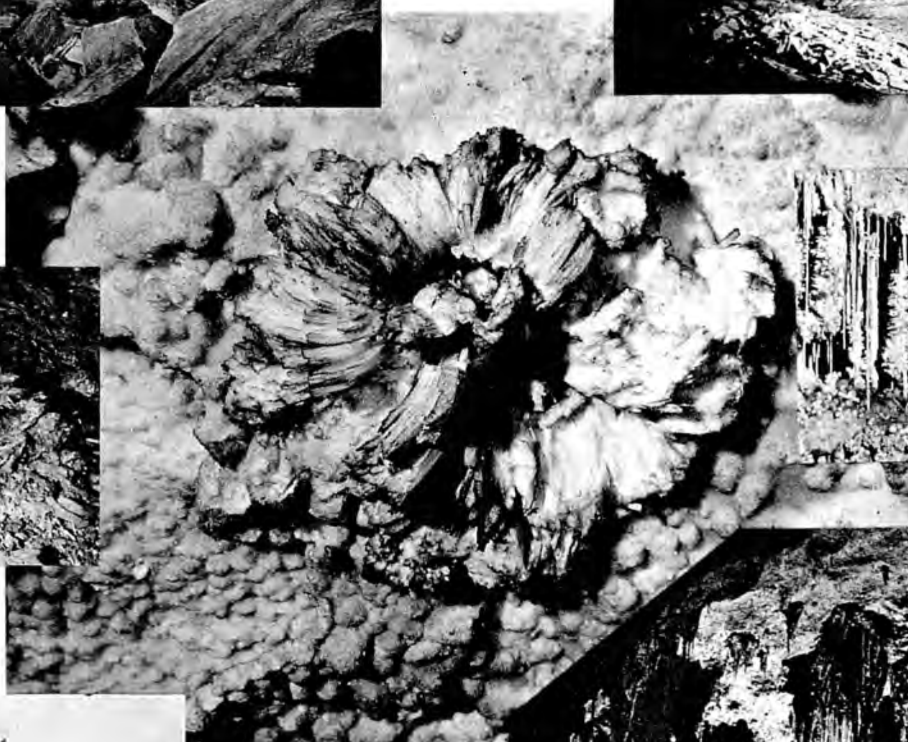
CAVE RESEARCH FOUNDATION



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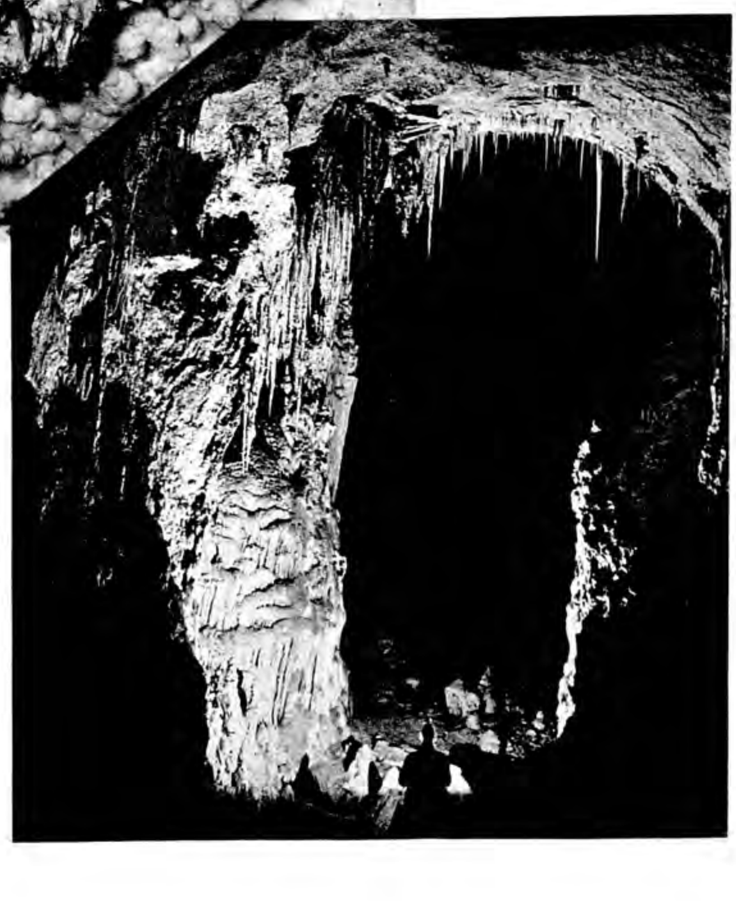

1973

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R. Pete Lindsley, Guadalupe Escarpment Area
Dallas, Texas

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.

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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.

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.

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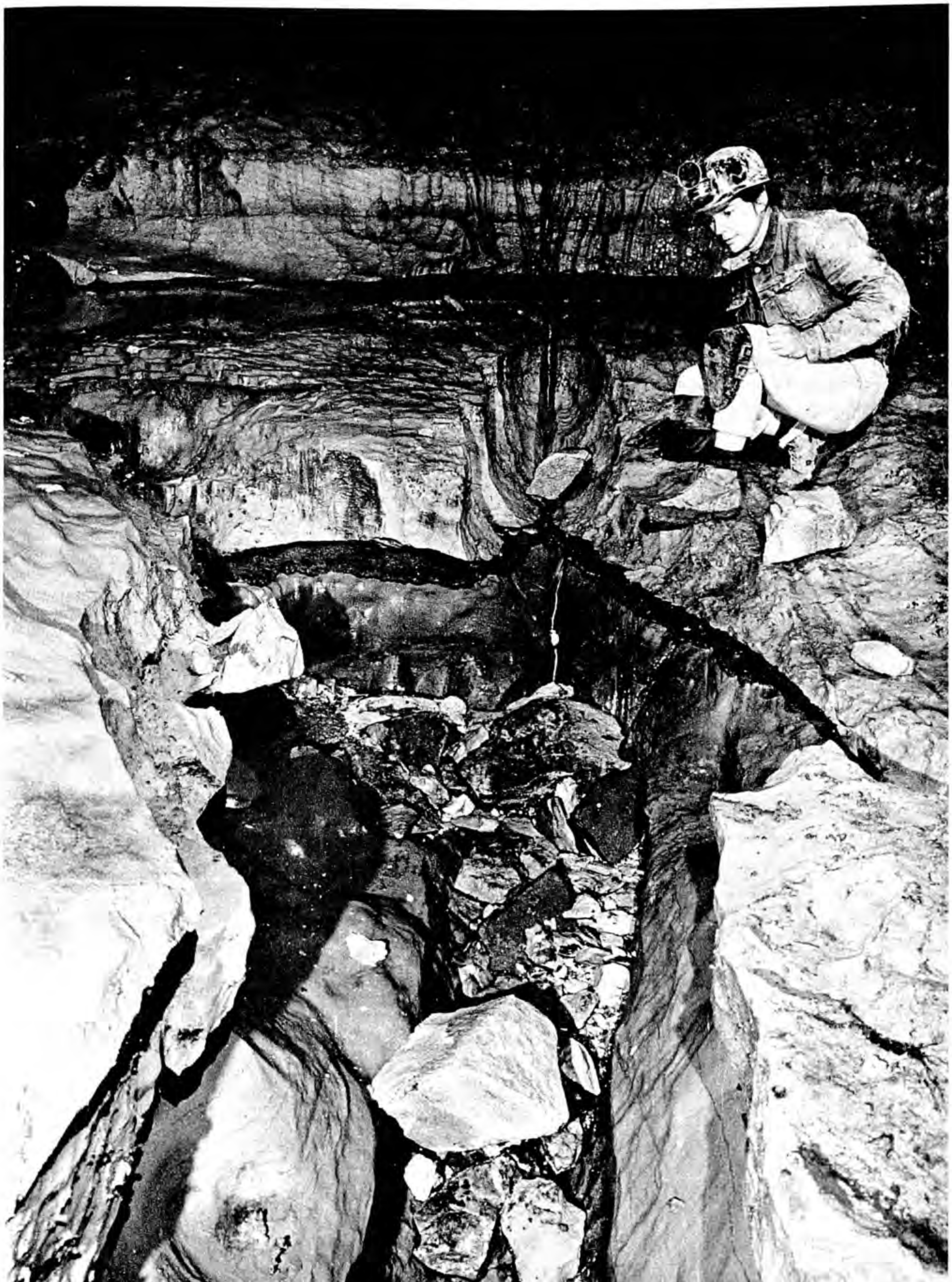
William B. White
Chief Scientist
1961-1973

THE SCIENTIFIC PROGRAMS



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.

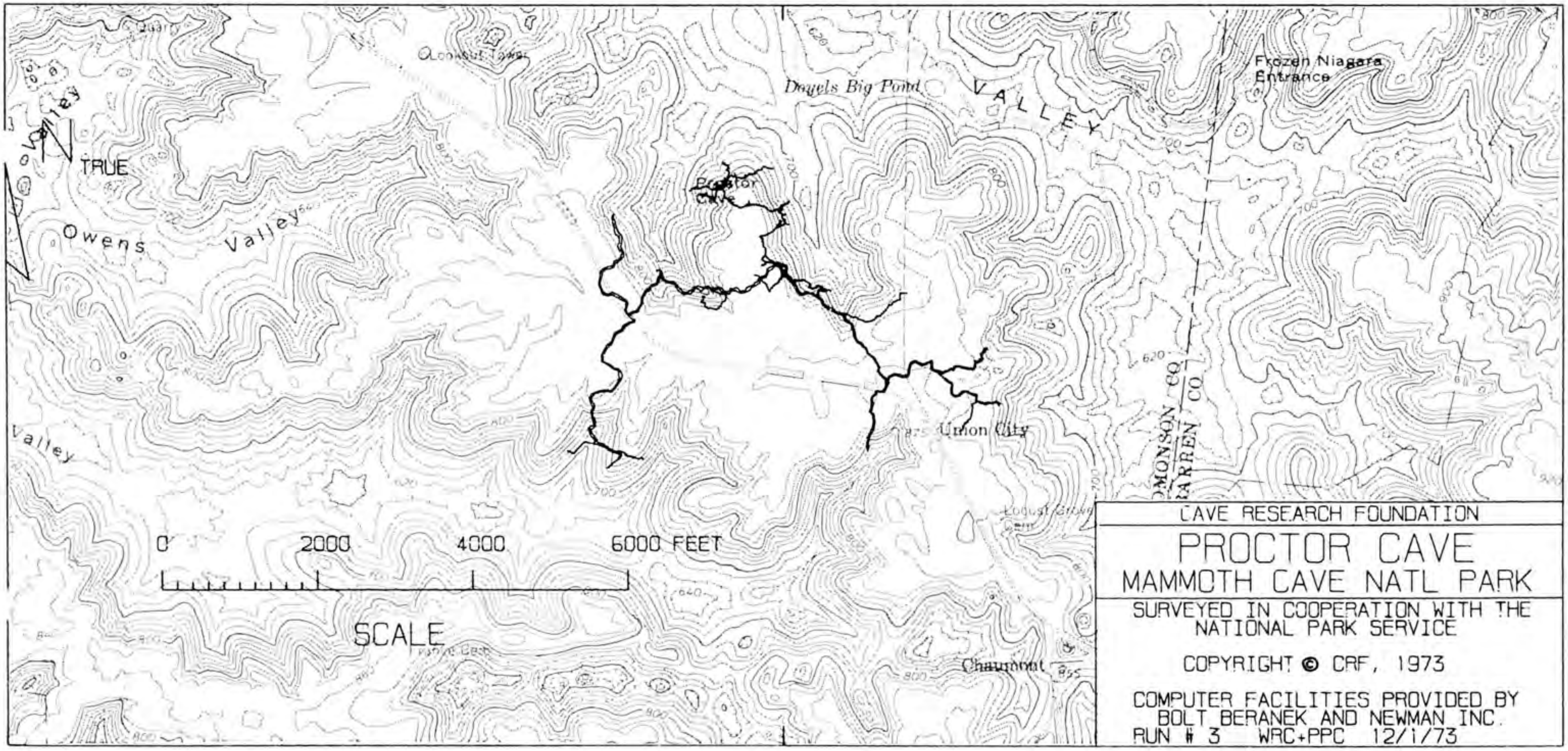
Another virgin area lying east of the Frozen Niagara Entrance was entered via a tight canyon off Cocklebur Avenue. It contains impressive domes and a segment of trunk passage, and several canyon leads remain.

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.



Frozen Niagara Entrance
Doyels Big Pond
VALLEY
TRUE
Owens Valley
Proctor Cave
Union City
Valley
EDMONSON CO
BARREN 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
COMPUTER FACILITIES PROVIDED BY BOLT BERANEK AND NEWMAN INC.
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.

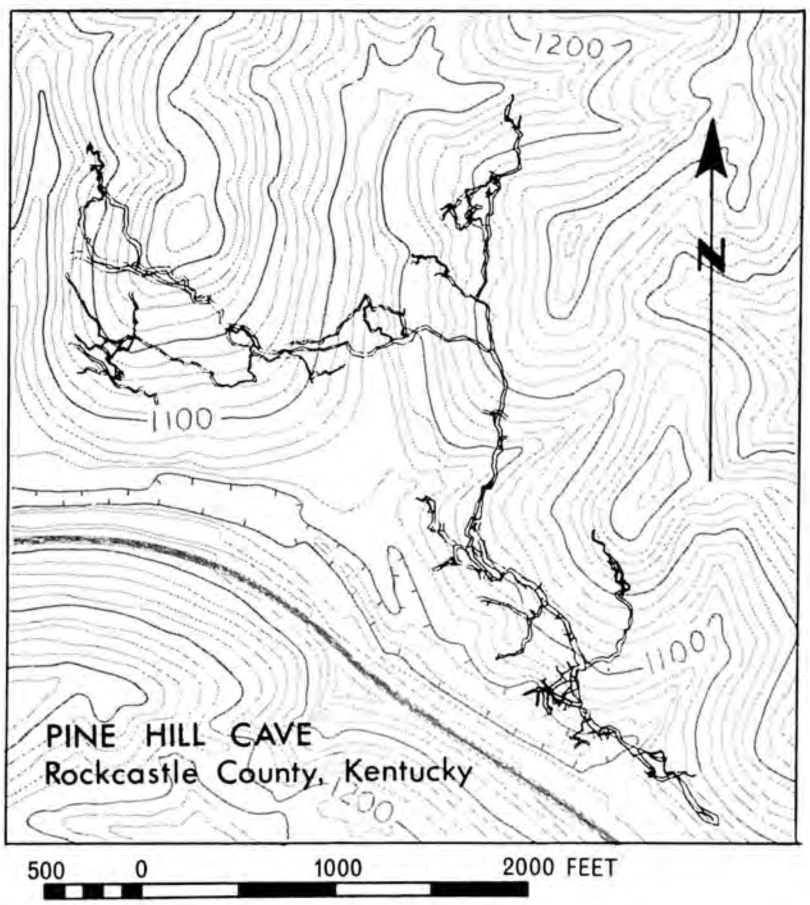
SURVEY OF PINE HILL CAVE

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
1100
1200
PINE HILL CAVE
Rockcastle County, Kentucky
N
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.

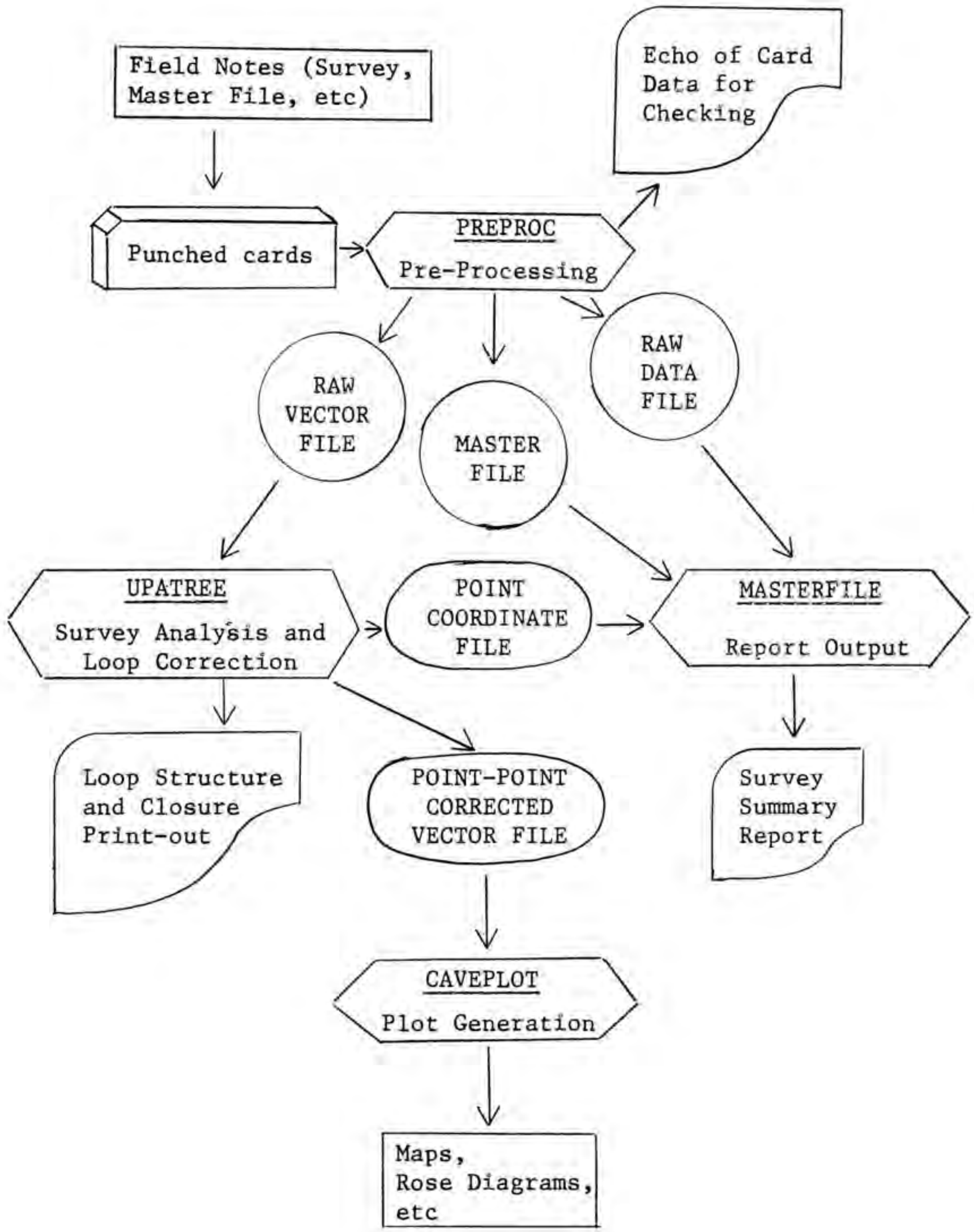


Fig. 3 Information flow in the new CRF-West cave data processing system.

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

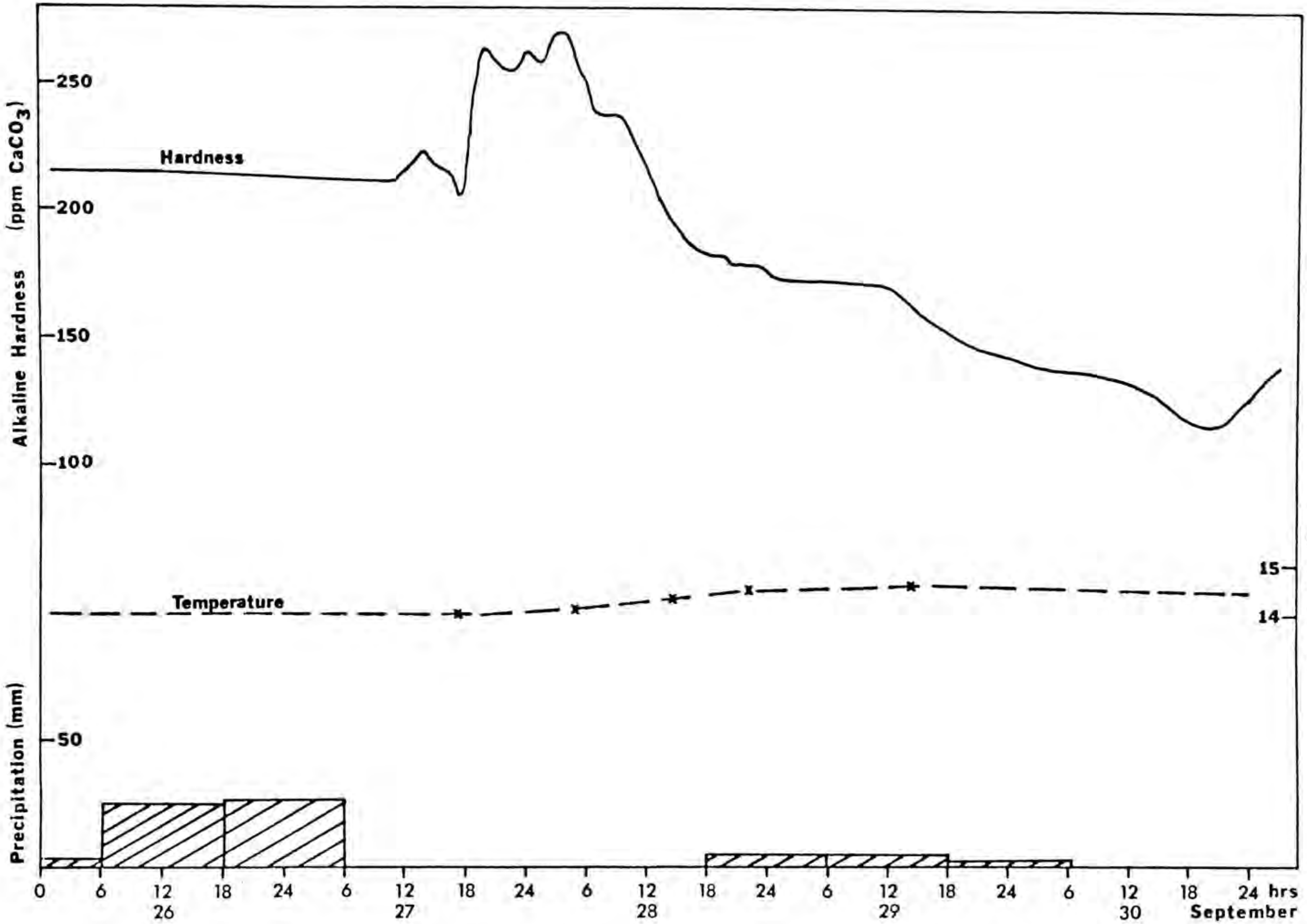


Figure 4. Chemical hydrograph showing rise in hardness after storm input.

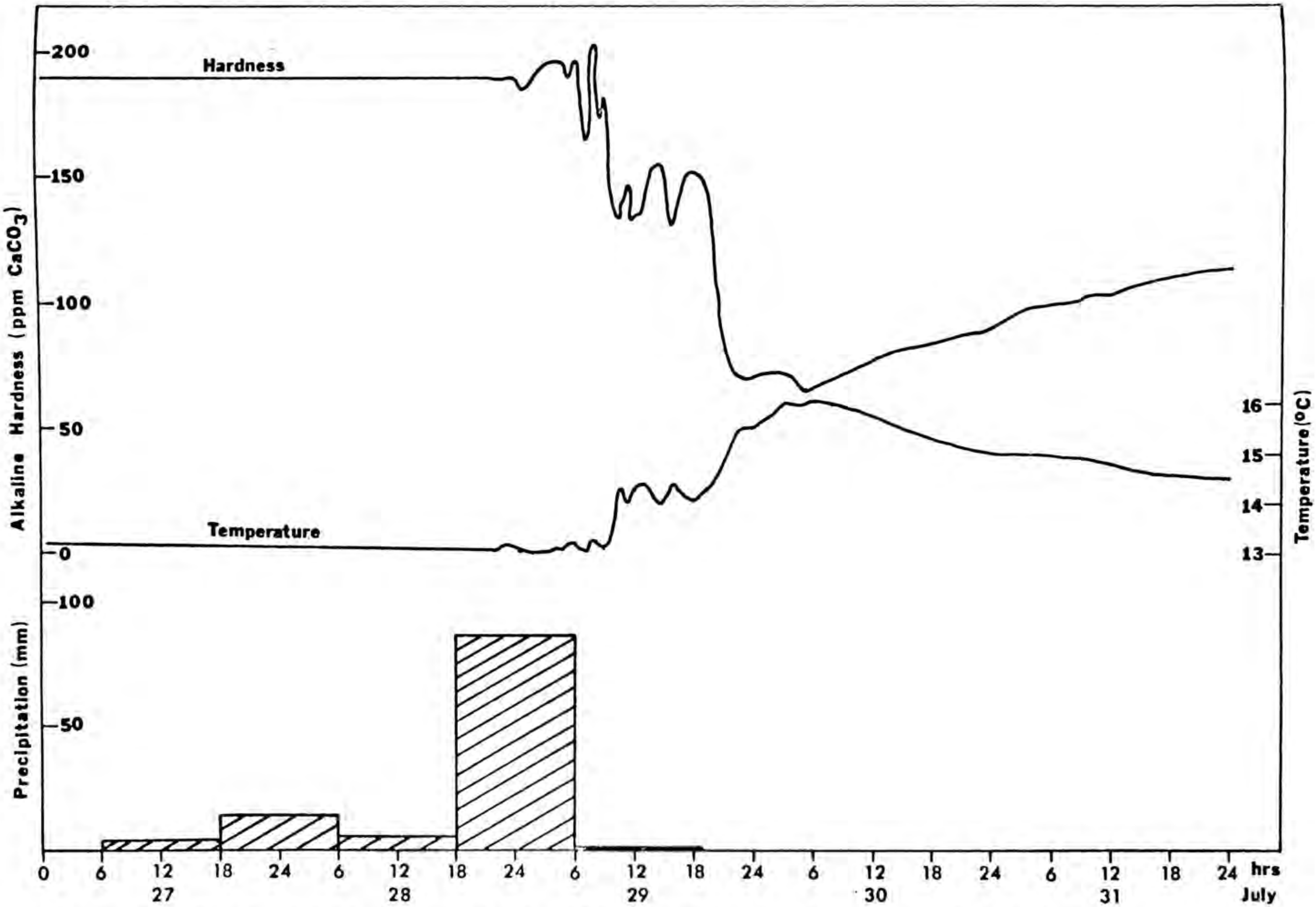


Figure 5. Chemical hydrograph showing fine structure after sharp pulse input.

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.

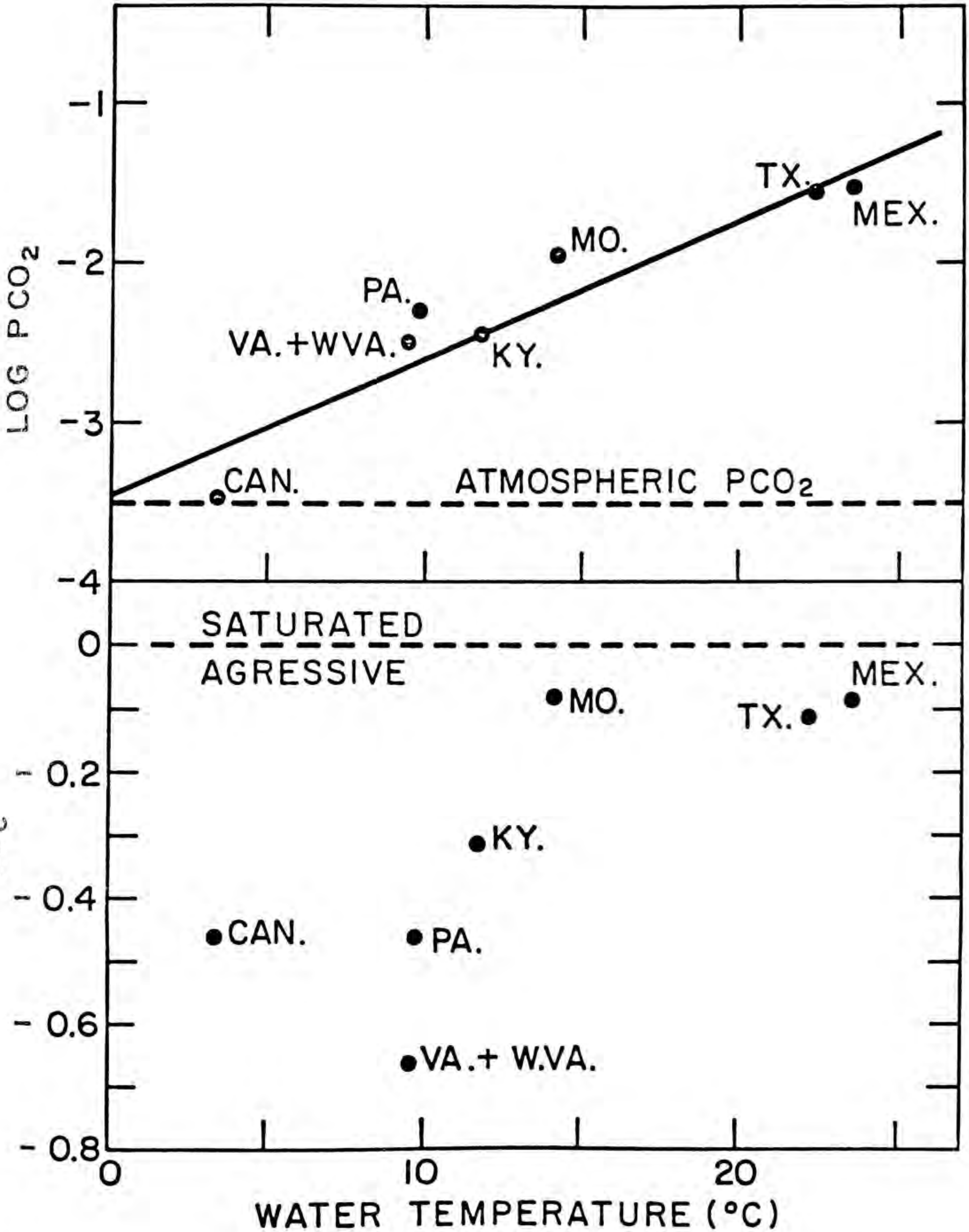

Figure 6. Grand means of theoretical CO_2 pressure and saturation index for regionally grouped karst waters.

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)	$\frac{U^{234}}{U^{238}}$	$\frac{U^{234}}{U^{238}}$	$\frac{Th^{230}}{U^{234}}$	$\frac{Th^{230}}{Th^{232}}$	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.

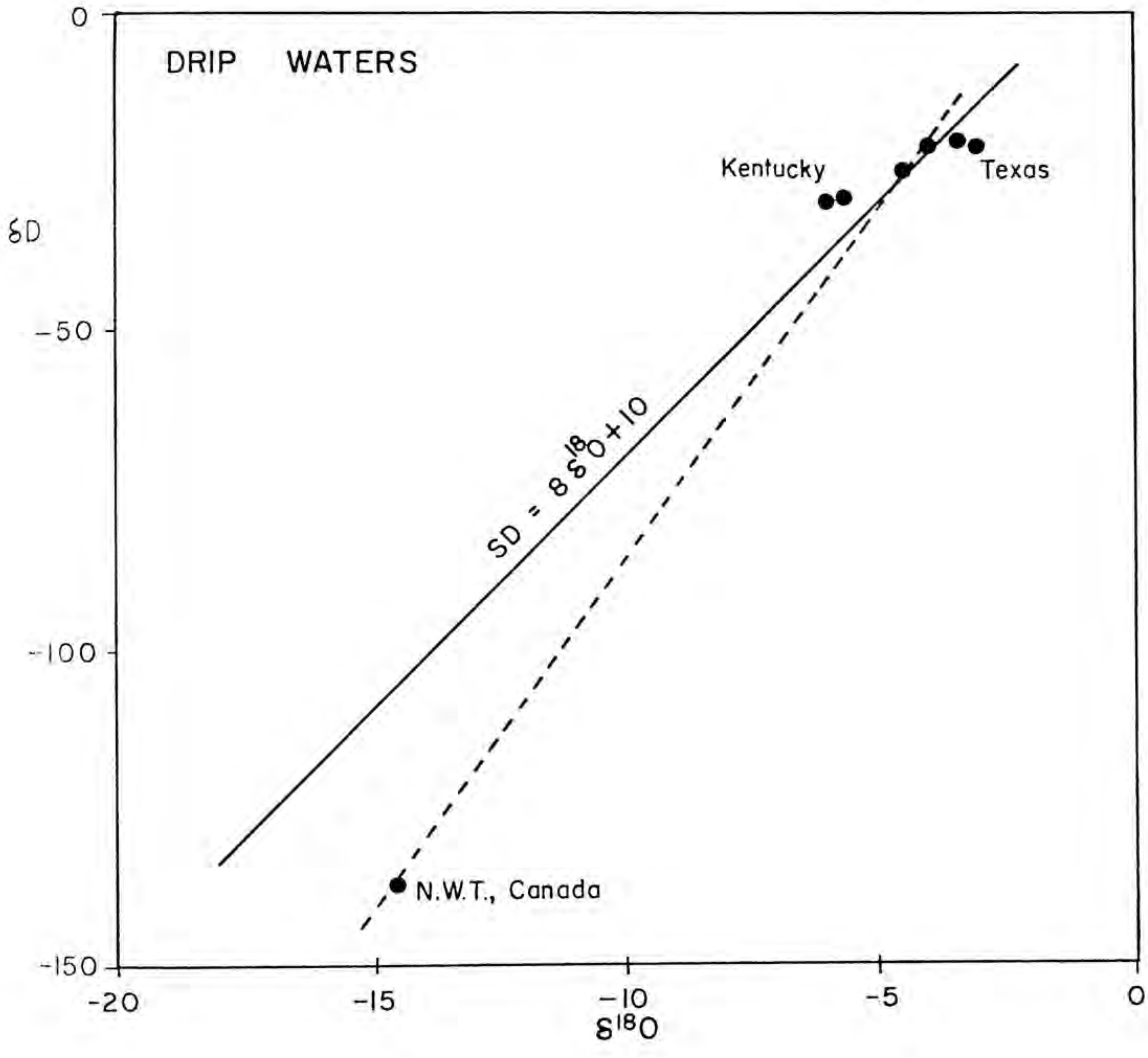

Figure 7. Relationship between deuterium isotope shift and oxygen isotope shift for waters collected from Texas, Kentucky, and northwestern Canada.

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.

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* 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.

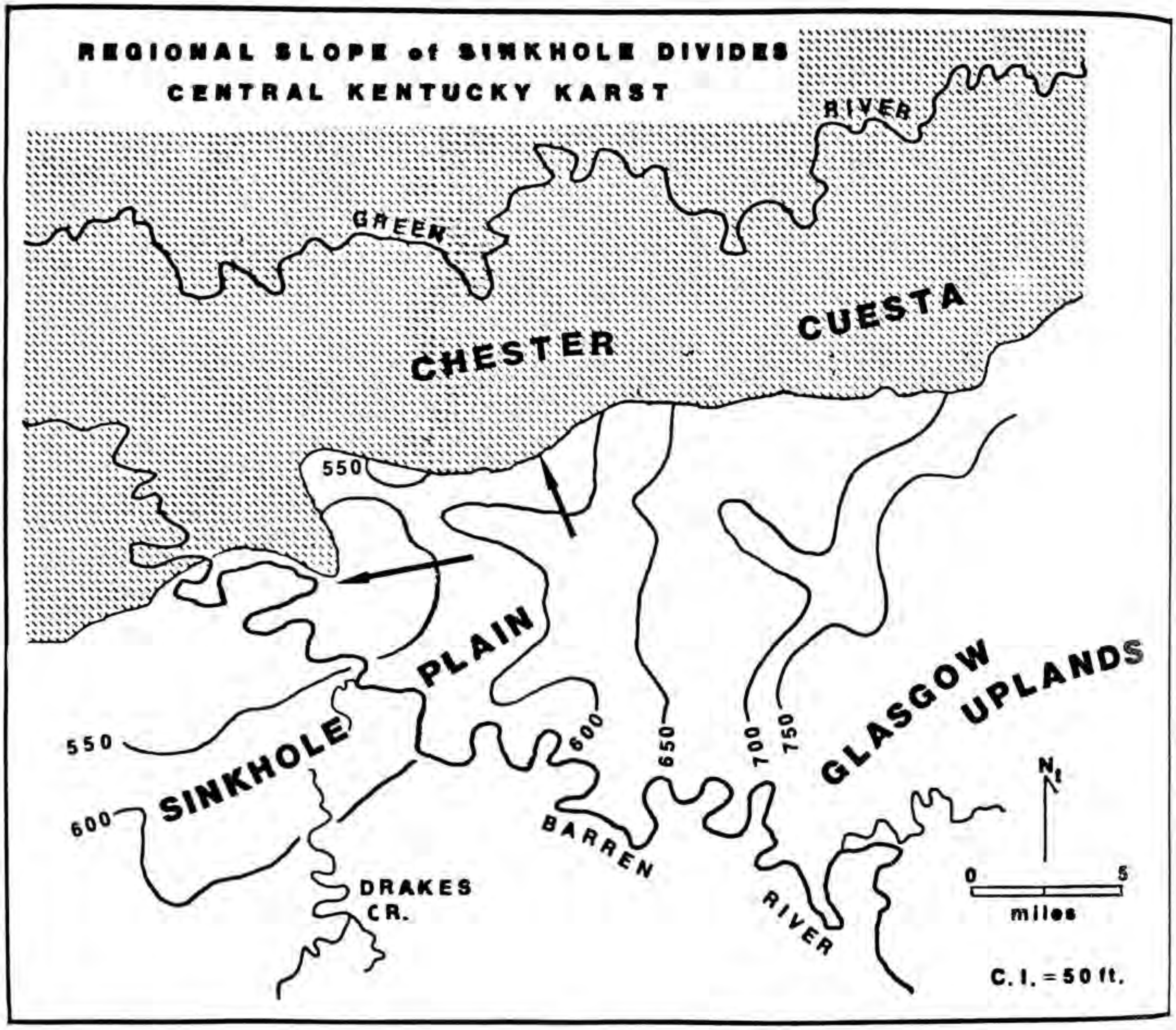


Figure 8. Regional slope of the Sinkhole Plain surface as represented by sinkhole divides and direction of the maximum piezometric slope of ground-water in the study area.

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.

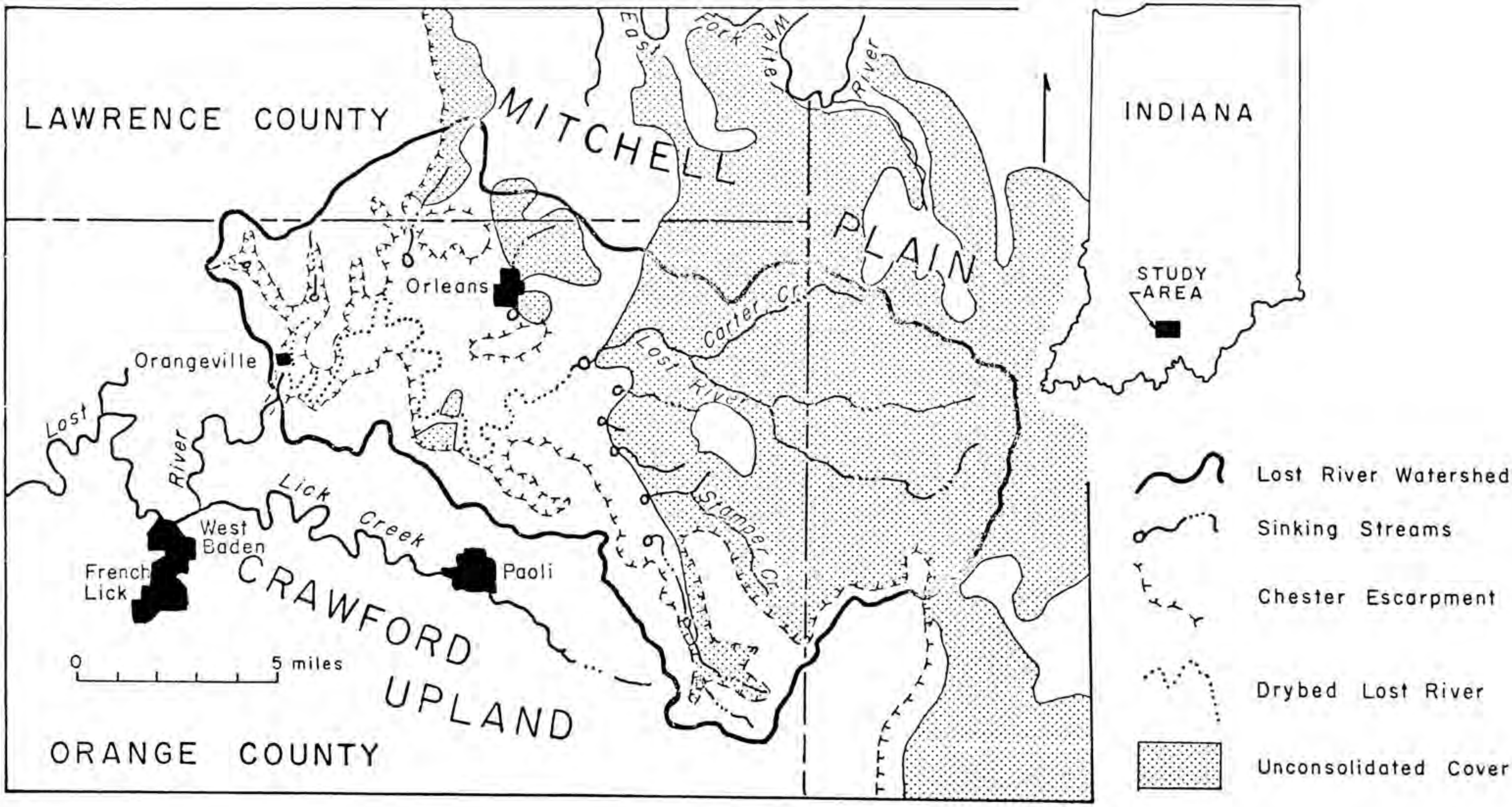


Figure 9. Physiographic units and geomorphic features of the Lost River Karst, south-central Indiana.

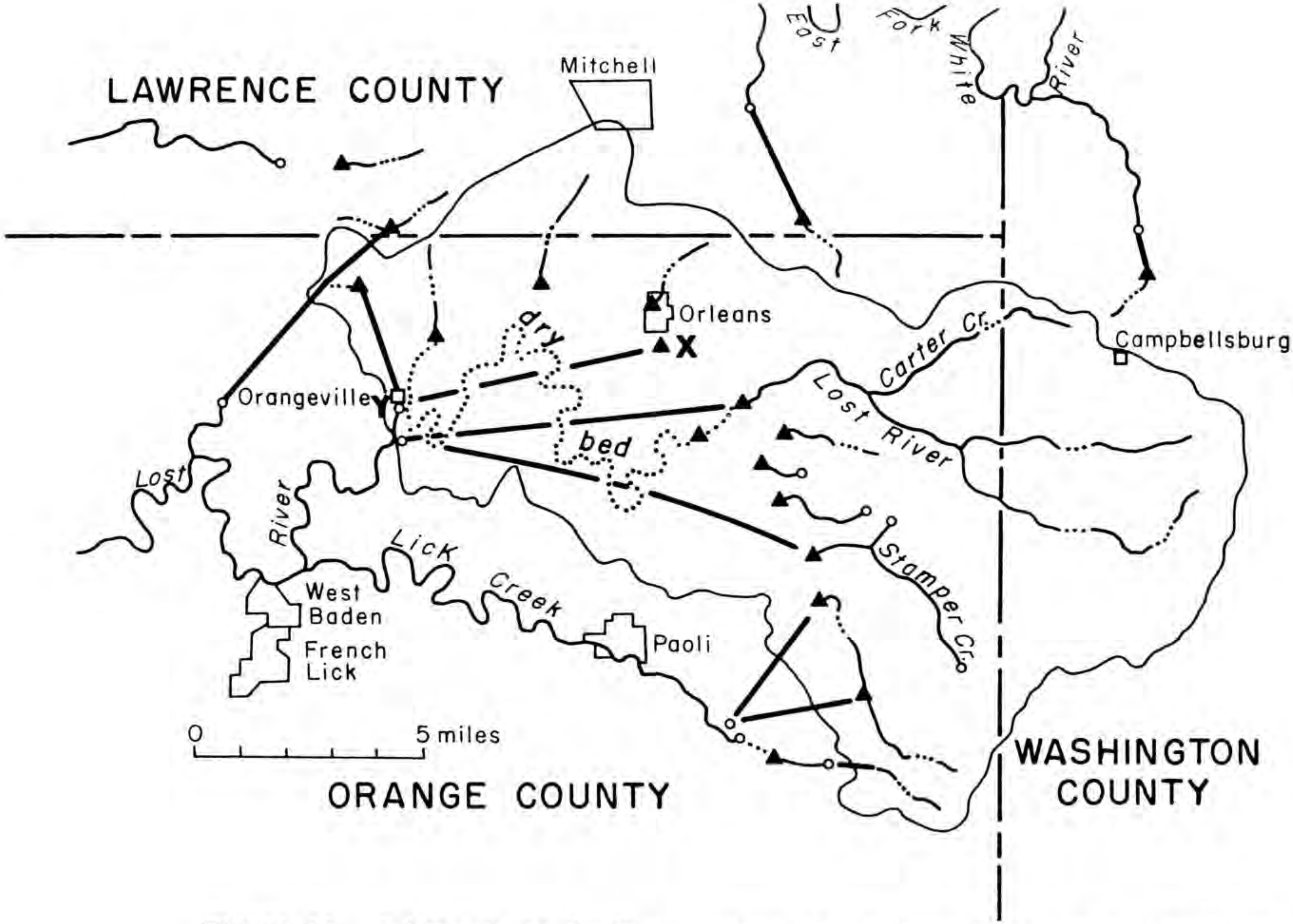


Figure 10. Subterranean drainage routes of the Lost River Karst (from the work of Murdock and Powell, 1968). X represents the treatment plant at Orleans and Y represents the karst spring at Orangeville. Secondary effluent travels via underground drainage from point X to point Y.

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 Decorated Cave, 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 back-flooding 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 $\gg$ 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	1m² 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 α -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. α max. met. rate-routine met. rate -growth rate per se -life history(α,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 vs (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.

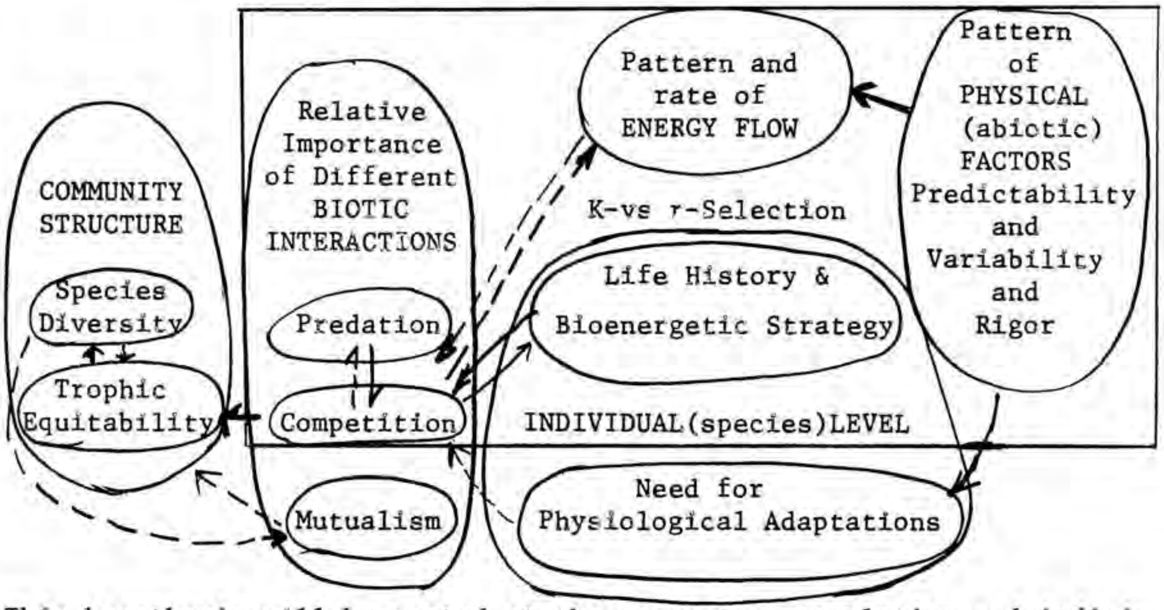
The general importance of this study is that it will provide a species level explanation for a community response to manipulation of pattern and rate of nutrient supply. This can be done because caves are simple systems where biotic and abiotic factors can be independently manipulated.

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.

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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.

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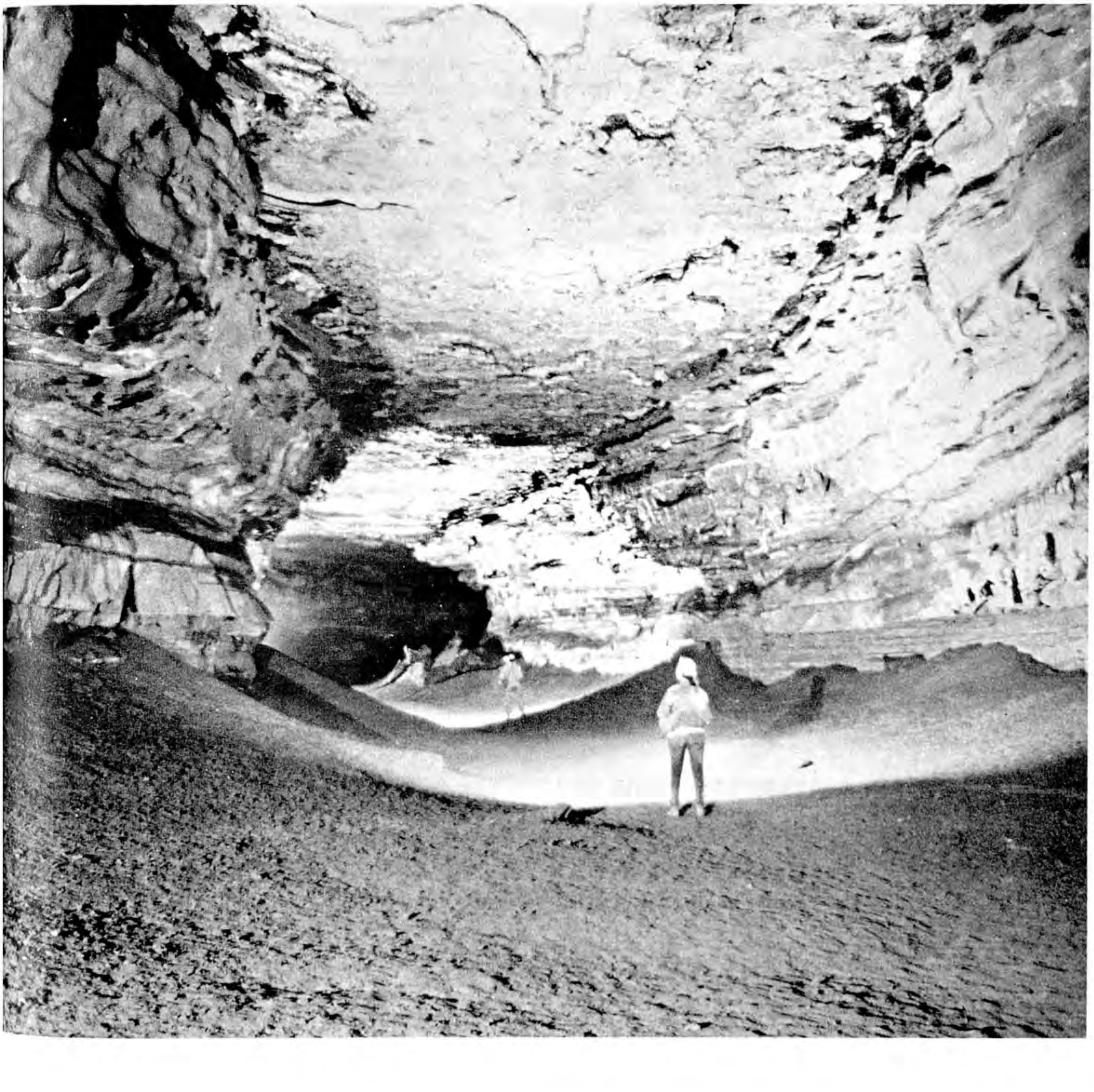
MANAGEMENT PUBLICATIONS



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.

<u>Field Operations in the Guadalupe Escarpment Area</u>

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.

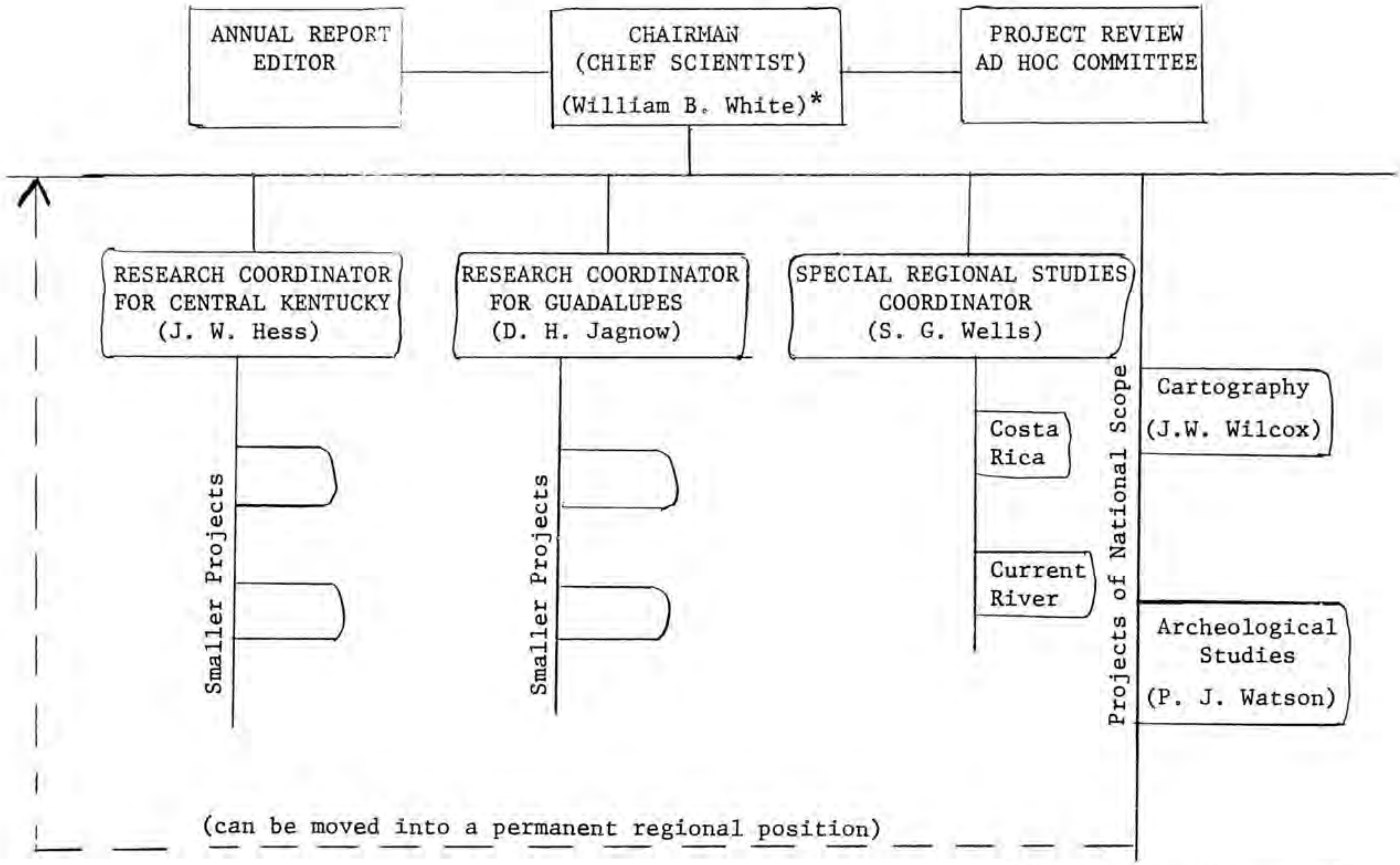
Both line and staff positions have been created. The staff positions include an editor for the annual report and an ad-hoc committee of senior investigators assembled for the purpose of reviewing proposals and applications for the CRF annual fellowship.

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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