was entered via a tight canyon off Cocklebur Avenue. It contains impressive domes and a segment of trunk passage, and several canyon leads remain.

The breakdown fill at the end of Gothic Avenue was penetrated, yielding a 200-foot, well decorated extension of this large passage.

CRF survey in Mammoth Cave currently totals 56.97 miles, of which 26.70 miles are in previously unsurveyed passage. The surveyed length of the cave, including earlier surveys by Kämper, Walker, and others as compiled by J.F. Quinlan in 1969, is approximately 71.2 miles.

Exploration and Survey in Joppa Ridge

On the first day of the Labor Day Expedition, Richard Zopf, Tom Brucker, Steve Wells, and Bill Hawes went through the long crawl in Proctor Cave with instructions to descend an 80-foot pit and explore the drain as far as they were able. On reaching the pit area, however, they became intrigued with leads at an upper level and checked them first. They followed a canyon to a small dome, chimneyed up the dome, squeezed through a tight canyon at the top, and emerged through the floor of a 25-foot wide by 15 foot high trunk passage. Forgetting about the pit, they ran down the passage in both directions, exploring a mile and a half of virgin trunk.


TRUE
Owens Valley
Valley
Lookout Tower
Doyels Big Pond
VALLEY
Frozen Niagara Entrance
Proctor Cave
Union City
EDMONSON CO
WARREN CO
Chaumont
0 2000 4000 6000 FEET
SCALE
CAVE RESEARCH FOUNDATION
PROCTOR CAVE
MAMMOTH CAVE NATL PARK
SURVEYED IN COOPERATION WITH THE NATIONAL PARK SERVICE
COPYRIGHT © CRF, 1973
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RUN # 3 WRC+PPC 12/1/73

Seven subsequent survey teams have logged over 17,000 feet in the new section, tripling the known length of Proctor Cave (Fig. 1). To the east, upstream, the trunk ends against the north side of Joppa Ridge in a shaft complex with high and low leads. To the west, a major tributary (immediately blocked) comes in from the north and the passage becomes larger. There are domes with impressive flowstone formations where it passes under the head of the valley that contains the Proctor Entrance. Beyond this is another major intersection. To the north, probably downstream, the trunk terminates against the valley wall after about 2000 feet. To the south it extends over 3000 feet, entirely across Joppa Ridge, and contains extensive displays of gypsum.

Though several good side leads remain, it appears that the extent of the major trunk network at the original very high level has now been defined. There are several promising points for descent to lower levels. A party rappelled into one of these in October and surveyed 800 feet downstream in a walking canyon carrying an active river. The passage was becoming much larger where they turned around.

Two cave-to-surface radio correlations have been made to check the accuracy of the underground survey.

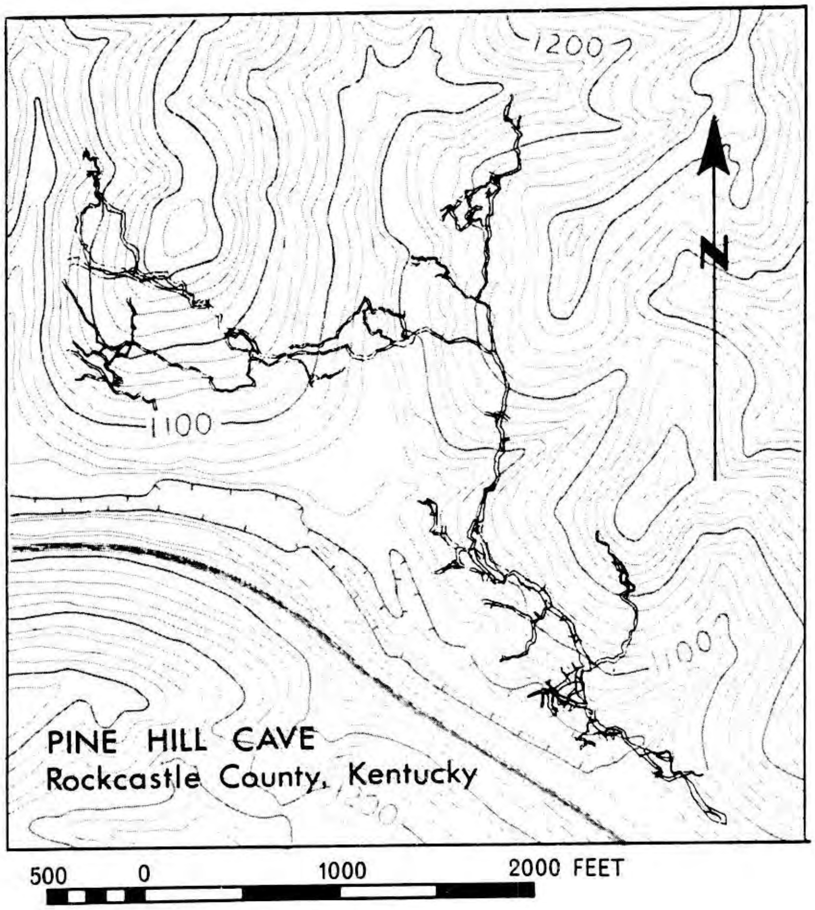
SURVEY OF PINE HILL CAVE

Thomas Cottrell

Pine Hill Cave is located near Mt. Vernon in Rockcastle County, Kentucky. It lies within the 80 foot thick Ste. Genevieve member of the Newman Limestone which here dips SE at 1°, whereas the cave dips generally SE at 1/2°. The elevation of the impressive 30 feet high by 20 feet wide entrance is 950 feet. At present we have 25,333.2 feet of survey and have leveled over a mile of the main stream passage (Fig. 2). The survey was done with Silva compass and steel tape.

The main stream that flows the length of the cave rises from a siphon and flows more than a mile before ending in a siphon. One tributary drains the right fork and another drains the midsection. The passages vary from a 6 foot high by 25 foot wide elliptical tube and 40 foot high by 10 foot wide Canyon along the main stream to the smaller canyons and tubes that drain various shafts. Near the entrance several leads on the left are mostly remnants of an older level. Along the main passage short pieces of this passage appear at the ceiling level and are silted up on both ends.

Skylight Dome offers a 110 ft entrance drop and there are three other entrances nearby which are related to Pine Hill. Members of the Dayton A.S.S. have explored a small very windy cave directly over known passage in Pine Hill Cave. A small cave in a sink at the end of a tobacco field has shallow pits that likely drain into the right fork of Pine Hill. The Blue Grass Grotto has recently surveyed over a mile in Miracle Cave. Miracle Cave likely takes the water from Pine Hill's downstream siphon. The water probably appears at the spring one mile east of Pine Hill. This surface stream then disappears into Mullins Cave (Sinks of Roundstone).


1200
1100
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PINE HILL CAVE
Rockcastle County, Kentucky
500 0 1000 2000 FEET

Various Pine Hill fauna have been studied. The cave is often used as a geology field trip by nearby colleges and universities. Traffic is usually heavy on weekends, and much vandalism has resulted along the better known passages. The Pine Hill survey has been carried out cooperatively with cavers from the Dayton-Xenia area and from the Central Ohio Grotto.

CARTOGRAPHY IN THE GUADALUPE MOUNTAIN AREA

R.G. Babb II, J.J. Corcoran III and J.M. Hardy

This report summarizes the cartographic activities for the Guadalupe Escarpment Area.

Caves in the Guadalupe Escarpment

CARLSBAD CAVERNS	Current surveys (cave)	6,951 ft
	Current surveys (surface)	57,596 ft
	Total cave surveys to date (including control surveys except leveling)	96,162 ft
NEW CAVE	Current surveys (cave)	5,271 ft
	Current surveys (surface)	7,825 ft
	Total cave surveys to date	17,827 ft
SPIDER CAVE	Current surveys (cave)	590 ft
	Current surveys (surface)	600 ft
	Total cave surveys to date	7,253 ft
DRY CAVE	Current surveys (cave)	1,796 ft
	Current surveys (surface)	906 ft
	Total cave surveys to date	17,652 ft

Other Area

HARVEY'S CAVE	Current surveys (cave)	1,102 ft
	Total surveys to date	1,102 ft

Primary objectives for 1973 included extensive surface surveys in support of cartographic and geological programs. Control surveys were largely carried out with a WILD T1A Theodolite and Hewlett-Packard Electronic distance meter. Additional surveys were accomplished by Transit-tape traverse and limited Transit Triangulation. The purpose of these surveys was to allow the relative locations of associated caves to be determined with sufficient accuracy to prevent large redrafting and resurvey problems in the future as more becomes known about these caves.

Cave survey efforts were principally confined to two caves, Carlsbad Caverns and New Cave, both located in Carlsbad Caverns National Park.

Carlsbad Caverns surveys took place in the Left Hand Tunnel, Big Room, and Lower Cave areas. Mapping in the Left Hand Tunnel was thought to be nearly completed by late 1972, and 1973 work was intended to finish off unmapped areas in preparation for final drafting of three quadrangle maps of this part of the cave. Numerous new discoveries in the summer and late fall of 1973 have complicated these plans, however. Theodolite surveys were conducted in the Big Room as baselines for plane-table topographic surveys already underway in support of J. McLeans Gravity survey above and around the cave. Lower Cave surveys added much detail to the existing maps of known passages.

Attempted completion of the map of New Cave, or at least the known parts of the cave, met with success in the late summer of this year. Final drafting of the master map at the scale of 1" equals 50 ft has begun, and plans are now being made to publish the map at a final scale of 1" equals 250 ft.

Future plans include the publication of a map and report on Spider Cave, and the maps of several smaller caves within the next year. Sometime in 1975 we hope to have ready for publication the map of the Rainbow-Ogle cave system and a small scale but fairly complete map of Carlsbad Caverns. Less definite, but probable, plans call for the publication of maps of some of the major caves outside Carlsbad Caverns National Park. Preliminary versions of the Carlsbad Caverns Quadrangle maps will be circulated internally starting in late 1974, but as yet no firm plans for publication have been agreed on.

COMPUTER PROGRAMS FOR CAVE SURVEYING

R.G. Babb II, J.J. Corcoran III, and J.M. Hardy

This report outlines the capabilities, limitations, and characteristics of all the CRF computer programs currently in use, as well as those under development, by the authors at the University of New Mexico, Albuquerque, New Mexico.

Existing Programs

CAVE 17 -- Brunton Survey Processing

Language: FORTRAN IV, converted this year to G-level Fortran under OS/360.

Function: Accepts raw Brunton compass survey data and reference points and coordinates, and produces coordinates used in drafting cave maps.

Characteristics: 1. <u>Input data pre-processing</u>

a. 80-column cards are punched directly from survey notebooks (only basic survey information is processed; other commentary is read and listed).

b. Conversions

(i) Angles -- all types of Brunton angle measurements (0-360, quadrant, mils) are converted to radians.

(ii) Distances -- all types of distances (feet and inches or tenths, and metric) are converted to feet.

c. Effective magnetic declination may be specified or changed at any time.

2. <u>Loop processing</u>

a. Ordering is controlled manually by reordering the input data cards.

b. Correction is performed by the transit rule. No instrument idiosyncrasies are corrected. All calculations are done in double precision.

3. <u>Output information</u>

a. Echo of original data.

b. Closures: absolute error vector, as well as relative error.

c. Corrected sights: point-to-point bearings, distances, and vertical angles are calculated and printed.

d. Statistics: total survey length, total number of loops, average closure error, average sight length.

e. Corrected coordinates are punched on cards for input to the plotter and masterfile programs.

4. <u>Limitations</u>

a. Up to 8 character point names.

b. Up to 1000 points.

c. Speed -- 900 sights/min IBM 360/65 cpu time.

THEOD -- Theodolite/Transit Survey Processing

Language: FORTRAN IV (BPS Fortran D, not yet converted to an OS Fortran)

Function: Similar to CAVE 17, except that angles are treated differently. Used for processing theodolite and transit surveys.

Limitations:
1. Input commentary is more restricted than for CAVE 17.
2. A maximum of 400 points may be processed at one time.

MASTERFILE -- Master File Generation

Language: FORTRAN IV-G under OS/360, and COBOL for the Honeywell 2200.

Function: Used to generate survey summary reports for the NPS (including geological, biological, historical, and archeological, as well as cartographic information). The master file information, on 80-column punched cards, is read, formatted, and printed. Uses punched output from CAVE 17 and THEOD, as well as much manually punched information.

STRING -- Survey Sight Ordering

Language: FORTRAN IV-G under OS/360

Function: Orders survey sights by loop systems, followed by the associated side sights. It is a first attempt at an algorithm for unscrambling survey sights in complex networks. It uses the standard CAVE 17 input data format and will take sights in any order for sorting.

ROSE -- Rose Diagram Claculation

Language: FORTRAN IV-G under OS/360

Function: Generates information for plotting a rose diagram of survey sights for geological studies. Uses the same input format as CAVE 17. Output is a table of vectors and magnitudes.

CAVEPLOT -- Cave Map Plotting

Language: FORTRAN IV-G with custom-written OS/360 Assembler subprograms.

Function: Plots line maps from punched output from CAVE 17 and THEOD. The program has an automatic "Quad-ing" feature that allows the user to specify scale, size of quad, and origin offsets. It will follow a survey from quad to quad automatically. The plots are up to 30 inches wide, and points are plotted to plus or minus .005".

Programs Currently Under Development

The following four programs are intended to replace the six programs described above, as well as to provide a more powerful, efficient, and flexible data base oriented cave information processing system.

PREPROC -- Raw Data Pre-Processing

Language: FORTRAN IV-G under OS/360

Function: To create and maintain cave information data bases.

Inputs:

1. Raw survey data of all types (theodolite, transit, brunton, geodetic control information, etc).
2. Master file data
    a. Commentary on surveys (date, location, personnel, special features, leads).
    b. Information referred to surveyed points (historical, scientific, etc).

Outputs:

1. Print-out of raw data for proofing and field checking.
2. Pre-processed raw data file (on magnetic tape).
3. Master file updates (see 2) under inputs, above).
4. Raw vector file updates (uncorrected sight vectors, stored on disk).
    a. End point names + optionally a uniqueness code to resolve duplicate names for different points.
    b. (dX, dY, dZ) -- the vector.
    c. Instrument and target left-wall, right-wall, ceiling, floor, and height.
    d. Precision estimate (based on the type of instrument and other factors).

UPATREE -- Hierarchical Survey Connection and Loop Correction

Language: PL360, a block-structured assembly level language for the IBM 360 patterned after AlGOL. Runs under OS/360.

Function: Combines the functions of the old STRING program (topological sorting of survey networks) with loop correction similar to CAVE 17's. Raw vectors in a direct access file created and maintained by the PREPROC program are processed to produce corrected coordinates as well as loop structure and closure information.

Input: The raw vector file for a cave system. Each vector has a precision estimate associated with it to reflect both subjective accuracy (for example, survey technique--hand-held vs tripod-mounted Brunton) as well as objective accuracy (for example, theodolite vs transit survey) appraisals. Supposedly more precise surveys are corrected first, and then control all less precise surveys. 16 precision levels are used, ranging from 15 for geodetic or other control surveys, to 0 for points that are known to need resurveying, but are included so that the master file will reflect all currently assigned point names.

Output: Corrected coordinates with a reliability estimate based on the accuracy of the sights used to define the position, as well as the observed closure error of any loops involved. Loop structure and closure information and other statistics are also generated.

Design Goals:

1. Be able to process in core the largest cave survey systems in existence (The Flint-Mammoth cave system currently contains on the order of 30,000 sights -- the program is designed to handle about 40,000 sights for the in-core version).

2. Produce "near-optimal" survey correction in much less than 1 hour of cpu time even for the largest cave systems known.

3. Indicate which surveys are most in need of resurveying by pointing out all significant discrepancies between estimated precision and computed accuracy.

The general reasoning behind the design goals listed above is that, even for cave systems as large as Carlsbad Caverns or Flint-Mammoth, all new surveys and resurveys should be reflected in the "best" coordinates for all points in the system. We plan to recompute the entire cave system after each survey trip. Normally most coordinates will not be significantly different as a result of the new information but, for example, running a theodolite control survey through a complex maze of already surveyed Brunton lines would affect a large number of coordinates.

MASTERFILE -- Master File Data Base Report Generation

Language: FORTRAN IV-G under OS/360

Function: Essentially the same as the old MASTERFILE program, except that disk and tape files will be merged to avoid much manual key punching of information.

CAVEPLOT -- Cave Data Plotting

Language: FORTRAN IV-G under OS/360

Function: Same as the old CAVEPLOT but with the following additional capabilities:

1. Rose diagrams

2. Cross-sections along any given axis

3. Three-dimensional plots

A diagram of the flow of information among the four programs described above is given in Fig. 3.

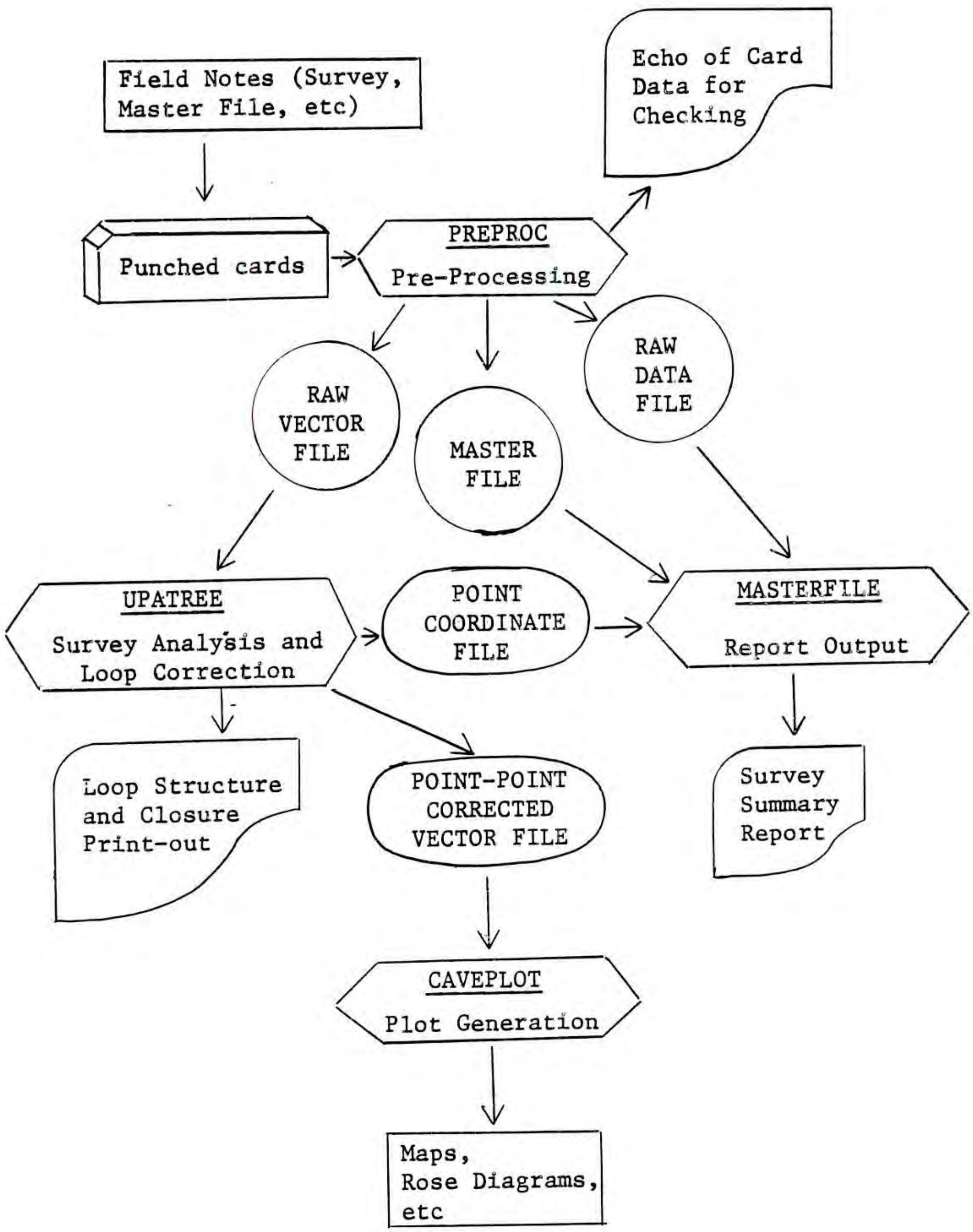

Fig. 3 Information flow in the new CRF-West cave data processing system.

HYDROLOGY

HYDROLOGY OF THE CENTRAL KENTUCKY KARST

John W. Hess and William B. White
(MACA-N-12)

Analysis of Karst Aquifers from Spring Hardness Hydrographs

The karst aquifer, with its storage of ground water in small joints and fissures and in open caverns and with unfilled storage volume in the dry caverns above the ground water surface, can be regarded as a black box subject to a stimulus (sudden input pulses of water from storms) which generates a response that is measurable in the aquifer chemistry at the big karst spring. From analysis of the hardness hydrographs of known short term storm events, one can deduce something of the contents of the black box. This analysis has been applied to the Turnhole drainage of the South Central Kentucky Karst. Continuously recording instruments measure discharge, temperature, and electrical conductivity (proportional to hardness) of the Turnhole drainage at Owl Cave. A rain gage network measures the input. Hydrographs of specific storm events show changes in chemistry that represent surges of water from deep storage driven out by increasing hydrostatic head in the catchment area. Characteristic fine structure indicates arrival time of local inputs. The most detailed structure is observed when a very sudden and sharp pulse is injected into a nearly drained aquifer.

Throughout the water year 1972-73 there were a large number of maxima and minima in the temperature and hardness recordings that correspond to pulses through the aquifer induced by sudden rainfall inputs. Two of these pulses, shown on an expanded time scale, are shown in Figs. 3 and 4. Fig. 3 was obtained on 27 September to 1 October 1972 and corresponds to a period in which the previous total recharge into the aquifer had been very small. The ground was dry and the flow from the springs was low. There came an extended period of rains which provided a fairly large amount of water into the aquifer over a period of several days. The hardness of the water was initially high and remained high during the low flow conditions. After a lag time of only a few hours after injection of the pulse, the hardness of the water flowing through Owl Cave increased by approximately 20%, reached a broad maximum with some ill defined structure. Hardness then began to decrease to a minimum reached three days later at which time it began to rise again and eventually recovered its normal level after a period of two weeks. This leading pulse of increased hardness which does not correspond to a great increase of discharge was interpreted by Ashton (1966) to represent water flushed out of the phreatic zone by the increased hydrostatic head due to the large amount of water injected into the headwaters region of the aquifer system. Fig. 4 shows it in times of very low flow, and at such times there is a long lag between the injection of the pulse and the minimum in hardness which corresponds to the maximum in discharge. In

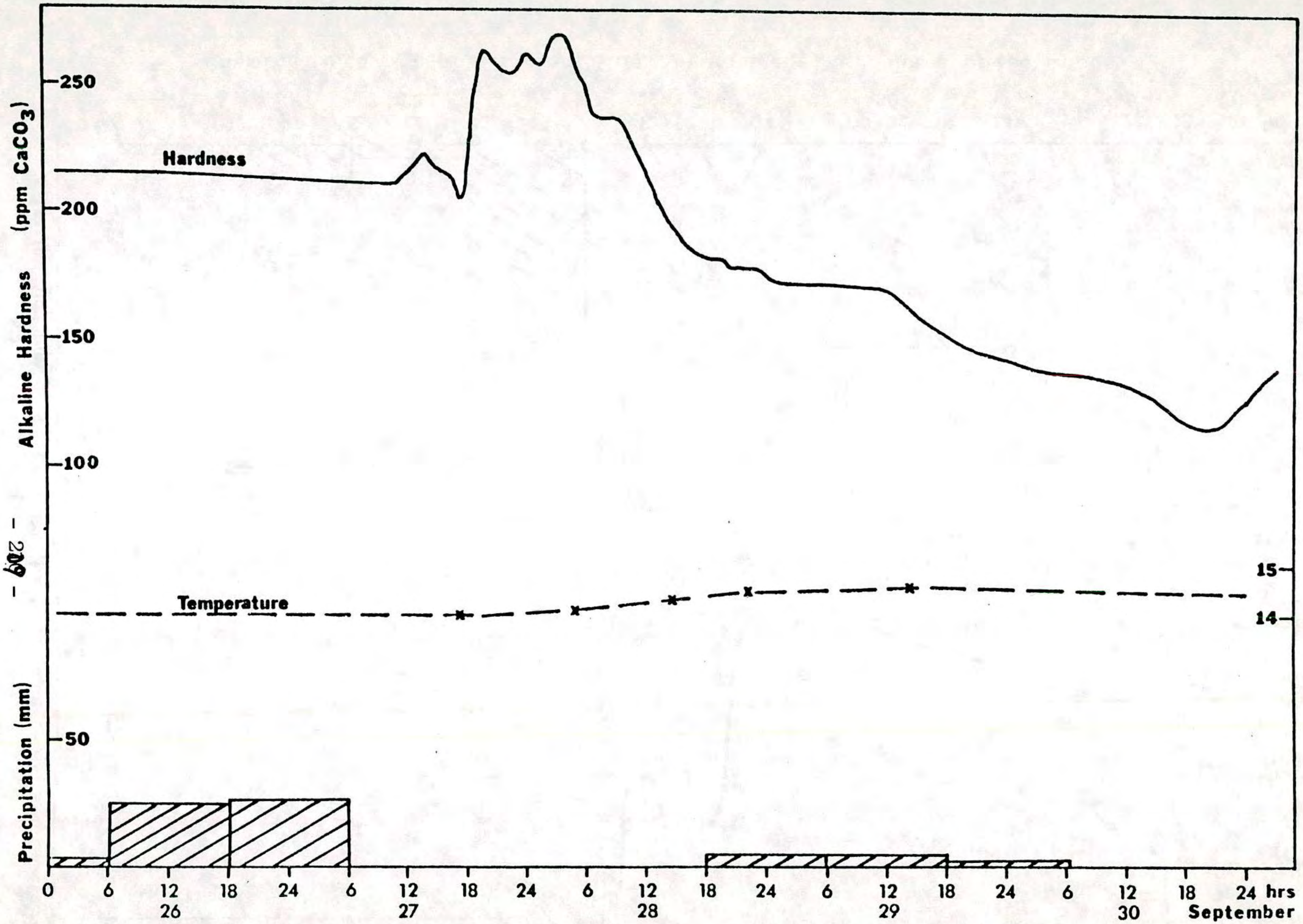

Figure 4. Chemical hydrograph showing rise in hardness after storm input.

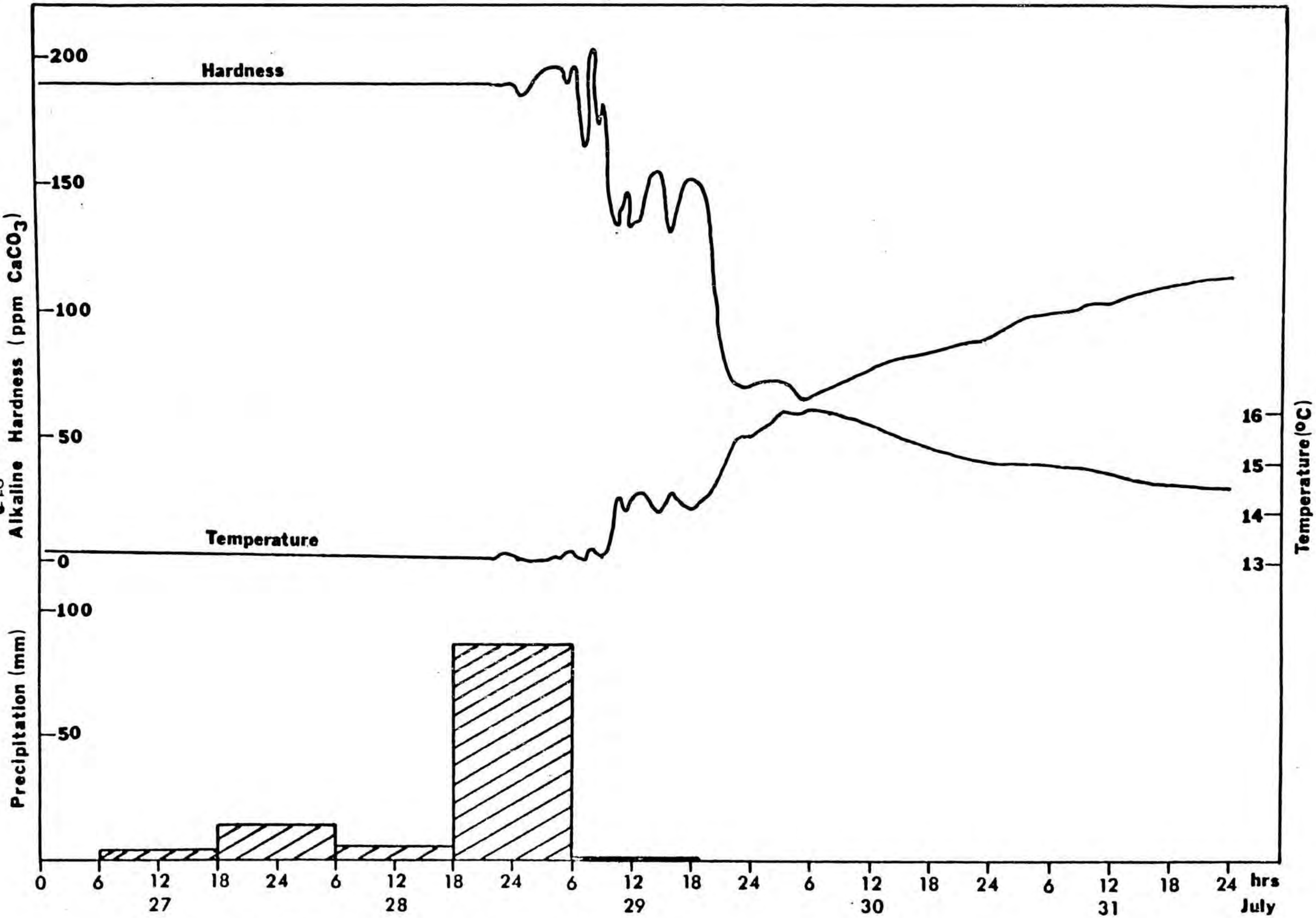

Figure 5. Chemical hydrograph showing fine structure after sharp pulse input.

contrast to this, the hydrograph of Fig. 5, obtained in late July to early August, 1972, was initiated by a very sharp and intense rainfall pulse in which 75 mm of rain fell within a period of 12 hours. The hardness hydrograph of Fig. 5 is distinctly different in shape from Fig. 4. There is no significant rise in hardness above the normal background level. Approximately 12 hours after the input pulse the hardness began to decrease and went through a complex series of minima and maxima over a period of about 24 hours. A total of 7 minima in hardness followed by small hardness rises were observed before the hardness dropped to a minimum value only 30 hours after the rainfall pulse occurred. There then followed a long and gradual recovery to initial hardness levels over a period of two weeks.

From these two observations and many others of similar kind, several conclusions can be drawn: (i) The rise in hardness immediately following an input pulse is observed. This represents a more highly saturated water flushed out by increased hydrostatic head. Whether this water in fact originates from the phreatic zone or whether it is flushed from lateral low-permeability parts of the aquifer may still be open to some question; (ii) The fine structure on the hydrograph could be correlated with different inputs arriving after different time delays are observed. The leading pulse of high hardness water is only observed under certain restricted conditions of aquifer stage. It occurs when the ground water levels are generally low and when they have been constant for an extended period of time. When the new rainfall is superimposed on a high ground water stage or when ground water stages have been fluctuating considerably the leading edge does not appear on the hydrograph records. When the rainfall pulse is broad and drawn out over a several day period, the fine structure on the hardness hydrograph is smeared out and is not very detailed. Conversely, when the input precipitation pulse is very sharp and well defined in time, a considerable amount of resolution of fine structure from the different local inputs is observed.

Seasonal Variations in the Carbonate Geochemistry of the Waters of the Central Kentucky Karst

The bi-monthly water chemistry sampling project started last year was continued until October 1973, completing one full year of sampling. Sampling sites included six Haney Springs (Collin's, Cooper, Adwell, Bransford, Blair, and Three Springs Springs), three sinking streams on the Sinkhole Plain (Sinking Creek, Little Sinking Creek, and Gardner Creek), Mill Hole, Cedar Sink Stream, Owl Cave, Echo River Spring, River Styx Spring, Pike Spring, and Graham Spring. The temperature, specific conductance, and pH were measured in the field along with an estimate of the discharge. The pH was measured by glass electrodes with buffers and electrodes all adjusted to the temperature of the water. A sample was collected and placed on ice until just before the laboratory measurements of bicarbonate, total calcium and magnesium, and calcium were made. The samples were then acidified and brought back to the Geochemistry Lab at Penn State where they are being analyzed for magnesium, potassium, and sodium by atomic absorption spectroscopy. The raw analytical data will then be processed to obtain saturation indices for calcite and dolomite and a theoretical carbon dioxide pressure.

GEOCHEMISTRY OF KARST WATERS IN NORTH AMERICA

Russell S. Harmon, William B. White, John J. Drake and John W. Hess*

The relation of solutional removal of limestone to climatic factors has proved to be very much a non-trivial problem. The investigation turns on a seemingly simple question: Does the maximum rate of solution take place under arctic climates where the CO_2 solubility in water is higher, or does it take place in tropical environments where greater biological activity produces more CO_2? Related, of course, would be a whole series of ancillary questions: the influence of temperature on the kinetics of carbonate reactions which would promote a closer approach to equilibrium in warm or hot climates; the increased length of the growing season in the tropics and thus a proportionally longer time for the production of CO_2; and finally the presence of thicker and richer soils which would allow more contact between gaseous CO_2 and infiltrating water. Measurements of chemical parameters, although many have been made, lead to rather equivocal results. We hope to show that these uncertainties arise because of an inadequate separation of the many factors that influence the chemistry of carbonate waters.

A karst water can be characterized by its chemical constitution. Of the various quantities obtained from chemical analysis and from calculations from the chemical analysis, the most useful are total hardness (calculated from either $Ca^{++} + Mg^{++}$ or from HCO_3^-, saturation index (defined as log [ion activity product/solubility product]) and theoretical CO_2 pressure (calculated from pH and HCO_3^-). Hundreds of data sets have been collected from karst springs and seepage waters from Canada, United States, and Mexico. These data show a large variation which can be separated into contributions from [the effect of hydrogeologic setting] + [short term seasonal effects] + [climatic effects]. The first two terms dominate the variance, and climatic influences are easily disguised. Multiple linear regression analysis allows the variance to be separated, and climatic controls on the chemistry of karst waters can be identified.

The procedure was to select first only data on spring waters. We have lumped conduit flow springs with diffuse flow springs, because it was often not possible to distinguish them. We then group the analyses into coherent data sets. All analyses for climatically similar, geographically restricted areas form a set. These are labeled "Mexico," "Pennsylvania," etc. on the figure. This gives us a very large number of individual measurements within each set.

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*With the active collaboration of Roger L. Jacobson (presently at the University of Göttingen), Prof. Derek C. Ford, John Fish, Julian Coward, and Ralph Ewers (all of McMaster University) and James F. Quinlan (National Park Service).

Our only parameter describing climate at the present time is tempeature. This is unlikely to be entirely sufficient, and precipitation data will later need to be included. However, none of our data sets is from extremely arid, alpine, or tropical rain forest areas, so that temperature alone is not an unreasonable first approximation.

The chemical data were correlated to temperature of the water by simple regression analysis, using one independent variable. Both mean air temperature averaged over ten years of record and the mean water temperature as measured by us were correlated with latitude corrected for elevation (all of our areas of measurement were on the order of a few hundred meters above sea level) and correlation coefficients of 0.996 and 0.983 were obtained. Any one of these three variables would, therefore, have been an equally good choice for the climatic variable.

More interesting are the plots of the derived parameters given in Fig. 5. The saturation index turns out to be a rather poor indicator of climate. The graph merely shows that the spring waters are all to some degree undersaturated, although the more tropical springs fall closer to the saturation line. The tremendous scatter in the data probably represents variance due to hydrogeologic environment to which degree of saturation is very sensitive.

The carbon dioxide pressure, however, is a very good measure of the influence of temperature on carbonate water chemistry. These points fall very close to the regression line, and the correlation coefficient of 0.95 is one of the most significant that has been obtained. The CO_2 plot leaves little doubt that the rate of weathering is higher in warm climates because of the availability of CO_2, and this in turn accounts for the higher water hardnesses often observed.

INFILTRATION STUDIES IN CARLSBAD CAVERNS

James Hardy and John McLean

We have begun a study to measure the rate of infiltration into Carlsbad Caverns. Small concentrations of a tracer such as bromine will be spread over small areas of the surface above the cave. Drips and pools in the cave will be sampled periodically to determine flow-through times and flow paths taken by the tracer. Concentrations of the tracer will be determined with the neutron-activation technique using equipment at the University of New Mexico. Field work during 1973 consisted of sampling drips and pools in the cave to determine the background concentration of bromine.

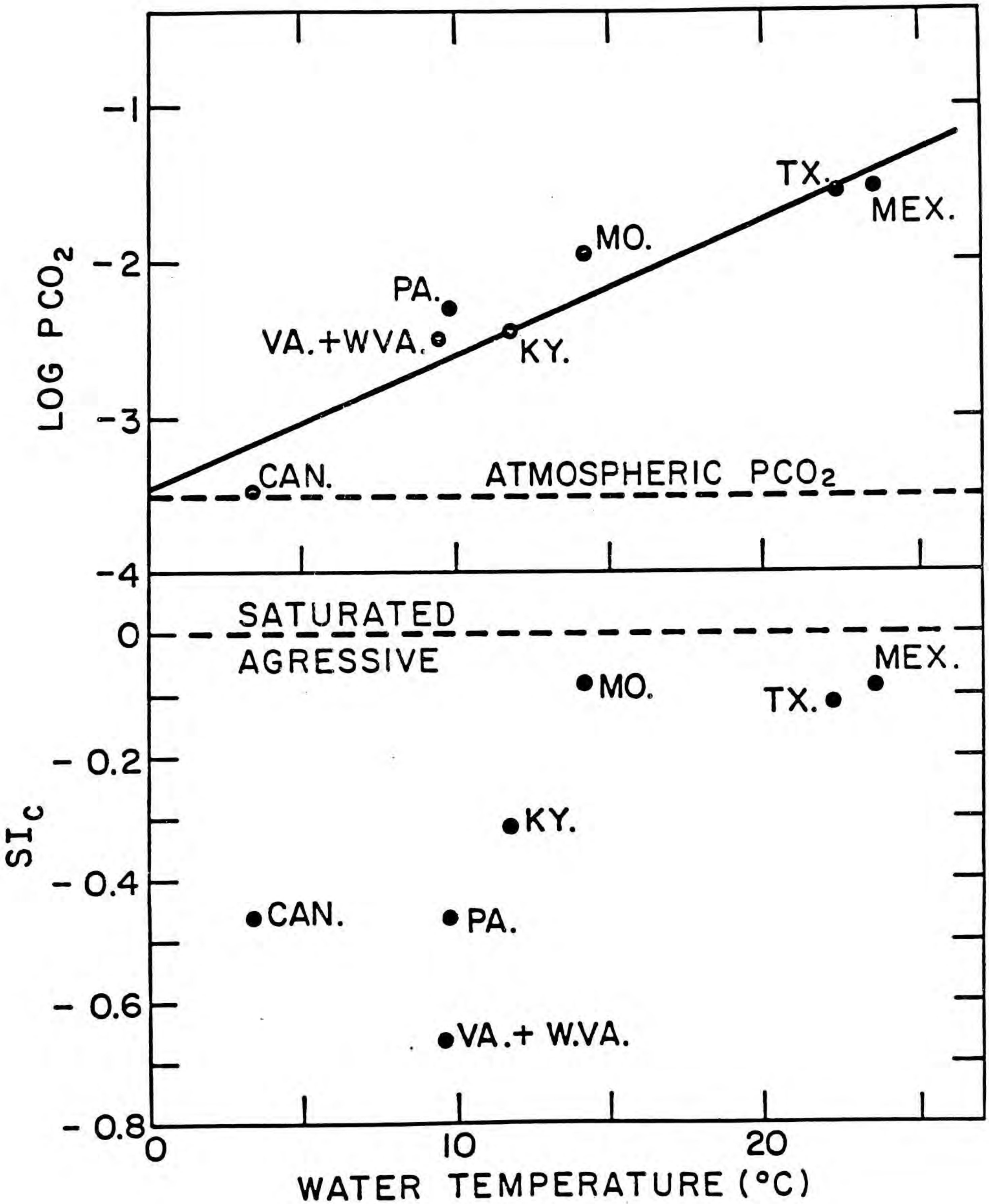

Figure 6. Grand means of theoretical CO_2 pressure and saturation index for regionally grouped karst waters.

FLOOD BEHAVIOR IN THE GREEN RIVER BASIN

Elizabeth L. White

Fluctuating base levels in general and extreme value floods in particular play an important role in processes of cavern genesis and sedimentation. For this reason the present day behavior of the Green River was examined. Flood records for gaging stations at Brownsville and Munfordville, Kentucky, were analyzed for approximately 40 years (1913-1966 noninclusive). The Brownsville watershed is 2762 square miles; the Munfordville watershed is 1673 square miles. The maximum instantaneous peaks per water year were then processed through a method-of-moments computer program (EXVAN) written at The Pennsylvania State University. From these a mean annual flood (in csm -- cubic feet per second per square mile) was calculated for each watershed. The mean annual flood (that flood which has an expected return period of 2.33 years) for the Munfordville Basin is 18.02 csm; for Brownsville Basin it is 14.9 csm. In comparison, other limestone basins on the order of 100 square miles have mean annual floods on the order of 10 csm. Small drainage basins on noncarbonate rocks have typical mean annual floods on the order of 30 csm.

SEDIMENTATION & MINERALOGY

MINERALOGY OF CARLSBAD CAVERNS AND CAVES OF THE GUADALUPE MOUNTAINS

Carol A. Hill

In the past year epsomite, $MgSO_4 \cdot 7H_2O$, and brushite, $CaHPO_4 \cdot 2H_2O$, have been found for the first time in Carlsbad Caverns. These two minerals were analyzed by x-ray diffraction techniques. The epsomite occurs as fluffy, white masses in the cave soils near the Pump Room. This epsomite cotton grows during the winter months and disappears in the summer months, apparently in response to changing humidity. Mirabilite-thenardite cotton reported by Hill, DuChene and Jagnow grows in the same area and exhibits approximately the same cyclic growth pattern as the epsomite cotton. Brushite occurs as an ivory-colored residue on top of floor guano deposits in the Auditorium near the main trail. The brushite forms in circular rings at the perimeter of areas that have been wettened by dripping and splashing water. Calcium in solution reacts with the phosphate from the guano to form brushite. The guano is probably a combination of predominantly bat guano with smaller amounts of bird guano. Cave swallows, Petrochelidon fulva, have "colonized" Carlsbad Caverns since the spring of 1966 and do penetrate into the Auditorium area.

Hydromagnesite ($Mg_5(OH)_2(CO_3)_4 \cdot 4H_2O$) balloons have been discovered in Left Hand Tunnel, Carlsbad Caverns. These balloons are white, opaque and have a pearly luster. There are about 20 balloons in this area, the largest being approximately 1.5 cm in diameter with a wall thickness of approximately 1 mm. The balloons occur in an area that contains a predominance of hydromagnesite moonmilk. The moonmilk appears as globs on the tips of popcorn. The balloons seem to result when these hydromagnesite globs are somehow "blown" up. The only other cave where balloons have been reported is Jewel Cave, Jewel Cave National Park.

Carlsbad Caverns has a great abundance of massive gypsum in the forereef (reef talus) section of the Big Room. These massive gypsum blocks lie on top of (postdate) clay soils and predate later carbonate flowstone and dripstone deposits. Massive gypsum blocks are not confined to Carlsbad Caverns alone but are present in a number of caves in the Guadalupe Mountains. One of the most interesting questions on the origin of the Guadalupe caves is the significance of these gypsum blocks. Remnants of massive gypsum have been noted in the following caves:

Carlsbad Caverns, Carlsbad Caverns National Park
New Cave, Carlsbad Caverns National Park
Cottonwood Cave, Guadalupe Mountains
Black Cave, Guadalupe Mountains
Hell Below Cave, Guadalupe Mountains
McKittrick Cave, McKittrick Hill Area

Endless Cave, McKittrick Hill area
Dry Cave, McKittrick Hill area
Sand Cave, McKittrick Hill area

The gypsum blocks are not confined to a particular formation but are present in the forereef (Capitan Fm., reef talus), backreef (Yates and Seven Rivers Fms.) and the reef itself (Capitan Fm., reef core). The extent in area of the caves with known gypsum blocks is approximately 400 square miles. The vertical difference between the highest known cave with gypsum blocks and the lowest cave with gypsum blocks is over 3200 feet. Evidently whatever caused the gypsum blocks to deposit took place on a regional scale. Weathering of the Castile Fm. (interbedded gypsum, anhydrite, halite, potash and limestone) which at one time overlaid the forereef and part of the reef core does not, in all likelihood, explain the abundance of gypsum in the backreef caves, especially the McKittrick Hill caves. A more regional explanation must be found.

Studies have begun in Black Cave, Lincoln National Forest, Guadalupe Mountains, to determine the nature and origin of the black coatings that cover the upper surfaces of the floors, walls and speleothems of the cave. The coatings are not manganese, and they are not the result of soot from Indian torches or guano fires. X-ray diffraction patterns show that the black material is carbon. A complete investigation of Black Cave is planned in the near future.

SEDIMENTATION IN KARST DRAINAGE BASINS ALONG THE ALLEGHENY ESCARPMENT IN SOUTHEASTERN WEST VIRGINIA

Thomas E. Wolfe

The following is the abstract of the Ph.D. Dissertation with the above title. Dr. Wolfe held the 1969 CRF Fellowship.

The stratigraphy of Holocene and Pleistocene deposits in the caves and related karst features along the base of the Allegheny Escarpment provides a basis for study of depositional events immediately beyond the maximum limits of Pleistocene glaciation during approximately the last 500,000 years. This study proposes to: distinguish between major sedimentary events as recorded in the surface and subsurface deposits of three karst drainage basins; correlate sedimentary stratigraphy where possible from passage to passage, channel to channel, and basin to basin; examine and explain some of the processes of karst sedimentation; compare subsurface deposits with deposits described in the geomorphological and sedimentological literature; and determine the effect, if any, of sediments on the solutional development of caverns and karst drainage basins in the Greenbrier limestone.

A review of the literature shows a lack of information on stream transported and deposited cave sediments. Where such studies have been made, sedimentary structures have been overlooked or misinterpreted. A study of sedimentary deposits in Appalachian caves by the author indicates

that a large quantity (over 75%) of the deposits found in caves of that area is derived from overlying or adjacent clastic rock and is deposited by streams at a time not contemporaneous with the origin of the cave passages. This contradicts the views of some geomorphologists. Additional evidence from scallop measurements on the floor, ceiling, and walls of passages indicates velocities of different magnitude and directions from those which are responsible for the transport of a coarse bedload common to most passages. Scallops and passage profiles also indicate that fills may shield the cave floor from further solutional activity once a thick deposit of clastic material accumulates. Such deposits protect and preserve former large-scale scallops produced during passage solution. This allows for comparisons between scallop velocities and velocities which transported the sediments. Ancient deposits at higher levels in the caves indicate that the conditions of passage solution and deposition of fills have remained relatively constant during approximately the last 200,000 years. However, some caves show evidence for massive, single depositional events with little sorting or rounding. This suggests periglacial activity on the Greenbrier karst at elevations around 2,500 ft; an elevation considerably lower than previously described sites in the area.

A model for the development of surface and subsurface drainage and sediments across the Greenbrier limestone is developed. This is based upon the changes in the tributary karst basins progressing in a downstream direction along the Greenbrier River. Karst "sieve-type" deposition, the accumulation of bedload at the upper clastic/carbonate contact, is an important feature of this model. Periglacial debris, now inactive, which accumulated during colder periods along the escarpment face is reworked by surface streams. This provides a source of coarse bedload for the sieve deposits. Fines are winnowed out and carried into the caves or accumulate in terraces below the karst risings in the lower basins.

The use of kaolinite 3.58Å/illite 10.0Å ratios from clay mineral samples shows weathering variations which are useful in provenance determination if considered along with data on milky quartz pebbles and identifiable lithologies. Dating by Thompson from travertine deposits directly on top of, or interbedded with, fluvial sediments helped to establish relative and absolute dating of the deposits. It appears that travertine deposition is most active during the warmer inter-glacial periods. Although sediment deposition occurs throughout the warm and colder periods, it appears that massive single depositional events occurred during periglacial periods when travertine deposition was minimal.

POLLEN STUDY OF CAVE SEDIMENTS

Gilbert Peterson

The entire suite of samples from older cave sediments was devoid of recognizable pollen. Thus we may conclude that pollen, if originally transported into the cave, is not preserved through geologically significant periods of time.

Of the 43 modern cave samples, only 9 contained sufficient pollen for counting. These nine samples represent cave sediments from the Eyeless Fish Trail in Crystal Cave and the River Hall-Echo River area of Mammoth Cave. These cave passages are respectively a shaft drain complex draining the Mammoth Cave Plateau and a passage thought to be periodically backflooded by the Green River. All successful samples were from cave sediment rather than from water sampling.

Shaft Drain Samples

Eyeless Fish Trail is the largest and the only successfully sampled shaft drain complex. Smaller drains and showers and the sampled shaft drains in Colossal Cave apparently do not carry large amounts of surface organic material.

The sediment in the stream passage in Eyeless Fish Trail is a thin layer over the bedrock floor and consists of sand and finer sediment. Organic matter such as leaves and twigs is locally present. The drainage system is not and probably never will be entirely known because of the small size of the upstream passages. However, the presence of organic matter suggests a direct opening to the surface of the Mammoth Cave Plateau, which is the source of drainage to Eyeless Fish Trail. That pollen is found along the entire length of this drainage complex shows that pollen is transported into the cave system for considerable distances. Also, the pollen spectra do not change greatly along the passage. All samples have very similar spectra. The outstanding characteristic of the shaft drain samples is a very high percentage of pine (over 40%) compared to a regional pine percentage of 1.5%. The shaft drain sediments are also characterized by low percentages of ragweed and grasses and have a very high arboreal pollen value (over 80%).

Backflooded Passages

Samples from Columbian Avenue contained no pollen, but pollen is locally abundant in River Hall. The sedimentation in Columbian Avenue is primarily from ponded water during spring floods. The sediment is silt and clay and accumulates very slowly. In River Hall, on the other hand, sedimentation is more complex and the sediment sources are not readily discernible. River Hall sediments range up to sand size, like those of Eyeless Fish Trail. Also, organic matter is locally abundant. Samples from River Hall are characterized by a low percentage of arboreal pollen, about 29%.

Baselevel Conduits

Pollen sampling from Owl Cave, Cedar Sink and Mill Hole was unsuccessful. Although pollen was present in Owl Cave sediments, it was insufficient for counting.

Traps for Airborne Pollen

The experiments with pollen traps failed to produce evidence that pollen is deposited in the cave passage by moving air currents. The entrapped sediment contained essentially no pollen but consisted of mineral grains. The experiments must be judged inconclusive.

Surface Samples

Of the surface samples from the Green River floodplain, only the sediment samples contained sufficient pollen for counting. As was the case with underground samples, the water samples contained little or no pollen. Green River sediment samples contain a high percentage of ragweed and a correspondingly low percentage of arboreal pollen.

Soil and moss samples from the wooded Mammoth Cave Plateau have a high pine value (26.8% average), considerably higher than the regional surface samples. The one pond sample from the Mammoth Cave Plateau is more like the regional pond samples than the Plateau soil and moss samples. All of the regional samples except two are within Küchler's oak-hickory forest zone, and average 46.2% arboreal pollen. Two samples, however, are in the mixed prairie-forest zone, and average 6.9% arboreal pollen. Since the study area lies within the oak-hickory forest zone, I am assuming that pond samples from this zone will best serve as a basis for comparison to cave sediment pollen.

Discussion

Pollen analyses of cave and surface sediments from the study area fall into two distinct categories: those with high arboreal pollen (AP) and those with low AP. In the low AP group, samples from the Green River floodplain, and samples from River Hall all show AP values between 21 and 35%. This suggests that the sediments in River Hall are palynologically similar to those of the Green River, and that the Green River is the probable source of sediments for River Hall.

The high AP group includes soil and moss samples from the Mammoth Cave Plateau and sediments from the Eyeless Fish Trail which drains the plateau. The surface samples average 66.3% AP and the cave sediments average 80.1% AP. These high AP values suggest that surface drainage from the Plateau is responsible for sedimentation in the Eyeless Fish Trail. The high AP values in this sample group are largely due to a high percentage of pine (about 40%) which apparently is a local phenomenon of the Plateau surface soil. Pine averages only 1.5% in the regional surface samples.

The cave sediments reflect the local environments of inputs, but are not representative of the regional pollen picture obtained from pond sediments. The low AP group contains less AP than the regional spectra, and the high AP group contains more. Once inside a cave passage, the pollen spectra are homogeneous, and sorting by moving water is relatively unimportant. Although a high pine value occurs in the Eyeless Fish Trail, it only reflects a similarly high value at the Plateau surface.

The only cave passages rich in pollen are those containing sediment of at least sand size. Such passages are subject to considerable reworking of sediments during floods, and no stratification is evident. Although sediments attain a thickness of several feet in Columbian Avenue, they are not rich in pollen, presumably because pollen settles out before the silt-laden floodwaters reach Columbian Avenue. Thus, cave pollen is not associated primarily with silt but with environments where sand is also deposited. Laminated silty cave deposits, which may represent a continuous chronological record, do not appear favorable for pollen analysis.

PLEISTOCENE PALEOCLIMATE INVESTIGATIONS IN THE CENTRAL KENTUCKY KARST

R. S. Harmon

During 1973 work was begun on the absolute age dating of several speleothem specimens from the Flint-Mammoth Cave System. Results of these analyses are given in the table. It was hoped that the flowstone specimens from Davis Hall (72036:4) and Great Onyx (72035:1) would be especially useful in both a paleoclimate and geomorphological study of the cave system, but the old age of the youngest layers of both deposits preclude this. These ages do, however, attest to the antiquity of the caves and offer support to the hypothesis that the caves may be pre-Nebraskan in age. Sample 72041 is a piece of stalagmite from Great Onyx which is being further analyzed for stable isotope composition. Additional ages of the top and middle layers will also be determined.

Table 1

Speleothem Analysis

Sample #	Location	U (ppm)	U^{234}/U^{238}	U^{234}/U^{238}	Th^{230}/U^{234}	Th^{230}/Th^{232}	Age (Yrs BP)
72035:1	Great Onyx	1.13	1.145 ±.021	>1.386	1.196 ±.035	32	>350,000
72036:4	Davis Hall	0.30	.995 ±.050	>.986	1.029 ±.059	6	>350,000
72041:5	Great Onyx	0.54	1.101 ±.071	1.145 ±.112	.708 ±.064	5	129,400 ±23,300

This past year work was also begun on determining the stable isotope and trace element composition of drip waters. In order to understand paleoclimates it is first necessary to understand the present conditions under which speleothems are deposited. From Fig. 7 it appears that drip waters from Kentucky conform to the Crzy-Dansgaard relationship for oxygen and hydrogen isotopic composition of meteoric waters, indicating that no major fractionation of isotopes occurs in the soil zone, an assumption inherent in obtaining paleoclimate information from speleothems based upon their isotopic composition.

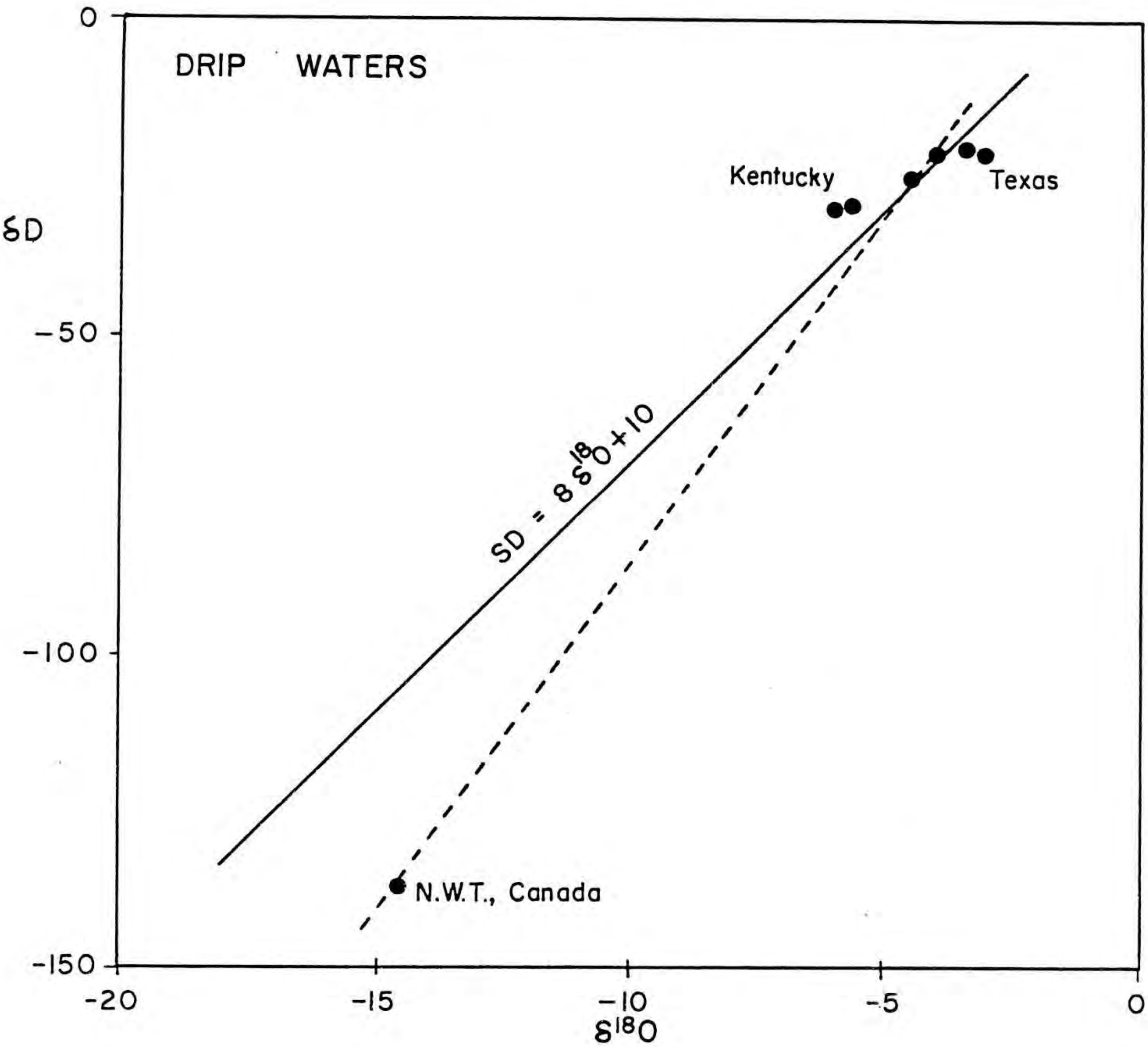

Figure 7. Relationship between deuterium isotope shift and oxygen isotope shift for waters collected from Texas, Kentucky, and northwestern Canada.

GEOMORPHOLOGY

GEOLOGY AND GEOMORPHOLOGY OF CRYSTAL CAVE

Arthur N. Palmer and Margaret V. Palmer
(MACA-N-37)

The hand leveling survey of Crystal Cave was completed during the summer of 1973, providing an approximate total of 2000 data points at which the elevation of geomorphic features and geologic contacts have been determined. The leveling survey was extended through the Overlook area and Columbian Avenue to the Austin entrance and tied to Brunton and transit surveys on the surface.

A survey of the land surface over Crystal Cave was conducted with a tripod-mounted Brunton compass to relate surface landforms and drainage features to the cave and to map the surficial geology. As a supplement to the geologic mapping, a portable refraction seismic unit was used in selected areas to determine depth to bedrock and subsoil bedrock type.

Bedrock and sediment samples were obtained from both the cave and the surface, and a detailed stratigraphic column and petrographic description are being prepared. The tentative stratigraphic section observed in Crystal Cave is as follows:

Formation	Member	Thickness (feet)	Dominant Lithology
Big Clifty			Quartz arenite
Girken	Beech Creek	43-44	Biosparite
	Elwren*	9.5-11.5	Shale, biosparite
	Reelsville	16-16.5	Micrite, biosparite
	Sample	6-7	Biosparite, dolomite
	Beaver Bend	17-33	Oosparite, dolomite
	Paoli	35-40	Micrite, oomicrite
Ste. Genevieve**	Aux Vases	35-50	Oosparite, dolomite
	Joppa	10-15	Oomicrite, micrite
	Karnak	5-10	Biosparite, shaly micrite

Formation	Member	Thickness (feet)	Dominant Lithology
	Spar Mt.	0.6-2.9	Dolomite, micrite
	Fredonia	36-60	Oosparite, micrite, dolomite
St. Louis	Horse Cave***	10 ft exposed	Oomicrite, dolomite

Although the rock units exhibit considerable facies change and variation in thickness, it is possible to trace major units throughout the Central Kentucky Karst with only macroscopic inspection.

Structural maps are being prepared from the hand level data for each major geologic horizon. Passage trends and gradients are being compared with the local structural attitude of the controlling beds or horizons. At Crystal Cave the mean dip of the Ste. Genevieve - Girken contact (as designated by the USGS) is 59.8 ft/mi in the direction N24W, obtained from the attitude of the regression plane through 58 elevation measurements on the contact in the lower levels of the cave. The equation $Z = 0.005E - 0.010N - 150.12$ fits the contact with a coefficient of multiple correlation of 0.897, where Z = depth below station A1 at the Crystal entrance (in feet), E and N = east and north coordinates with respect to station A1 (in feet). Known elevations on the contact vary from this surface by as much as 5 ft. Comparison with other geologic contacts and with passage trends is in progress.

* The position of the Elwren is in dispute. Most earlier workers have correlated the Elwren with a shaly sequence high in the member designated as "Beech Creek" in the above column. The position shown here is in accordance with Pohl [1970, Ky. Acad. Sci. Proc. 31 (1-2)].

** The Ste. Genevieve - Girken contact has been mapped at several different horizons by various workers. The USGS geologic map of the Mammoth Cave Quadrangle by Haynes shows the contact at roughly 14 ft below that suggested by Pohl (1970, op. cit.). The top of the Ste. Genevieve is considered here (in accordance with Pohl) to be a dark gray intraclastic calcarenite one to two ft thick, easily recognized as the friable unit in which the "Turnpike" has been excavated (See 1970 CRF Annual Report, p. 13).

***As suggested by Pohl (1970, op. cit.). See figure.

GEOMORPHOLOGY OF THE SINKHOLE PLAIN IN THE PENNYROYAL PLATEAU OF THE CENTRAL KENTUCKY KARST

Steve G. Wells

Research has been completed for the study of the geomorphology of the sinkhole plain in the Central Kentucky Karst. Based on the results of the investigation, the geomorphic evolution of the sinkhole plain was delineated as follows:

The sinkhole plain of the Central Kentucky Karst has been developed by an integrated surface and subsurface drainage system graded to the Barren and Green rivers. The late history of the sinkhole plain is recorded in the ground water flow paths in the sinkhole plain, as well as sinking streams in the surrounding area.

The present lowering processes, which have been detailed in this study, have apparently been operative at least during the Pleistocene, and the geomorphic history presented here is based on these processes. In other words, there is no evidence of a major change of denudational processes within the Pleistocene.

The geomorphic history recorded in this karst area involves the successive lowering of the regional baselevel and is exhibited as a succession of cave levels beneath the present level. The oldest and highest cave level beneath the sinkhole plain is preserved as Smiths Grove Cave in the Graham Springs drainage basin. It is at an elevation of 540 to 550 feet. This level, as well as the present ground water surface, slopes towards the Barren River which has apparently served as a baselevel for both. The profiles of sinking streams (Sinking Branch and Little Sinking Creek), now in the Turnhole Bend drainage basin, can be projected to the same level as the trunk passage in Smiths Grove Cave, and therefore appear to have been integrated with the Graham Springs drainage basin at that time. It is therefore concluded that the present surface and subsurface divide between Graham Springs and Turnhole Bend drainage basins did not exist at that time.

A later, lower baselevel is preserved at Graham Springs and along the Barren River by a terrace, several abandoned meander loops, and two abandoned spring outlets. These features are at an elevation of 435 to 450 feet. In caves within the Graham Springs drainage basin is a level at 440 to 450 feet which drains presently to outlets at Graham Springs at an elevation of 415 feet. It is not known whether this level originally was graded tothe 440-450 ft level at Graham Springs and has since been regraded, or whether it is younger and is being formed and graded to the 415 ft level.

During or after the development of the 440-450 ft level in the caves, the sinking streams formerly part of the Graham Springs drainage basin system were diverted to the Turnhole Bend drainage basin in the subsurface. Presently, these sinking streams and Turnhole Bend drainage flow to Green River.

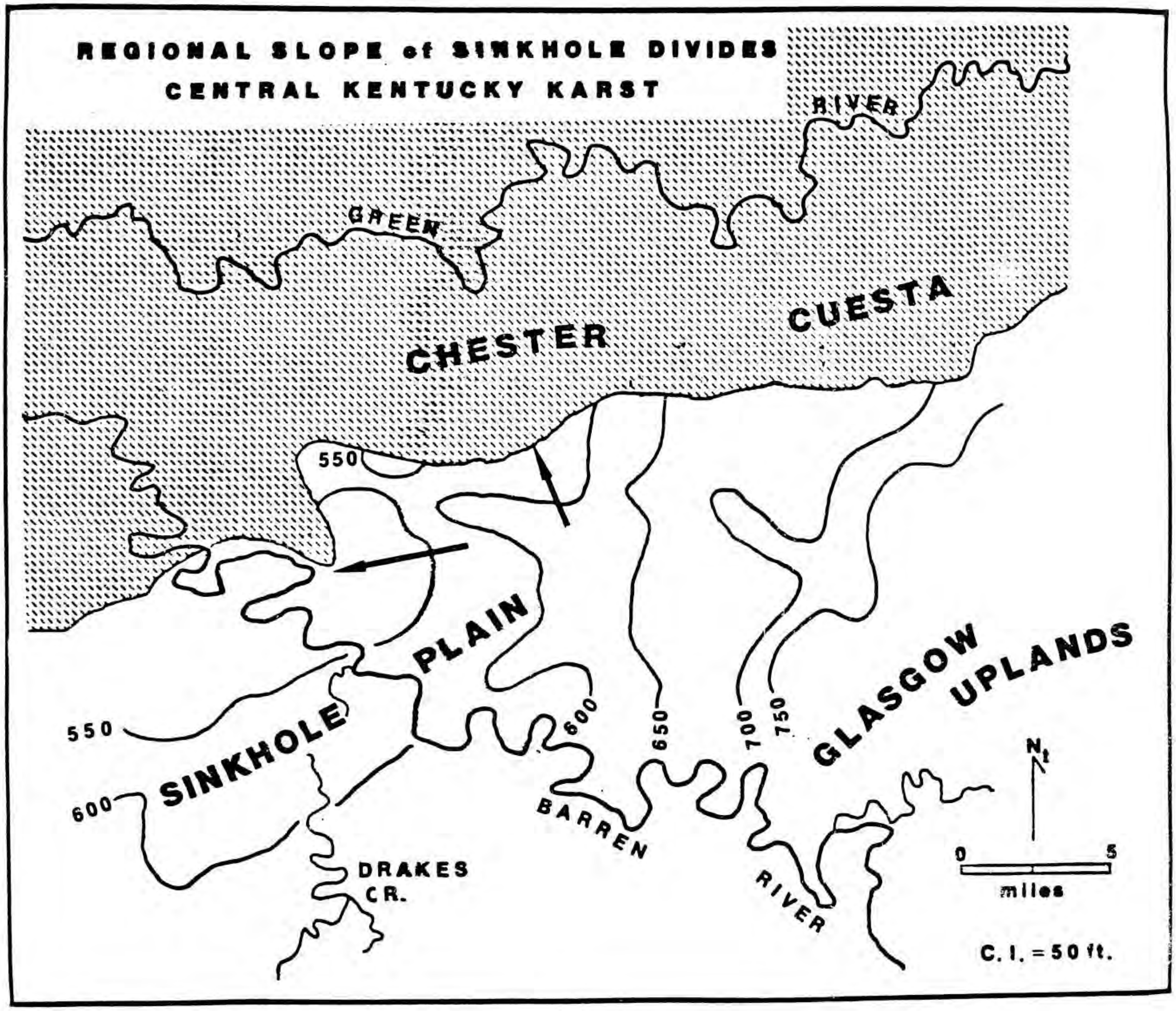

Figure 8. Regional slope of the Sinkhole Plain surface as represented by sinkhole divides and direction of the maximum piezometric slope of ground-water in the study area.

Concordance of the regional slope of the sinkhole plain (determined) from sinkhole divides) with direction of the maximum piezometric slope is illustrated in Fig. 8. The slope of the sinkhole plain is both concordant and discordant to the structure, and shows no evidence of regional control by resistant stratigraphic units. Surface of the sinkhole plain is influenced by the surface and subsurface drainage and normal, solutional-denudational processes.

PRACTICAL PROBLEMS RELATED TO THE GEOMORPHOLOGY AND HYDROLOGY OF THE LOST RIVER KARST, INDIANA

Steve G. Wells

The objective of this study was to review typical examples of practical problems encountered by a community located in karst. Orleans, Indiana, was chosen to demonstrate the magnitude of environmental hazards in regions of carbonate terrain, because its practical problems have been sporadically documented for the past half century. The community of Orleans is located in the Lost River Karst of southern Indiana (Fig. 9) and is confronted by problems of water supply and sewage disposal.

The interrelationship of the hydrology and geomorphology in the Lost River Karst limits the number of potential sources of water and makes these sources highly susceptible to pollution. Surface and subsurface water sources have been used by Orleans for the past fifty years for domestic purposes. High mineral content (calcium carbonate as hardness, chlorine, sulfates, iron, and magnesium) in the water obtained from drilled wells and leakage of the impounding reservoir are two water supply problems that face Orleans. Contamination of the karst ground water and surface streams have been shown by previously conducted ground water tracings (Fig. 10). The inefficiency of the Orleans sewage treatment plant and the organic wastes from the surrounding farmlands results in pollution traveling several miles through underground drainage networks and eventual pollution of the discharge point, the Orangeville Rise. Recommendations are offered to deter the exploitation of the subsurface drainage as a part of a sewage system.

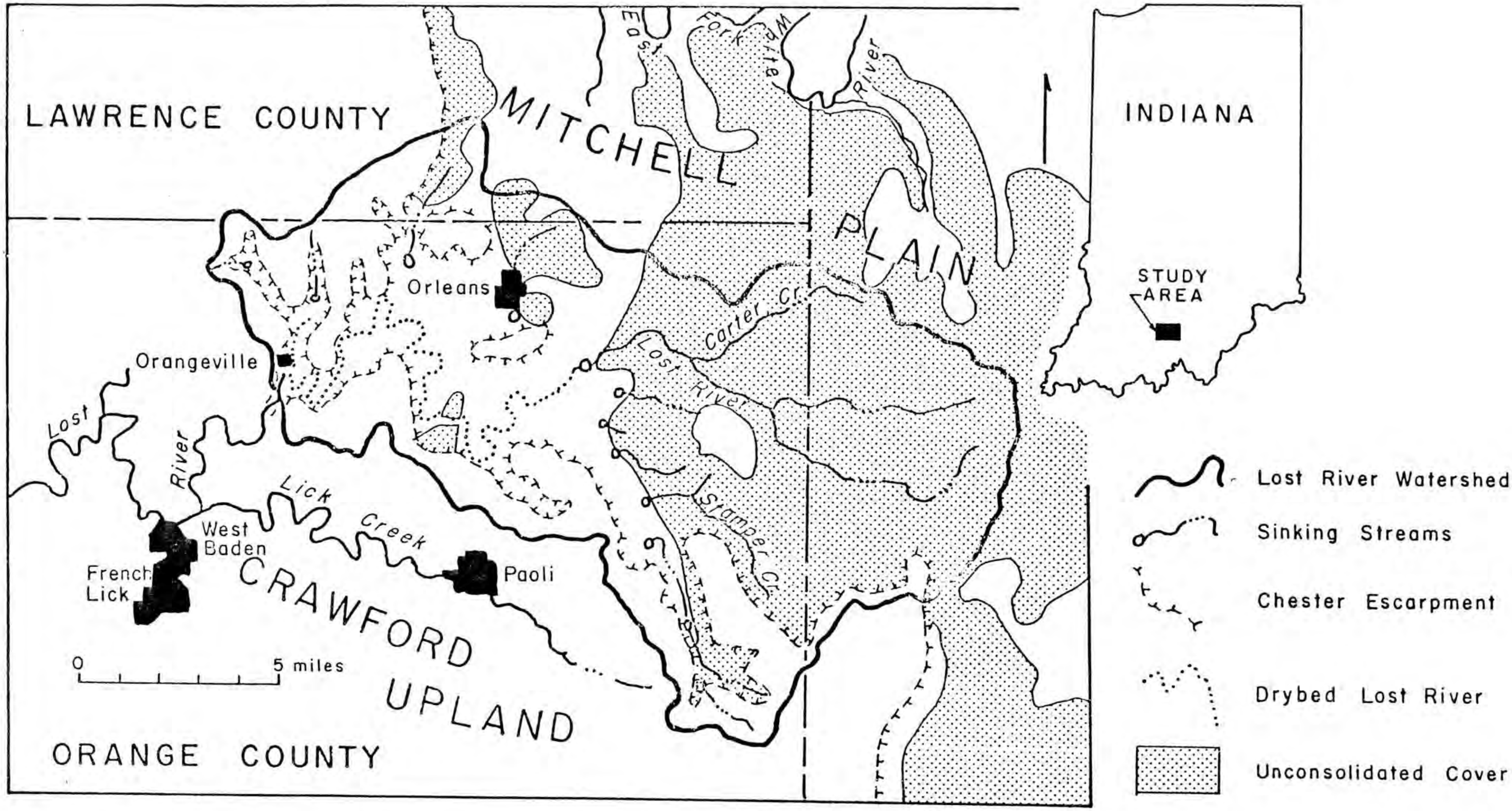

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Figure 9. Physiographic units and geomorphic features of the Lost River Karst, south-central Indiana.

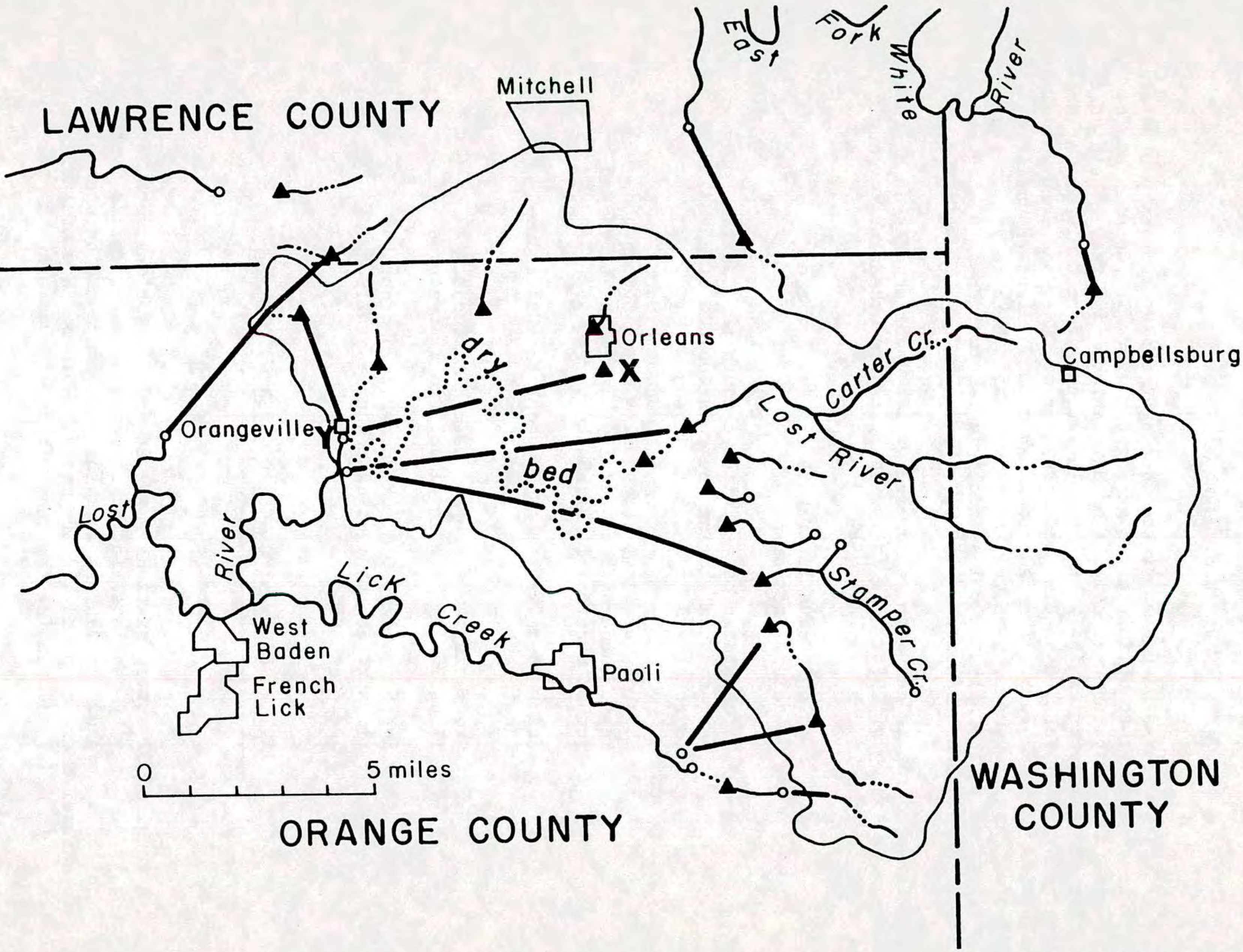


Figure 10. Subterranean drainage routes of the Lost River Karst (from the work of Murdock and Powell, 1968). X represents the treatment plant at Orleans and Y represents the karst spring at Orangeville. Secondary effluent travels via underground drainage from point X to point Y.

SPELEOGENESIS IN THE GUADALUPE MOUNTAINS

David H. Jagnow

Fifty-two caves have been visited during the past two years of field work in an attempt to delineate the geologic factors influencing speleogenesis in the Capitan Reef complex of New Mexico and Texas. The distribution of caves studies is: 23 in Lincoln National Forest, 19 in Carlsbad Caverns National Park, 8 on BLM land northeast of CCNP, and 2 in Guadalupe Mountains National Park. The few known caves in Guadalupe Mountains National Park are small, some require a full day's hike to get to the cave, and they generally yield less geologic information than elsewhere in the Guadalupe Escarpment.

This program is near completion and will be published as an MS thesis during the spring of 1974. The following items are scheduled for inclusion in the thesis:

1. Geologic cave literature summary for the Guadalupe Escarpment
2. Structural cross-sections through the Capitan Reef complex showing the relationship of caves to stratigraphy and base levels
3. Maps of Wen Cave, Lechuguilla Cave, Cottonwood Cave, Queen of the Guadalupes, and the Left Hand Tunnel Portion of Carlsbad Caverns
4. Joint rose diagrams throughout the Guadalupe Escarpment
5. Cross-section survey of Left Hand Tunnel illustrating base level solutional features
6. Approximately 50 black and white photographs illustrating the geologic factors influencing speleogenesis

GRAVITY SURVEY AT CARLSBAD CAVERNS

John McLean

A total of 32 survey stations were set and 97 stations were leveled during 1973. Gravity readings (including repeated measurements) were made on 152 stations. As many as half these readings may be unusable due to excessive drift in the gravity meter. Work on this project was suspended in mid 1973, pending the acquisition of a more stable gravity meter.

INVESTIGATION OF OGLE CAVE, NEW MEXICO

R.G. Babb, John Corcoran, Harvey R. DuChene, James Hardy, Carol A. Hill, David H. Jagnow, Ann and Richard Loose

The comprehensive study of Ogle Cave, in Carlsbad Caverns National Park, was continued during 1973 with cartographic additions and revisions. Ogle Cave is located near the entrance of Slaughter Canyon. Entrance to this cave is gained by a 185 ft rappel. However, this strongly joint controlled cave is connected to Rainbow Cave via a tight "joint" passage. Plans are being made to publish a collection of papers on Ogle Cave and the surrounding area.

ECOLOGY

SURVEY OF THE CAVE FAUNA OF CARLSBAD CAVERNS AND GUADALUPE MOUNTAINS NATIONAL PARKS

W. Calvin Welbourn and William R. Elliott

During 1973 biological investigation was concentrated in the Slaughter Canyon area of Carlsbad Caverns National Park, where eight caves were investigated. Six investigated in Slaughter Canyon were DecoratedCave, Goat Cave, Lake Cave (Vandalized Cave), Longleggs Cave, New Cave, and Rainbow Cave. Two caves, Midnight Goat Cave and Ringtail Cave, were investigated in Midnight Canyon (southwest of Slaughter Canyon). Also investigated were Watertank Cave and the Devil's Spring area in Carlsbad Caverns. One cave in Guadalupe Mountains National Park was also investigated.

There were several important additions to the cave fauna. Probably most significant were the numerous specimens of an isopod, Brackenridgia, found in Decorated Cave, Lake Cave, Ringtail Cave, and Watertank Cave. One additional specimen was found near Devil's Spring in Carlsbad Caverns. This represents a significant addition to the range of this isopod, previously considered rare in New Mexico. Specimens of free-living mites were found in Midnight Goat Cave, Goat Cave and Rainbow Cave. These new records of free-living mites will be significant in determining the species distribution in the Guadalupe Mountains: the only previously reported records were from Carlsbad Caverns.

With work progressing on the biological examination of caves and cataloging the fauna, a supplement to Bailey 1928 and Barr and Reddell 1967 might be appropriate in the future. In the coming year more effort will be placed on examining the remote caves in both parks, and on concentrated study of individual caves and/or sections of caves to obtain more information on the population dynamics, predator-prey relationships and ecology of the Guadalupe Escarpment cave fauna.

BIOLOGICAL SURVEY OF NEW MEXICO CAVES

W. Calvin Welbourn

During 1973 a systematic survey of the cave fauna of New Mexico was begun. Fourteen caves in seven counties were investigated outside of Carlsbad Caverns National Park: six were gypsum, six were limestone and two were lava tubes.

Investigation to date has produced much new information on the New Mexico cave fauna. Literature to date has dealt almost exclusively with the cave fauna in the Carlsbad Caverns region (Barr and Reddell 1967 and Bailey 1928) so most records outside this region are new. Most notable finds were free-living mites in three caves. Of these, one was outside the Guadalupe Escarpment area by 150 miles. The other two were in the Guadalupe Escarpment. Millipeds of the genus Speodusmus were found to be common in five caves and present in others. Rhadine beetles were found in four caves (all gypsum) outside the Guadalupe Escarpment region. Ambystoma tigrinum (some with Trombiculid mites) were found in two caves outside the Guadalupe Escarpment.

In the future, more emphasis will be placed on examination of caves at higher elevations in northern New Mexico and caves west of the Rio Grande River. More caves in all regions, especially in the Guadalupe Escarpment will be examined. The fauna will be compared and compiled into a faunal distribution and relationship for the state. Currently specimens are being processed and identified.

CAVE CRICKET ACTIVITY RHYTHMS

Glenn D. Campbell

Using mark recapture techniques and in situ observations the aggregation, dispersion and periodic movements of several species of cave crickets (Ceuthophilus conicaudus, C. carlsbadensis, and C. longipes) within two caves of Carlsbad Caverns National Park (Water Tank Cave, Spider Cave) were studied.

According to Reichel, Palmer, Park and Barr, the cave cricket is of paramount importance in the energetics of many caves. As a generalized predator the cave cricket feeds on both hypogean and epogean fauna and flora. Epigean elements constitute the greater percentage of its food, and the predation upon surface organism takes place during migrations to the surface. Several studies by Nicholas, Reichel, Palmer, and Park on the genus Hadenoecus (subfamily Ceuthophilinae) and Richards on the genera Gymnoplectron and Pallidoplectron (subfamily Macropathinae) have been carried out both in the lab and in the field. Specific activity rhythms have been formulated for these genera and applied to subfamily levels. This study will deal with the specific rhythm exhibited by Ceuthophilus (subfamily Ceuthophilinae), and compare this rhythm to those demonstrated for other crickets. Also, the factors influencing the rhythm (or rhythms) will be delineated.

The two caves were selected on the basis of their contribution to a population study of this nature. Water Tank Cave is a very small cave with three species of crickets. The opportunity to investigate each species population and their niche separation would greatly contribute to the aspect of dispersion factors. Spider Cave is a much more extensive cave with a very large single species population. This cave's dynamics lend to a coded marking system to investigate aggregations and movements of individuals.

A mark-recapture census was used to estimate the total numbers of the cave cricket, Ceuthophilus conicaudus, in Spider Cave. The Lincoln-Peterson Index with Baily modification estimated a population number (10,098 - 13,116) for this cave. Monthly checks on the population have shown a tremendous drop in total numbers of crickets this fall and winter.

Casual observations at the entrance of the cave have shown a nocturnal migration of crickets leaving the cave at sundown. Pit-traps placed around the entrance show that the crickets forage a considerable distance from the entrance.

CONTROL OF SPECIES DIVERSITY IN TERRESTRIAL CAVE COMMUNITIES

Thomas L. Poulson
(MACA-N-14)

The table that follows places the study of species diversity in context. Up until recently I have concentrated on natural experiments. This past year I have started manipulative experiments.

I started manipulative studies on substrate type because earlier studies of stream bank communities did not differentiate substrate diversity from variability and/or predictability of food input by flooding as the major controlling factors. In these study areas, and others, it is difficult to sort out substrate diversity from food input pattern, since both are related to flood regime and nearness to source of food input. For example, the stream area with low diversity is mainly fed by backflooding from the distant base level Green River and has a silt-sand substrate. It floods predictably in spring but has a high organic content only during unpredictable summer floods. The area of highest diversity is mainly fed by inwash from a number of close, vertical shafts and has a silt-sand-gravel-rock-detritus substrate with a low organic content. It is predictably replenished during spring flooding. This sort of confounding has led to the design of substrate manipulation experiments in areas that do not flood but have high species diversities.

Substrate manipulations, alone and in combination with leaf litter in areas with no microclimate problems, have shown that substrate diversity has a minor positive influence on species diversity as compared to food in the form of presterilized leaf litter. In the first year pure m^2 plots of sand and of mud were set up near plots with half and half, sand/mud and rock/silt, and a m^2 plot with randomized $4dm^2$ subplots of sand, mud, rock, and silt. These were censused visually and with unbaited pitfall traps monthly for a year. Then litter was added as a treatment to the mixed m^2 plot and a litter/silt plot was added. This set-up was replicated in another area and both are now being followed for a second year. The rank order of diversity is mixed >> rock-silt > mud > mud-sand > sand, but there is no linear relation (based on regression analysis) such as seen in studies of foliage height diversity. There are some species which clearly do select particular substrates

Table 1a

TESTS OF HYPOTHESES FOR CONTROL OF SPP DIVERSITY

Level Organization OPERATION	Community NATURAL EXPERIMENT Census(visual + trap)	Species OBSERVATION field/lab-data/expts	spp/Community MANIPULATION EXPTS Census(visual + trap)
HYPOTHESES/TESTS			
A. Physical			
1. <u>Substrate diversity</u>	within vs between cave patch size (grain)	mean free path	$1m^2$ plots, pure & mixed (mud,sand,detritus,rock)
2. "Microclimate"			
a. <u>rigor</u> i. moisture ii. flooding	within cave between seasons within cave between streams	-choice of gradient -mean free path -weight loss -"drowning" resistance (metabolic rate-time) -washout-injury (artificial stream)	-add moisture (drip bottle) -increase sat. deficit (electric fan)
b. <u>variability</u> moisturext°	within cave between seasons entrance/stream banks	-rate of acclimation (metabolic rate)	-wet/dry cycling (programmed fan)
B. BIOTIC INTERACTION			
1. <u>Predation</u>	within vs between cave (local and regional)	-diet (of presumed pred) -efficiency (cal return/item) -food needs (metabolic rate)	-remove predation (-exclosure -fishing predators) -add predation (-enclosure)
2. <u>Competition</u>	within vs between cave (local and regional) between seasons between habitat patches (alone vs together)	-as above + avoidance? (mean free path habitat selection)	-remove competitor and follow K (due to immigration) -microsuccession on horse manure, etc. (absolute cal.available)

Table 1b

TESTS OF HYPOTHESES FOR CONTROL OF SPP DIVERSITY

Level Organization OPERATION	Community NATURAL EXPERIMENT Census (visual + trap)	Species OBSERVATION field/lab-data/expts	spp/Community MANIPULATION EXPTS Census (visual + trap)
HYPOTHESES/TESTS C. ENERGY FLOW 1. rigor-i.e. food standing crop [cal/area + cal/gram] 2. rates (cal/t vs grams/t) (renewal vs turnover i.e. productivity) 3. predictability seasonality? 4. variability	Within Cave- -quality & quantity mud-sand organic % detritus import guano import (cricket, bat, cave rat, "spelunkers") -stream's import (discrete vs diffuse) -distance from ent. (espec. crickets) Between Caves - -local -regional	Food Finding - -threshold ∝ -sensory system (# sense organs, sensitivity, brain computer) -search pattern i.e. mean free path (rate movement, turning rate) -changes mfp and substrate Eating Rate -metabolic needs -maintenance i.e. standard met. rate -cost of foraging, etc. i.e. routine met. rate -kinds of items eaten -energy return (net cal/unit effort) (size of item etc) -storage capacity (crop, gut, fat) Growth and Egg Prod'n. ∝ max. met. rate-routine met. rate -growth rate per se -life history (∝, clutch (size-frequency)	1. rigor -quantity of food (one type) -dispersion (cal/area) -quality of food (cal/gram) 2. rates-renewal & turnover -microsuccession -decreasing cal (liver-cheese, horse manure, leaves) -continual renewal food -equal cal. avail at 1 time for each kind of food us (liver-cheese, horse manure, leaves) -same wt. (diff turnover+) control = blank pitfall trap 3. predictability -seasonal food addition -in food poor area -removal of seasonal input -"fish" crickets both 1-3 yr+ expts

that are associated with their preferred foods, notably the beetle Neaphaenops which keys on sand, when cricket eggs are abundant in spring-summer but tends to avoid sand at times of year when cricket eggs are scarce as it switches foraging strategy. This kind of substrate preference is relatively rare as seen from the fact that the switching seen in some of the major species makes the order of diversity change with time of year. When sterilized litter was added as a "substrate" treatment last summer the rank order of diversity changed to mixed > litter >>> sand sand > mud-sand > rock-dirt = mud. Statistical analysis comparing pure substrate to substrate-litter manipulation is not complete but it appears that litter has had a very great effect on diversity, and so food patch type is implicated as being more important than physical substrate on which foraging is concentrated. This result coupled with the stream comparisons, the observation of specific avoidance of litter by some species, and microsuccession on the litter have led me to concentrate on pattern and rate of food input for the next two years. The following section outlines proposed experiments.

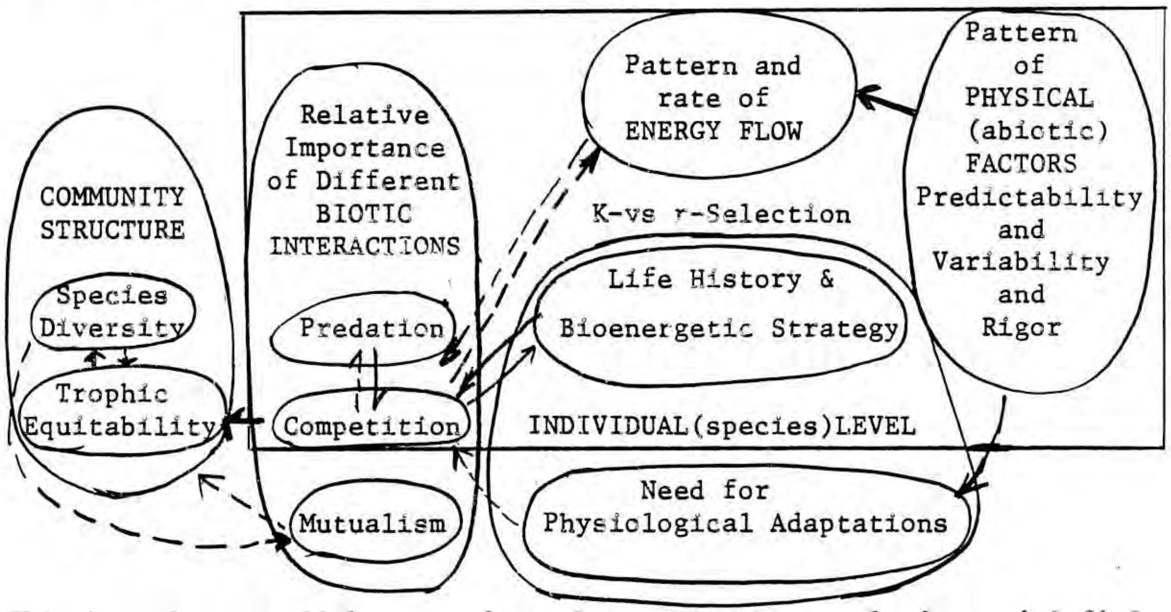
The general importance of this study is that it will provide a species level explanation for a community response to manipulation of pattern and rate of nutrient supply. This can be done because caves are simple systems where biotic and abiotic factors can be independently manipulated.

The speculative part of this proposal is the hypothesis that distribution of energy flow is the force underlying community organization. This is seen as a tendency for increase in number and efficiency of energy transfer steps with evolutionary time and with succession. It is proposed that community responses, as measured by species diversity and equitability, are imperfect reflectors of this tendency. It may be that some apparently inconsistent patterns of species diversity and equitability in the literature are the result of confounding these within habitat effects and between habitat effects. For this reason I will concentrate on the within habitat community response to patterns and rates of food input and leave the equally important between habitat patterns for future analysis.

I propose a two year study of the effects on community organization of pattern and rate of food input in terrestrial cave communities of Mammoth Cave National Park. The results will be of general applicability because cave communities are simple models of decomposer communities, an important class of systems that depend on allochthonous food input. Decomposer communities include springs, some streams, soil, and forest litter. Of these the terrestrial systems are least understood. It seems impossible to manipulate one parameter at a time and there are other methodological difficulties. The soil/litter animals and microflora require difficult and complicated extraction methods; there are many species few of which are taxonomically known; they are impossible to observe in situ, and only a few have been cultured. For all of these reasons little is directly known of the trophic biology of soil/litter organisms--what we do know is inferred from anatomy. In caves, as explained in D36 of this proposal, these problems are not so serious. Furthermore, I have 6 years of field experience with the terrestrial organisms of the Mammoth Cove area, and this has familiarized me with the biology of many of the species.

This proposed study, of pattern and rate of food input, is part of a long term study on the control of species diversity in terrestrial cave systems. The variables which influence species diversity are summarized by the tables, and my hypotheses for how those variables determine within habitat species diversity is schematized here.

The proposed research concentrates on the processes enclosed by the box. In words, this means that pattern of food input--i.e. rigor (calories/g and cal/area), variability, and predictability--and rate of food input (related to renewal) constitute selective pressures that shape life histories and bioenergetics (foraging patterns and metabolic efficiency).



This hypothesis will be tested at the community, population and individual levels of organization.

At the community level both natural and manipulative experiments are proposed to assess the effects of food rigor (calories/g) and rate of renewal on diversity patterns in areas of low and high natural food densities (calories/area). The factorial design of the manipulations includes two levels of food rigor (leaf litter and vertebrate feces), food non-renewal (allowing microsuccession) and renewal, and two distances from stream entrance sources of natural food input. The response variables will be number of species, census histories for component species, categories of bioenergetic strategies, and such derived statistics as species diversity, species equitability, and equitability of metabolic rates (i.e. trophic equitability).

The population level responses to manipulation generally will be important as clues to the biotic interactions that should be manipulated in future experiments. The specific objective is to verify different food webs, suspected on the basis of species associations observed in natural experiments involving the same variables which are to be manipulated in the proposed manipulative experiments.

The population level responses will be explained by properties at the individual level which are related to the so-called r- and K-selected strategies. The life history properties of these strategies will be inferred from seasonal patterns of size-frequency and minimum size of young measured in the field, from timing of life history events in the food manipulations, and from fecundity and egg size data derived from field collections. Foraging pattern and metabolic efficiency (collectively, bioenergetic strategy) will be inferred from field data on search pattern, laboratory studies of metabolic cost/distance moved, patterns of activity, and resistance to starvation.

STUDIES OF SEASONAL RESPONSES OF TERRESTRIAL CAVE COMMUNITIES TO NATURAL DIFFERENCES IN FOOD SUPPLY

Thomas L. Poulson and Thomas C. Kane

We are just completing 18 months of monthly visual and pitfall trapping in areas which represent different patterns and rates of food input. These data are important as a baseline for the next two years of study.

The suite of natural experiments on food pattern and renewal that have been examined, by pitfall trapping plus visual census, include the following extremes. Cricket eggs are the least rigorous food input with high cal/area and cal/g, have the least variable renewal rate, are most predictable, and have the highest renewal and turnover rates in grams and cal/time. One beetle species, Neaphaenops, monopolizes this food resource and is the subject of separate studies by Kane and by Kane, Norton and Poulson. The other extreme is leaf and twig fragments brought in by vertical shaft drains. This resource has high rigor with low cal/area and cal/g, is variable in time and space, has low predictability, and has the lowest turnover and renewal rates in grams and cal/time. Despite variability and low predictability of renewal rate, the low turnover seems to favor a very diverse and trophically equitable community of troglobites including 3 carabid beetles (Neaphaenops, Pseudanophthalmus menetriesi, and rarely P. inexpectatus), a spider (Anthrobia), a phalangid (Phalangodes), a dipluran (Plusiocampa cookei), 2 collembolans (Pseudosinella and Arrhopalites), a mite (Linypodes), a millipede (Scoterpes) a scavenger beetle (Ptomaphagus), and the "cricket" (Hadenoecus). Between these extremes are all other combinations of food pattern and flux. The resource types include diffuse and concentrated cricket guano, Neotoma fecal dumps, fresh leaf litter imported by Neotoma, fresh litter falling in at entrances, washed in litter of large variety and sizes that is partially leached during transport, and fine organic silt left at the high water line as backfloods from Green River recede.

STUDIES ON THE LIFE HISTORY AND BIOLOGY OF THE CAVE BEETLE NEAPHAENOPS TELLKAMPFII

Thomas C. Kane, Russell Norton, and Thomas L. Poulson

In deep cave areas with loose substrate the life history of *Neaphaenops tellkampfii* is keyed to the seasonal pattern of cave use by the "cricket," *Hadenoecus subterraneus*. Reproduction of *N.t.* seems to be related to the massive egg input by *H.S.* in the spring. At this time *H.s.* egg density increases 10-fold even after predation by *N.t.* Our 31 feeding observations suggest some switching to cricket nymphs and other cave animals as cricket egg density drops through the summer to a low in early fall when the predation rate approaches 95%.

Our reconstruction of *N.t.* life history in areas of *H.s.* egg input is as follows: (1) Female *N.t.* lay lots of eggs, either after the maximum spring *H.s.* egg density or the maximum in 1st instar *H.S.* nymphs that hatch 2 to 3 months later; (2) We cannot be certain of the timing for (1) because we find only a few early larval *N.t.* in the period from late summer through winter; (3) 4th instar *N.t.* larvae first appear in numbers the next February, most build cells under rocks in March and pupate in April when *H.s.* egg density is again highest and when *N.t.* adult sex ratio is approaching 2♀:1♂ due to earlier male mortality; (4) *N.t.* females are dying and the overall population density reaches its lowest in late spring as *H.s.* subadults leave the deep cave for entrances and the outside; (5) N.t. pupae hatch in 2 to 3 months with a resultant recruitment of teneral adults in July and August when most of the *H.s.* eggs are hatching. At this time many female beetles are dying and the sex ratio of teneral adults is bringing the overall sex ratio back toward 1:1; (6) By early fall *N.t.* recruitment is ending, the overall sex ratio is back to 1:1 and the population density is maximal again just as adult crickets move into the deep cave for the winter.

COMPARISON OF FORAGING STRATEGIES IN TWO POTENTIALLY COMPETING CAVE BEETLES, NEAPHAENOPS TELLKAMPFII AND PSEUDANOPHTHALMUS MENETRIESII

Thomas C. Kane

The central theme of this work is that terrestrial cave organisms are forced, by seasonal food input and spatial heterogeneity of food resources, to adopt particular life history and foraging strategies.

Laboratory studies have focused on the metabolic efficiency of foraging on leaf litter, where the microarthropod food of *P.m.* predominates, on mud, and on sand, where the cricket egg food of *N.t.* predominates. The hypothesis being tested is that *P.m.* is a feeding generalist and that the larger N.t. is a feeding specialist on cricket eggs.

On the basis of weight change, which can be related to calorie cost, N.t. does well at finding eggs but poorly at finding microarthropods (Tomocerus, Sinella, or Hypogastura). On the other hand, P.m. does reasonably. It is less efficient than N.t. on a weight-relative basis, at finding microarthropods but never finds eggs, since it does not dig.

The differences in feeding and the slight advantage of N.t. in metabolic efficiency are related to the costs of foraging in sand and leaf litter for the two species. P.m. seems to be excluded from sand, both because there are few microarthorpods and cost of locomotion is highest even with a hiding place which allows them to reduce their overall rate of locomotion. Cost of locomotion is least in leaf litter for P.m. and N.t. However, N.t.'s larger size and inefficiency at catching microarthropods seem to overshadow its metabolic advantage. N.t.'s large size of 6 - 7 mg allows it to utilize a 4 mg cricket egg, even with a high cost of locomotion on sand, but makes it difficult to get sufficient food, even with the largest of microarthropods at 1 mg (average microarthropod weight about 0.2 mg), when foraging in litter. P.m. is small enough, at 3 - 4 mg, that it is effective at catching microarthropods so it can subsist in litter on small food items.

FIELD EXPERIMENTS IN SIMPLE CAVE COMMUNITIES: PREDATION STRATEGIES OF TWO CO-OCCURRING CARABID BEETLES

Thomas C. Kane and Thomas L. Poulson

Two species of obligate cave beetles, Neaphaenops tellkampfii and Pseudanophthalmus menetriesii (Coleoptera:Carabidae) occur in caves located in Mammoth Cave National Park, Kentucky. Neaphaenops occurs in all cave habitats but reaches its greatest abundance in areas of loose uncompacted substrate where it specializes in feeding on the eggs of the cave "cricket" Hadenoecus subterraneus (Orthoptera:Gryllacrididae). Pseudanophthalmus shows a more restricted distribution, being limited to areas with enough organic input to support substantial micro-arthropod communities. In these areas, Pseudanophthalmus often co-occurs with Neaphaenops.

We hypothesize that the difference in distribution and abundance of these two species is the result of Neaphaenops ability as a feeding specialist and Pseudanophthalmus as a feeding generalist. Several types of field observation and manipulation support this hypothesis:

1. Foraging strategy of Neaphaenops shows a significant preference for loose substrate and it digs large numbers of holes in such substrates. It avoids leaf litter. On the other hand, Pseudanophthalmus shows neither obvious substrate preference nor digging behavior, but its greatest occurrence is in leaf litter. The difference in mean free path of the two species tends to concentrate them in loose substrate and litter, respectively.

2. There is little change in micro-distribution when Pseudanophthalmus and Neaphaenops occur alone and together and after removal of one species in areas of co-occurrence. This suggests that the differences in foraging are the result of past competition.

3. Life history is related to seasonal pattern of food input. Pupation of Neaphaenops occurs in spring and subsequent adult recruitment occurs in early summer where the adults can feed solely on cricket eggs. Where cricket eggs are less dense and micro-arthropods are also present, recruitment in Neaphaenops occurs over a longer period and peaks in late summer - early fall. In the latter areas, recruitment in Pseudanophthalmus is sharply peaked and always occurs in late summer - early fall.

THE NEAPHAENOPS-HADENOECUS PREDATOR-PREY SYSTEM

Russell Norton
(MACA-N-36)

Summary of Recent Results

1. Neaphaenops has been observed feeding 31 times. Its chief food is the eggs of Hadenoecus, but it also takes the early instar nymphs and is a generalized opportunistic predator.

2. Hadenoecus oviposition is seasonal and egg densities after predation by Neaphaenops peak in early spring.

3. Neaphaenops has been observed *in copulo* 17 times, all except twice in the 6 1/2 month period between the end of December and mid-July.

4. Neaphaenops last instar larvae and pupae are markedly seasonal, appearing principally in late winter and early spring. The pupae require about 2 months to emerge as teneral (newly emerged, lightly scleritized) adults, which require 2-2 1/2 months to scleritize.

5. Neaphaenops adult recruitment also shows marked seasonality with most tenerals appearing from early spring to late summer. There is apparently a differential survival favoring females, which leads to a highly skewed sex ratio (2:1) before the newly recruited adults return the sex ratio to equality.

Norton, Kane, and Poulson conclude that Neaphaenops is seasonal as a result of a seasonal food supply. The respective seasonality and aseasonality of Darlingtonea and Rhadine are reviewed.

Other Results: Hadenoecus

Measurement of about a hundred Hadenoecus nymphs for cephalic capsule, hind femur, dorsal thorax, and eye length suggested hind femur length as the most convenient measure with the best separation of size classes. Therefore, hind femur length was taken for several hundred

Hadenoecus nymphs in an attempt to determine the number of instars in Hadenoecus life history. The measurements suggest that Hadenoecus (females) have 8 instars. The first 4 instars have mean hind femur lengths of about 3 mm, 5 mm, 6 mm, and 7 mm, respectively, seem clearly separated in size, feed within the cave, and cannot be sexed. The last 4 instars may not be clearly separated in size, can feed outside the cave, and can be sexed.

The egg of Hadenoecus hatches in about 3 months, but may take up to 6 months. The first instar nymph is white and nonfeeding and becomes a light tan just prior to molting about 5 weeks after hatching. The final, adult instar can live up to 1 year in the wild.

Thus it appears that Hadenoecus, an obligatory trogloxene and the prey, has a biannual life history, while Neaphaenops, a troglobite and the predator, has an annual life history.

THE POPULATION DYNAMICS OF CAVE CRAYFISHES AND THEIR COMMENSAL OSTRACODS FROM SOUTHERN INDIANA

Horton H. Hobbs III

The following is the abstract of a Ph.D. Dissertation by the same title. Dr. Hobbs was the recipient of the 1971 CRF Fellowship.

Approximately 1400 caves are known from two major karst areas in southern Indiana. Numerous taxa inhabit these caves: the blind, white troglibitic crayfishes, Orconectes inermis inermis (Cope) and Orconectes inermis testii (Hay), and the eyed, pigmented troglophile Cambarus (erebicambarus) laevis (Faxon) are prominent; Orconectes immunis (Hagen), Orconectes sloanii (Bundy), and Orconectes propinquus propinquus (Girard) also are occasionally observed. Entocytherid ostracods commensal on the exoskeleton of these crayfishes are Sagittocythere barri (Hart and Hobbs), Donnaldsoncythere donnaldsonensis (Klie), Uncinocythere xania (Hart and Hobbs), and Dactylocythere susanae Hobbs III.

Population studies were conducted on crayfishes and their ectocommensals inhabiting Mayfield's Cave (Monroe County) and Pless Cave (Lawrence County) for seven-month and two-year periods, respectively. The cave environments were relatively stable with respect to temperatures, relative humidity, pH, dissolved oxygen, and methyl orange alkalinity, variations being greatest during winter and spring flooding.

Crayfishes were tagged in Mayfield's and Pless Caves. Population sizes and home ranges in the 300 m study area of Mayfield's Cave and in the 540 m study area of Pless Cave were estimated. Individuals remained in one major area of the streams, with moderate movement both up and downstream. These home ranges of individuals overlap the ranges of other individuals, thus generating competition for food, space, and mating partners. Breeding O. i. testii males moved greater distances than nonbreeding males and females, possibly in search for mates. Sixty-five

percent of tagged O. i. testii moved upstream, indicating a possible restocking mechanism following floods.

Distances traveled by O. i. testii (Mayfield's Cave) were not related to individual size nor to elapsed time. Smaller individual male and female O. i. inermis (Pless Cave), however, moved greater distances downstream and larger crayfish showed a significant upstream movement (time not a factor).

Adult O. i. inermis demonstrated a marked decrease in growth increment that occurred as crayfish increased in size. Also, females increased in length significantly more than males. Smaller crayfish demonstrated significantly greater increases in length at each molt. Two major molting periods occurred for O. i. inermis (spring, fall).

Copulation of troglobitic crayfishes occurred during the fall and winter months and egg laying during late summer.

Of the ostracod species associated with cave crayfishes, S. barri was host specific to the troglobitic crayfishes, Dn. donnaldsonensis and Dt. susanae host specific to C. laevis, and Un. xania demonstrated a host preference for C. laevis and O. p. propinquus. There was relatively little interchange of ostracod species between the troglobitic crayfishes and the others, indicating a high degree of host specificity. C. laevis hosted significantly larger populations of ostracods than O. i. inermis and O. i. testii.

Maximum size of an ostracod population was limited by the size of the host and relatively unaffected by the length of the intermolt period.

Sexes and various instar stages of ostracods were selective for microhabitats on crayfishes (eye-antennae, gnathal, sternal-leg basal, and abdomen).

Numerous other symbionts were associated with crayfish exoskeletons, placing possible pressures on ostracods in competition for food and space.

ARCHEOLOGY

ARCHEOLOGICAL ACTIVITIES IN THE CENTRAL KENTUCKY AREA

Patty Jo Watson
(MACA-N-24)

Most of the past year's effort went into finalizing the manuscript for ARCHEOLOGY OF THE MAMMOTH CAVE AREA now in press (Academic Press, New York) and due to appear in April 1974. The complete table of contents of the volume is reproduced here.

Three archeology trips were made to Central Kentucky in fall 1973. A trip went to Lower Salts to record the Indian traces in the A survey (A15-A40) and to examine the relatively newly mapped H survey that takes off the A at A40. No aboriginal debris occurs in H at all. There was a trip to Mammoth Cave to record in the S and T survey crawl that takes off Ganter at A22. There was aboriginal activity all through the crawl with gypsum mining in the S survey and chert mining in the T survey.

A quick reconnaissance was made of surface sites on Indian Hill, a sandstone mesa near Brownsville. There is a little worked chert on the surface in at least one place on top and three shelter sites around the base of the bluff. There had certainly been aboriginal occupation of the shelters, but all appear to have been quite thoroughly disturbed.

ARCHEOLOGY OF THE MAMMOTH CAVE AREA: Table of Contents

HISTORY

THE HISTORY OF THE PEOPLES AND CAVES

OF FLINT RIDGE, KENTUCKY

Stanley D. Sides
(MACA-H-1)

The field program initiated in 1971 has progressed to the point that names and dates have been recorded from the Pike Chapman Entrance to near Dismal Valley. Nearly all names of interest have been found in Upper Salts, although Middle Salts has been only partially studied.

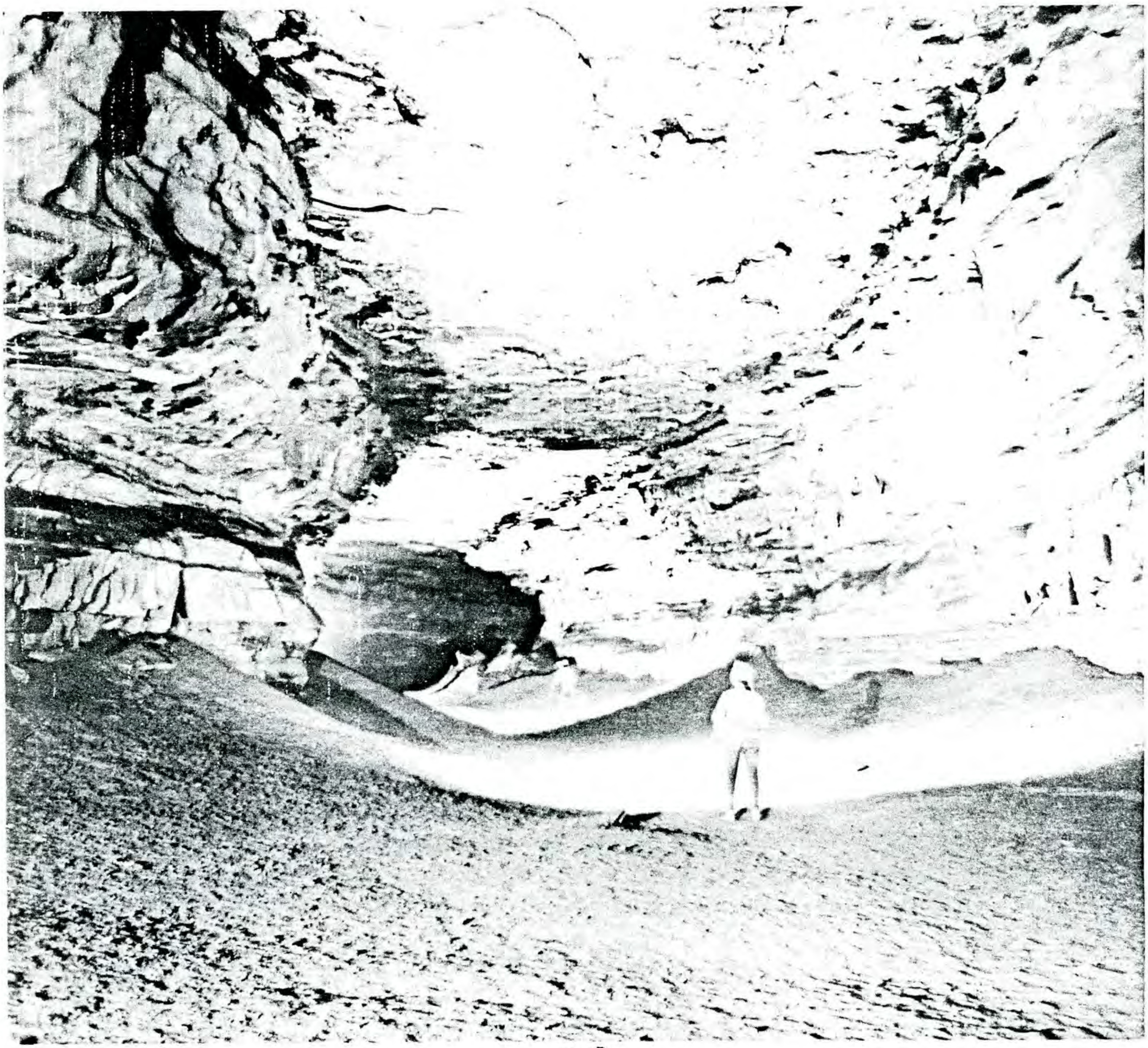
Ongoing study of "The Cave Man," Russell T. Neville, resulted in the discovery of several new pieces of information on the Neville Expedition to Salts Cave in 1927. Slides were taken of Neville photographs in the Faust collection. These were used in presenting the paper, "The Russell T. Neville Expedition in Salts Cave, Kentucky," at the Spelean History Session of the 30th Annual National Speleological Society Convention. George F. Jackson, one of the original participants on the expedition, gave his personal recollections of the expedition during the presentation of the paper.

We now know that Major Elliot was the primary guide for the party. Andy Lee Collins was originally selected to accompany the party, but at the last moment Homer Collins replaced him on the trip. They slept twice while on their 51-hour trip. The first "night" was spent at P-54, where wrappers and other debris from their fire can still be found. They went as far as the Pike Chapman Entrance, which was closed. The second sleep period was spent at K-13 in the famous "Neville Bedroom." They carried six gallons of water. Food consisted of 72 bread and butter sandwiches from the Mammoth Cave Hotel, 4 pounds of roast beef, 5 cooked chickens, candy, and cheese.

Research on the recent history of exploration in Salts Cave was directed toward activity by the Louisville area cavers around 1950. A key article to the understanding of their work is the important Louisville Courier-Journal article entitled, "Great Salts Cave: One of the Biggest in the World," LC-J Magazine, September 17, 1950. This well illustrated article should be read by all people interested in the history of the park.

George F. Jackson, Erwin Sloane, and William R. Halliday have all contributed significant new information to this project.

MANAGEMENT PUBLICATIONS



Main passage in Smiths Grove Cave. This high level fragment provides dramatic evidence that major cave trunks occur under the Sinkhole Plain as well as under the sandstone capped ridges.

Photo by Steve G. Wells.

MANAGEMENT

DIRECTORS AND COMMITTEES

Directors

Several changes in the Directorate were made at the fall Board meeting in Albuquerque, New Mexico.

Dr. William P. Bishop resigned as Treasurer but retained his position on the Board. Dr. Burns was appointed acting Treasurer in the interim.

Dr. William B. White resigned as Director effective immediately and as Chief Scientist effective June 30, 1974. Dr. David J. DesMarais, Indiana University, was appointed to fill the place on the Board of Directors and will become Chief Scientist July 1, 1974.

The present members of the Board of Directors are

Stanley D. Sides, President
Denver P. Burns, Secretary and Acting Treasurer
William P. Bishop
Roger W. Brucker
Joseph K. Davidson
David J. DesMarais
P. Gary Eller
John P. Freeman
John P. Wilcox

Officers and Management Personnel

For general management of the Foundation:

Controller	Dennis E. Drum
Personnel Data	William F. Mann
Publications Officer	Ernst H. Kastning
Historian	Stanley D. Sides

For the Central Kentucky Area:

Manager	P. Gary Eller
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	David J. DesMarais
Safety Officer	John W. Grover, Jr., Md.
Vertical Supplies	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
Finances	Dorothy M. Corcoran
Log Keeper	Rondal R. Bridgemon, Jr.

Operating Committees

Many of the functions of the Foundation are managed through operating committees, usually chaired by a Director. This is a new mode of managment, introduced several years ago, and is designed to free the President from much of the day-to-day routine as well as to keep Directors busy at the operating (hence the name) as well as the policy making level. 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. This committee has been re-organized as described later. By definition, all persons conducting research projects under Foundation sponsorship are members of the Research Committee.

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

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

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 maintenance 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
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

William P. Bishop, Chairman
Jacqueline F. Austin
Roger W. Brucker
Denver P. Burns, Acting Treasurer
Dorothy M. Corcoran
Dennis E. Drum, Controller
Gordon L. Smith
Philip M. Smith

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

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

The CRF Operations Manager has general responsibility for overview of the CRF field program in Central Kentucky, and particularly in Mammoth Cave National Park where the preponderance of activity occurs. Specifically, the Manager is responsible for

(i) Setting up the field schedule and assigning expedition leaders.

(ii) Serving as a central coordination center between Joint Venturers and expedition leaders, and ensuring that special expedition objectives (e.g. last-minute science-support field teams) are met during the expedition.

(iii) Maintaining liason with the National Park Service regarding all field activities.

(iv) Establishing procedural agreements with the National Park Service with respect to field activities (the use of cave keys, Local Operating Procedures, passes, etc.).

(v) Ensuring the conduct of field operations in an efficient and orderly manner, in harmony with CRF objectives in Mammoth Cave National Park.

Operationally, the following activities involving the Operations Manager may be noted:

(i) Since November 1972, twenty CRF expeditions to MCNP have been led by thirteen different leaders. Twelve trips were regularly scheduled expeditions, eight were small special-objective expeditions, and six were led by new expedition leaders.

(ii) To avoid the mid-week lull that has occurred during the traditional week-long August expedition, in 1973 there were two shorter August trips. It appears the productivity of the field program has been more than doubled by splitting the week in August into two shorter periods.

(iii) The National Memorandum of Agreement between the Cave Research Foundation and the National Park Service has been enacted and the local Operating Procedure for Mammoth Cave National Park is currently under review.

(iv) Continuity has been maintained in the use of the Flint Ridge Field Station (other than the periodic CRF Expeditions). J.W. Hess remained in residence until early October while conducting thesis research. The Field Station is presently occupied by NPS Ranger David McGinnis.

Field Operations in the Guadalupe Escarpment Area

A total of six major and two minor expeditions were fielded during 1973. Numerous other field trips have been made by various investigators. Cave areas that received particular attention this year are listed below:

- Carlsbad Caverns National Park (CCNP):
  - Carlsbad Caverns:
    - Lower Cave Maze
    - Mabel's Room Boneyard Area
    - Big Room
    - Left Hand Tunnel
  - New Cave
  - Midnight Goat Cave
  - Lake Cave
  - Spider Cave
  - Christmas Tree Cave
  - Water Tank Cave
- Guadalupe Mountains National Park (GMNP):
  - Heigler Goat Cave
  - Majestic Ice Cave
- McKittrick Hill (Bureau of Land Management)
  - Dry Cave
- Guadalupe Ridge (United States Forest Service)
  - Black Cave

Arrangements for more permanent field facilities at Carlsbad Caverns National Park have been made. Building #6 is now being used as the primary base of operations, office area and storage area for the field expeditions at CCNP and GMNP. Building #7 is being used for expedition sleeping and researcher housing. Elbert Bassham is acting as the Field Station coordinator. Karen Welbourn is acting as the food and meals coordinator for expedition meals. During 1973 the number of Western Joint Venturers has increased to approximately 60; of these 30% are also active in the East at MCNP.

PERSONNEL

General Statistics

Overall, the number of CRF Joint Venturers has increased over the past year and now stands at 294. Actually, the number of Central Kentucky personnel has decreased somewhat but is supplemented this year by the new JV's of the western area operation:

Number of JV's as of November 11, 1972	274
Attrition through discontinuance	-64
Continuing JV's	210
New JV's - Kentucky	45
New JV's - Guadalupe	39
Number of JV's as of November 10, 1973	294

Central Kentucky Area

Again, the Central Kentucky Area operation witnessed a net drop in JV's over the past year. This is actually due to a thorough scrutiny and discussion of the 1972 JV list which resulted in the discontinuance of many JV's who had long ago departed the Kentucky area or had lost interest in Foundation activities. Therefore, instead of 274 motivated people as of last November, we have 255 tremendously motivated people this November. Participation and morale is currently at a very high level, because:

(i) The Flint-Mammoth connection announcement on December 1, 1972. A lot of formerly active JV's are breathing new fire into the operation, and recruitment is up, as a result.

(ii) The continuing high level of success in exploration subsequent to the connection - continuing discoveries in Mammoth and the Joppa event.

(iii) The success of the new field station arrangement (Austin and Collins houses, and ticket office).

(iv) Increased incentive spurred by the excellence of the cartography operation. People can now see what they have mapped in a very short time!

(v) Lower personnel turnover. Since we've levelled off near the 300 personnel level, JV's have been staying with us longer. Cave party leadership is excellent and the trips are running smoothly.

Guadalupe Escarpment Area

The number of Western participants has increased appreciably since this time last year. At the end of 1972 there were approximately 48 Joint Venturers - now there are 60. Our recent acquisition of permanent facilities in Carlsbad Caverns National Park will be of immense value in holding coordinated expeditions for our larger numbers. Our recruiting efforts will continue to encourage primarily Joint Venturers interested in scientific research or those showing potential as future leaders in CRF activities.

RESEARCH COMMITTEE RE-STRUCTURING

For many years the Foundation's research programs have operated as a loose confederation of projects under the general monitoring of the Chief Scientist. Expansion both geographically and in terms of the number of projects has forced a more specific organizational structure.

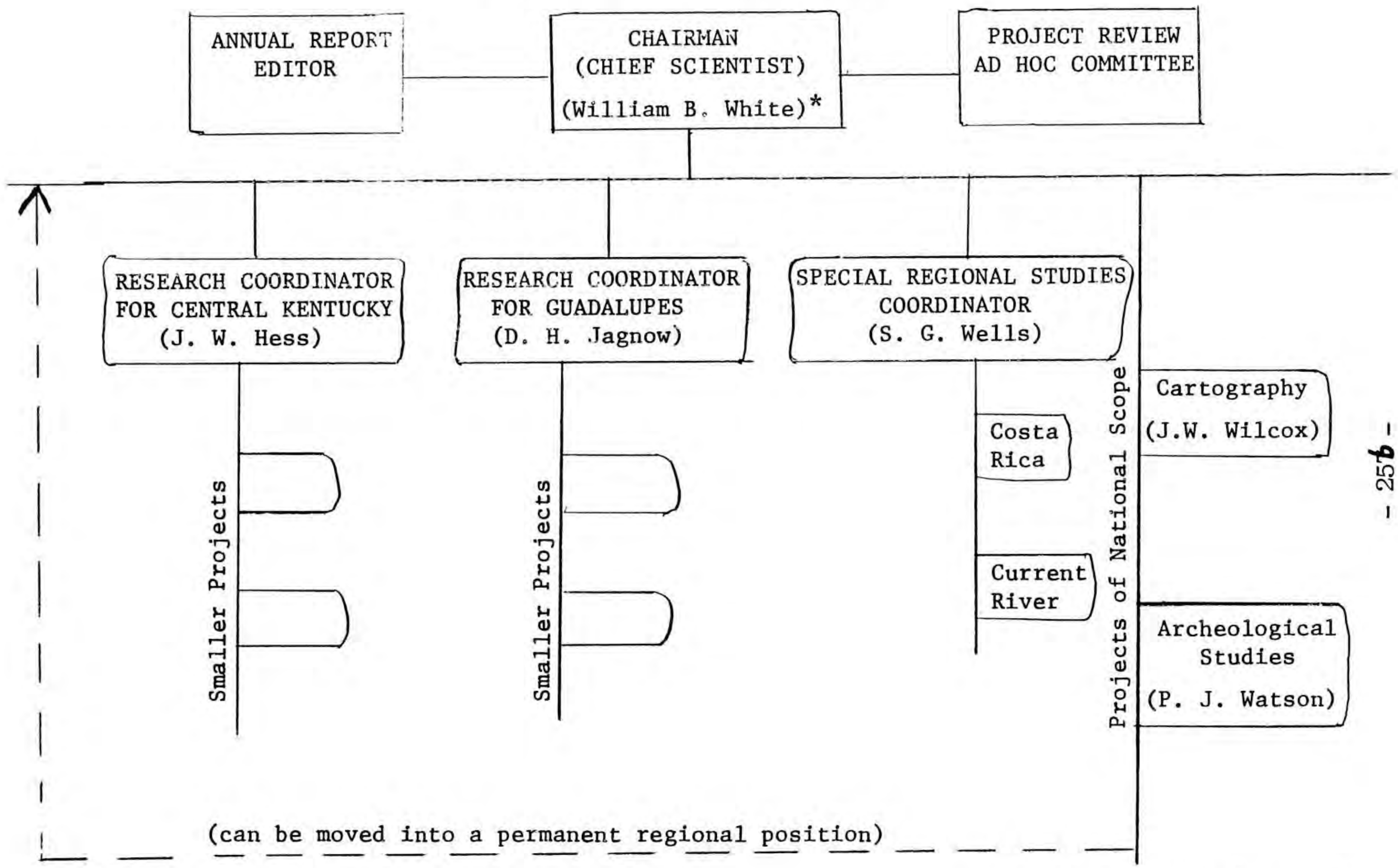
Both line and staff positions have been created. The staff positions include an editor for the annual report and an ad-hoc committee of senior investigators assembled for the purpose of reviewing proposals and applications for the CRF annual fellowship.

New line positions are the three research coordinators for the Central Kentucky Area, for the Guadalupe Escarpment Area, and for special regional studies. The individuals appointed to these positions have the dual responsibility of monitoring active research in their geographical areas and of nucleating new research in those areas by identifying worthwhile projects and the interested people to carry them out. The research coordinators act as a direct communication link between the individual investigators and the Chief Scientist.

The series of special regional studies was initiated this year because of a further broadening of CRF's geographical base. A geographical reconnaissance of the karst features of the Current River Scenic Waterway, and an expedition to Costa Rica to investigate the speleological resources of Barra Honda National Park for the Costa Rican government fall into this new category of activities.

Many of the projects under the supervision of the regional coordinators are single-investigator efforts typically of the dissertation research type. Projects of greater internal complexity, or of national scope, are headed by an identified principal investigator who reports directly to the Chief Scientist. Two projects currently so identified are the cartographic effort which cuts all geographical boundaries, and the archeological effort in Central Kentucky which, although geographically localized, involves a large internal staff of students and assistants and the cooperative efforts of many specialists from other institutions.

Research Committee Structure



*David J. Desmarais as of June 1974

PUBLICATIONS

BOOKS

RAMBLES IN MAMMOTH CAVE (originally published in 1845) was published by Johnson Reprint with a new introduction by Harold Meloy. It is the fifth of a series of volumes, CLASSICS IN SPELEOLOGY, edited by Richard A. Watson.

JOURNAL ARTICLES

Contributed Papers

26. Roger W. Brucker, John W. Hess, and William B. White. ROLE OF VERTICAL SHAFTS IN THE MOVEMENT OF GROUND WATER IN CARBONATE AQUIFERS. Ground Water 10 [6] (1972).

27. Cave Research Foundation. THE FLINT-MAMMOTH CAVE SYSTEM. Three-color map of cave system on topographic base. One sheet with text on back. Cave Research Foundation (1973).

28. Carol A. Hill. HUNTITE FLOWSTONE IN CARLSBAD CAVERNS, NEW MEXICO. Science 181, 158-159 (1973).

29. Carol Hill. BELL CANOPIES. Natl. Speleol. Soc. News 31, 58 (1973).

30. Carol A. Hill. HYDROMAGNESITE BALLOONS IN CARLSBAD CAVERNS. Natl. Speleol. Soc. News 31, 175-176 (1973).

Supported Papers

29. Richard A. Watson. LIMITATIONS ON SUBSTITUTING CHEMICAL REACTIONS IN MODEL EXPERIMENTS. Zeits. Geomorph. 16, 103-108 (1972).

Scientific Reports

5. Carol A. Hill. GUADALUPE CAVE SURVEY MINERALOGICAL REPORT FOR FIELD TRIP OF 27 MAY, 1973. Report to National Park Service, 5 pp.

Advisory Reports and Publications

11. Robert R. Stitt and William P. Bishop. UNDERGROUND WILDERNESS IN THE GUADALUPE ESCARPMENT: A CONCEPT APPLIED. Natl. Speleol. Soc. Bull. 34, 77-88 (1972).

12. Richard A. Watson. MAMMOTH CAVE--A MODEL PLAN. Natl. Parks and Conservation Mag. 46 [12] 13-18 (1972).

Reviews

William B. White. Review of Karst by J.N. Jennings and Karst: Important Karst Regions of the Northern Hemisphere by M. Herak and V.T. Stringfield. Science, 176, 664 (1972).

Richard A. Watson. Review of Genetic Relationship between Caves and Landforms in the Mammoth Cave National Park Area, A Preliminary Report by F-D. Miotke and A.N. Palmer. Caves and Karst 14, 44-46 (1972).

Theses

9. Thomas E. Wolfe,"Sedimentation in Karst Drainage Basins along the Allegheny Escarpment in Southeastern West Virginia, USA" Ph.D. in Geography, McMaster University.

10. Horton H. Hobbs III, "The Population Dynamics of Cave Crayfishes and their Commensal Ostracods from Southern Indiana" Ph.D. in Zoology, University of Indiana.

11. Steve G. Wells, "Sinkhole Plain Evolution in the Central Kentucky Karst," M.S. in Geology, University of Cincinnati.

PAPERS AT PROFESSIONAL MEETINGS

American Society of Zoologists; Southeastern Section (Symposium on Ecological Studies, Bowling Green, KY, April 1973)

Thomas L. Poulson, "Studies on the control of species diversity in terrestrial cave communities: Experimental manipulation of food and substrate"

Thomas C. Kane, "Predation strategies of two co-occurring carabid beetles, *Neaphaenops tellkampfi* and *Pseudoanophthalmus menestriesi*"

Russell Norton, "Convergent evolution between the cave "cricket" *Hadenoecus* and two of its egg predators, *Neaphaenops* and *Darlingtonea*"

National Speleological Society (Bloomington, Indiana, June 1973)

John W. Hess, Steve G. Wells, and Thomas A. Brucker, "A Survey of Springs along the Green and Barren Rivers in the Central Kentucky Karst"

Thomas L. Poulson (Symposium Chairman), "Evolutionary strategies of Cave Beetles: Seasonality and Food Habits"

Russell S. Harmon, "Chemical Composition of Cave Calcites"

Horton H. Hobbs III, "Movement of Troglobitic Crayfishes from Southern Indiana Caves"

Margaret V. Palmer, "History of Landform Development in the Mitchell Plain of Southern Indiana"

John W. Hess, "Hydrology of the Central Kentucky Karst"

Steve G. Wells, "Sinkhole Plain Evolution in the Central Kentucky Karst"

Stanley D. Sides, "The Russell T. Nevill Expedition in Salts Cave, Kentucky"

International Congress of Anthropological and Ethnological Sciences (Chicago, Ill. Sept. 1973)

Richard A. Yarnell, "Origins of Horticulture in the Eastern Woodlands"

VIth International Congress of Speleology (Olomouc, Czechoslovakia, Sept. 1973)

R.S. Harmon, J.J. Drake, J.W. Hess, R.L. Jacobson, D.C. Ford, W.B. White, J. Fish, J. Coward, R. Ewers, and J.F. Quinlan, "Geochemistry of Karst Waters in North America"

J.W. Hess and W.B. White, "Analysis of Karst Aquifers from Hydrographs of Karst Springs"

R.S. Harmon, P. Thompson, H.P. Schwarcz, and D.C. Ford, "Isotopic Dating of Speleothems as Related to Geomorphic History of Carbonate Terrains"

R.A. Watson, "Pseudo-Karst of the Klutlan Glacier, Yukon Territories, Canada"

P.J. Watson, "Prehistoric Miners of the Flint-Mammoth Cave System Mammoth Cave National Park, Kentucky, USA"

TALKS, SEMINARS, AND SYMPOSIA

Roger W. Brucker:

"Your Longest Cave: How it Grew" Banquet Speech, Natl. Speleol. Soc. Convention, Bloomington, Indiana.

Glenn D. Campbell:

"Cave Cricket Activity Rhythms" at Graduate Faculty Seminar, Texas Tech University.

Carol A. Hill:

"Cave Minerals," Sandia Grotto.

"Origin of the Black Coatings in Black Cave, Lincoln National Forest, Guadalupe Mountains, New Mexico" at Southwest Regional, NSS, Alamagordo, NM.

R. Pete Lindsley:

"Powell's Cave, Texas" at Dallas-Ft. Worth Grotto.

"Speleology in the Guadalupe Escarpment Area" After-Dinner talk at CRF Board of Directors meeting, Albuquerque, NM.

Arthur N. Palmer:

"Geomorphic Aspects of Karst Hydrology" at University of Connecticut April 1973.

"Karst Hydrology" Seminar in Groundwater Hydrology, Dept. of Geology SUNY at Binghamtom.

Richard A. Watson:

"The Flint-Mammoth Cave System" at University of Ljubljana Speleo-Club, Yugoslavia.

"The Flint-Mammoth Cave System" at Speleo-Club de Paris, Paris, France.

P.J. Watson:

"Salts Cave Archeology" Dept. of Anthropology, Washington University.

W. Calvin Welbourn:

"Cave Fauna in New Mexico" Southwestern Region, NSS.

"Cave Fauna in New Mexico" Sandia Grotto.

Steve G. Wells:

"Flint Mammoth Cave Connection and its Role in Kentucky History" Anderson Township Historical Society, Cincinnati, Ohio.

William B. White:

"The Flint-Mammoth Cave System" Windy City Grotto, Chicago.

"The Longest Cave" Nittany Grotto.

ABSTRACTS OF 1973 PAPERS

Role of Vertical Shafts in the Movement of Ground Water in Carbonate Aquifers

by Roger W. Brucker[a], John W. Hess[b], and William B. White[c]

ABSTRACT

Vertical shafts are roughly cylindrical voids in carbonate rocks. They range in diameter from inches to tens of feet and in height from inches to hundreds of feet. They are produced by vertically descending ground water from perched ground-water reservoirs or surface water. These features are common throughout the Interior Lowlands and Appalachian Plateaus Provinces. Vertical shafts form the headwater termini of complex drainage networks that aggregate the waters into master drains which carry the water to big springs. The drains evolve through time as base level is lowered but retain a dendritic pattern. Shafts are very short lived and occur only near the edge of the clastic caprock in the study area in south central Kentucky. Shafts are formed by free flowing sheets or films of vadose water streaming down the walls in supercritical flow. These waters are undersaturated with respect to calcite at both top and bottom of the shaft, although there is a measurable uptake of $CaCO_3$ as the water traverses the shaft walls. The shafts act as aeration chambers, and there is much loss of carbon dioxide from the ground water during movement through this segment of the underground route.

Huntite Flowstone in Carlsbad Caverns, New Mexico

Abstract. *Huntite flowstone has recently been discovered in Carlsbad Caverns. This flowstone occurs as a thin, white layer of microcrystals (approximately 1 to 60 micrometers in diameter) which appears buckled and crinkled. The huntite is believed to be precipitating directly from magnesium-rich solutions rather than forming by alteration of preexisting minerals.*

Underground Wilderness in the Guadalupe Escarpment

A Concept Applied

Robert R. Stitt [1] and William P. Bishop [2]

ABSTRACT

The concept of underground wilderness is not new to the discussion of protection of caves and karst features and has occurred regularly since before the Wilderness Act of 1964 became law. Those who have experienced the cave wilderness have never doubted its existence, but land managers have been slow to accept it. The definition of underground wilderness is discussed in terms of the value of the resource, its impact on an observer, and its defensible boundaries. The utility of the concept in management of the cave resource and the overlying lands is applied explicitly to the Guadalupe Escarpment of New Mexico and Texas. From the considerations of underground wilderness and its application to the Guadalupe Escarpment, concrete recommendations for underground wilderness in the Guadalupe Escarpment area are derived.

Limitations on substituting chemical reactions in model experiments[1]

by

RICHARD A. WATSON, St. Louis, Missouri

Zusammenfassung. Aus Gründen der Analogie wird aus Modellexperimenten auf natürliche Zustände gefolgert. Bei geologischen Modellexperimenten ist der Zeitfaktor ein besonderes Problem, das bislang noch nicht maßstabsgerecht erfaßt wurde. Um die Entstehung von Höhlenphänomenen in Kalksteinen zu erklären, wurden in einigen berechneten Modellexperimenten die Vorgänge dadurch beschleunigt, daß entweder statt des Kalksteins Salzblöcke verwandt und die schwach karbonatische Säure der Natur (Wasser) beibehalten wurde oder es wurde statt des Wassers Salzsäure verwandt und der natürliche Kalkstein wurde beibehalten. Aus diesem Vorgehen ergeben sich zwei Fragen: 1. Wieviel Stunden Lösungsvorgang im Modell ergeben wieviel Jahre natürlicher Kalksteinlösung durch Wasser in der Natur? 2. Entspricht der Lösungsvorgang von Wasser auf Salz oder von Salzsäure auf Kalkstein wirklich dem Lösungsvorgang von Wasser auf Kalkstein? Keine von diesen Fragen wurde hinreichend beantwortet. Es ergeben sich deswegen Zweifel an der Zulässigkeit von Folgerungen aus Modellen, in denen Lösungsvorgänge durch den Ersatz einer chemischen Reaktion durch eine andere beschleunigt wurde.

Summary. Reasoning from model experiments to natural situations is by analogy. A special problem in geological model experimentation is time, which has not been adequately scaled. In some model experiments calculated to explain the genesis of cave features in limestone, processes are speeded by substituting salt blocks for the limestone and retaining the weak carbonic acid of nature (water), or by substituting hydrochloric acid for water and retaining the limestone of nature. This raises two questions: First, how many hours of solutional activity in the model represent how many years of natural solution of limestone by water in nature? And second, is the solutional activity of water on salt, or of hydrochloric acid on limestone, actually analogous to the solutional activity of water on limestone? Neither of these questions has been adequately answered. This casts doubt on the viability of arguing from models in which solutional activity is greatly speeded by substituting one chemical reaction for another.

APPENDIX

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