TENTH ANNUAL REPORT

Of The

CAVE RESEARCH FOUNDATION

For the year ending

December 31, 1968

DIRECTORS OF THE CAVE RESEARCH FOUNDATION

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

Table of Contents

MASTER PUBLICATION LIST OF THE CAVE RESEARCH FOUNDATION

A. Contributed Papers

B. Supported Papers

C. Advisory Reports

D. Theses

E. Papers Given at Professional Meetings

Acknowledgments

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

The United States Steel Foundation has provided much appreciated financial support for the general CRF program.

INTRODUCTION

As the Foundation finishes the first year of its second decade of work in the Central Kentucky Karst, cartography continues to occupy a dominant position. The survey of the Flint Ridge Cave System is now approaching the 70-mile mark and is the largest cave known.

The Foundation continued its practice of awarding a $500 fellowship to a graduate student doing thesis research in the cave-related sciences. This year's awardee was Mr. Alan P. Covich of Yale University whose thesis topic deals with the limnology of a limestone lake in Yucatan. A grant was also made to Mr. David C. Culver for continued support of his ecological study of cave stream communities in the Great Savanna Karst of West Virginia.

The problems of clastic sediment transport, stratigraphy, and their usefulness as hydrologic and Pleistocene historical indicators continue to demand attention. A pilot project conducted this year in Flint Ridge by Messrs Carwile and Hawkinson has established the complexity of the subject. A more comprehensive study of the entire sedimentary complex is in the planning stages.

An event of signal importance was the publication of Burton Faust's "Saltpetre Mining in Mammoth Cave, Kentucky" culminating many decades of historical research. Mr. Faust was a member of the Cave Research Foundation until his untimely death in July, 1967. The Foundation is honored to have been able to help in a small way to bring this result of a life's work to fruition.

In March the Foundation was honored by a visit from Ota Ondrousek of Czechoslovakia. He is in charge of a speleological research organization in Czechoslovakia similar to the Cave Research Foundation. Mr. Ondrousek was escorted by the Foundation through the Central Kentucky Karst and given an inspection trip of the Flint Ridge Cave System. The Naturalist Staff of Mammoth Cave National Park cooperated to give Mr. Ondrousek a special trip into Mammoth Cave.

In August Professor Alfred Bögli made his second visit to the Central Kentucky Karst to continue his comparison studies of the Flint Ridge Cave System with Hölloch Cave in which much of his own research has taken place. He was given an inspection tour of part of the Flint Ridge Cave System to accomplish this.

THE SCIENTIFIC PROGRAMS

THE CARTOGRAPHY PROGRAM

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

The World's Longest Known Cave: The Flint Ridge Cave System is the world's longest surveyed cave with 68.59 miles of passages surveyed as of November 1, 1968. A sustained field effort by survey personnel in 1968 resulted in a productive year for the cartographic program. Caves in Flint Ridge and Joppa Ridge were examined and cartographically described. Several thousand man hours were spent underground as part of the program. This effort resulted in 28,759 feet (5.5 miles) of newly surveyed passage in Flint Ridge.

Discovery and Survey: In Flint Ridge three discoveries were of particular importance in that they provide access to parts of the Ridge in which no cave passages were known. Three additional areas provided a large amount of additional survey.

The first of these discoveries was a pair of passages explored from the Turner Avenue - Wirth Avenue area of the Flint Ridge Cave System. One passage known as Diamond Way for its gypsum sand and encrustations extended north for more than 2000 feet thus indicating the existence of a high-level drainage system for the area hitherto unknown. The second passage, also high-level, was surveyed to the south and west to three shaft complexes. The drains of these shafts led into previously surveyed low level passages in the Candlelight River area. Preliminary indications are the high-level passages were once drains for the shafts. More than 9500 feet of passage were surveyed in this area.

The second discovery was really the rediscovery of two major river passages in the area of the Colossal-Salts Link. One river flows north about 1500 feet from the Link to a point where the other river which flows from the east joins it. They flow to the northwest about 50 feet to a siphon. The river passage from the east is over 3000 feet long with a siphon at its upstream end. The rivers flow in large passages averaging 10 to 15 feet wide and 6 to 10 feet high. These streams are near base level in Flint Ridge and form part of the major drainage passages now active in the Ridge. The passage which leads to the rivers was explored in 1960; however, the lack of wet suits at the time deterred exploration or survey and the lead was not exploited until this past year.

The third discovery of significance was a passage trending north from Grund Trail which was surveyed for 80 stations covering a distance of about 600 feet. The survey was terminated by loose breakdown. The passage may provide access to the western portion of Flint Ridge now without surveyed cave.

The Storts Trail - Ralphs River Trail - Faust Way portion of the Flint Ridge Cave System provided more than 2000 feet of survey. This area of the cave is a series of low crawls, canyons, and shafts.

Passages were extended toward Great Onyx Cave and the newly surveyed passages of the area provide additional insight into its complicated plan.

A passage extending from Roebuck Trail to Woodward Way was surveyed thus providing a loop as a check on the accuracy of the Gravel Avenue survey. As with all other parts of the Flint Ridge Cave System when leads such as this passage are explored and surveyed the result is another step in defining the complex system of passages that underlie all of the Central Kentucky Karst.

A series of short surveys were made in the River Route area of Colossal Cave.

Numerous other areas of the Flint Ridge System yielded many thousands of feet of survey during the past year. In addition to the 28,759 feet of passage surveyed in Flint Ridge 3889 feet of old surveys were resurveyed to correct suspected errors and/or to record or upgrade information on passage detail.

Longs Cave, also known as Grand Cave, was surveyed a total of 5,213 feet. Elko Cave, another Joppa Ridge Cave, was found to be a small cave roofed with sandstone. It is a single room about 20 feet square and four feet high.

The vertical control program was continued in 1968 with all of the upper level passages of Great Onyx Cave and Longs Cave being leveled.

Walker Survey: The field survey books of the Walker survey of Mammoth Cave were examined during the year. The data were found to be useful as the benchmarks will provide a control grid for a descriptive survey of the passages of Mammoth Cave. Preparation is now underway of a manageable and logistically sound plan for the descriptive survey of Mammoth Cave.

Surface Reconnaissance: Surface reconnaisance of Mammoth Cave National Park was reactivated in 1968. The objective of this phase of the cartographic program is to locate and describe those surface features in the Park which have a direct or suspected relationship to underground features. Such features include entrances, faults, blowholes, springs and sinkholes. This work has resulted in the names of 71 known or suspected caves within the Park. Some of these names are for the same cave, others may not be caves but local names for such features as rock shelters or springs. The difficult phase of this work is to locate the caves and describe the entrances. This is extremely difficult while the vegetation is green; however, the entrances of Jim Cave and Martin Cave were located and described as were several caves whose locations were known previously.

Personnel: John Freeman, a member of the Cave Research Foundation, was appointed Associate Cartographer in July 1968. Gordon Smith conducts much of the surface reconnaissance.

THE HYDROLOGY PROGRAM

Suggested Research Programs for Carbonate Aquifers

The hydrology of carbonate terrains has received a great deal of attention in the past five or so years. There is a wide awareness that limestones and other soluble rocks are aquifers with many special problems of water supply development and pollution control. Among the many agencies who have tackled carbonate terrain problems may be listed the U.S. Geological Survey, various State Geological Surveys and Water Surveys, and a number of University Programs. There has been created a special working group on carbonate terrains with the International Hydrologic Decade. These programs vary widely in quality from a simple-minded drilling of more and more boreholes from which to run more meaningless pumping tests, to programs of great diversity and sophistication. It is probably not unfair, however, to say that the widely divergent nature of limestone aquifers has not been appreciated and that water flow behavior varies widely from one hydrogeologic setting to the next.

A major stumbling block to hydrologic research in limestone terrains is lack of adequate funding. There are a number of reasons for this. The total amount of money available for hydrological research in the United States is small. Most funding comes from mission-oriented agencies such as the Office of Water Resources Research and the Federal Water Pollution Control Administration. These agencies are beset with immediate and nasty problems in water management and pollution control and so are prone to assign priorities to engineering and development programs which promise immediate results rather than support longer range scientific programs aimed at understanding the causes of their troubles.

The competition for available funds is therefore large and because of the lack of definition of clear-cut research goals the selection of the highest quality programs from all offered is difficult. For this reason, it seems of value to tabulate some of the aspects of hydrologic research pertinent to maturely karsted aquifer systems, and to indicate what the Foundation is currently capable of doing and the directions in which it should consider heading.

(1) Drainage Net Behavior: Cave systems can be regarded, in many instances, as fragments of main drainage conduits. Examination of these provides clues to the behavior of the downstream main drainage lines. Such research would include mapping drainage nets--nothing more than cave cartography with an eye to terminal breakdowns and possible formerly connected segments of passage. It would include studies of passage morphologies in an attempt to deduce the formerly hydrologic role of some particular segment of passageway. It would include studies of solutional sculpturing of cave walls (scallops, for example) to seek clues about past flow conditions from the solutional features remaining on the cave walls.

(2) Hydrology: Under this category would come all of the quantitative measurements usually associated with water research. It would include gaging stations on the big springs to measure real discharge and annual hydrographs. Rain gauges would be needed to measure water inputs. Only when data of this

sort are available for a period spanning several water years will it be possible to even attempt more than a qualitative water balance in the karst region. Further refinements will require careful measurement of infiltration capacities of the terra rosa soils and the mechanism by which it enters the groundwater body. Is there any storage in a maturely karsted aquifer? If so, where is the storage located? In the main conduit systems near the base level, or is the water stored mainly in the rock and soil in the headwaters portion of the drainage net? Hydrologic research would also include dye tracing experiments to connect various parts of the net not accessible to direct exploration.

(3) Geochemical Mechanisms of Solution: Much is revealed about the behavior of limestone groundwater through the chemical composition of the water. Two ways are available for extracting this information: Hydrochemical facies mapping consists of doing fairly complete analyses of dissolved ions (Ca, Mg, Na, Cl, HCO_3) in wells, underground streams, and springs. From the distribution of these constituents in space, either by direct contouring of analytical data or of contouring of ion solubility products, one can learn much about the residence time of the water, of the general flow paths in the diffuse flow parts of the aquifer, and the prior history of the water before it reached the sampling point. The chemical hydrograph technique measures the same variables but determines them as a function of time. By looking at the variation of the chemical parameters with season and with discharge, information can be gained about whether the water is flowing through open channels or by diffuse flow.

(4) Hydrogeologic Controls: Water movement through limestone is by paths which ultimately are determined by the geologic characteristics of the aquifer. Variations in limestone lithology, stratigraphic variations such as the occurrences of chert or dolomite beds, presence or absence of capping or perching beds all play their role in selecting those beds which will carry the bulk of the flow and thus sustain the maximum solutional modification. Structural features such as major folds and faults often determine the disposition of the soluble beds with respect to water inputs and discharge points and thus determine the gross characteristics of the drainage net. Other structural features such as joint sets, fracture traces, and minor folds and faults can control the detail of passage orientation and thus the exact path through which the water moves. Research here consists of careful mapping of the stratigraphic, lithologic and structural characteristics of the aquifer and comparing these with known cave patterns and known groundwater flow paths.

(5) Theory: The usual equations of groundwater flow in homogeneous sandstone aquifers do not generally apply to maturely karsted systems. In the maturely karsted aquifer, flow is localized in conduits, and moves at high velocities, often in a turbulent regime. New mathematical models for groundwater motion in limestone must be invented and these will probably stem from engineering type fluid mechanics. An alternative to analytical calculation of flow behavior is the use of statistical models on various types to simulate the aquifer behavior.

(6) Pollution Transport Mechanisms: A full program of hydrologic research must not consider the water and its inorganic chemistry only, but must be concerned with the various pollutants which can be transported by underground flows. Much has been said about the long-range transport of pollutants in limestone but data are scant. Are natural clean-up processes operating? Cave streams have a well known aquatic life. Does the cave life succeed in scavenging the pollutants? How is the pollution dispersal pattern related to the nature and geometry of the drainage net? This is an area where there is an interface between the biological programs operating in cave systems and the hydrological research.

It is apparent from the above list that the Foundation has concentrated most of its activity in item (1) whereas most other programs have limited their attention to item (2). One is meaningless without the other and it is becoming an absolute necessity that some sort of quantitative measurements be started. The research on the drainage net itself cannot be ultimately tested until the quantitative flow data are available. Perhaps the best place to start is in gaging the big springs. Hydrographs for these springs are not known and yet all theorizing about the base level water behavior must remain speculation until these data are available.

Research described under (3) is well underway in a number of other areas but not in the Central Kentucky Karst. Here again, a large program would require considerable time and money but a geochemical inventory of the various waters in the cave could be tackled immediately.

The Deike thesis lays much of the groundwork for item (4). A better understanding of stratigraphic controls will be possible after the leveling program has accumulated a few years of data.

Theoretical investigations of groundwater flow behavior in limestone are underway by several CRF-related researchers. Here ideas are the critical limitation. There have been few major theoretical advances in groundwater hydrology in general in the past 20 years. A really useful mathematical model for the flow would be a tremendous breakthrough.

Little is presently being done on item (6). It is through this route that the best hope for financial support lies. Here is an area that the biologists and hydrologists would do well to discuss together.

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

This project has been in progress since the summer of 1963. Its objectives are to delineate the hydrologic role of some of the principal cave passages in Mammoth Cave and the Flint Ridge Cave System, to calculate paleo-flows and paleo-spring locations, and relate these to the geology of the aquifer and to the present day active system. Most of the highlights of this program were summarized in the 1967 Annual Report.

During 1968 the results were put in manuscript form in a paper which is to be submitted to the Geological Society of America Bulletin for publication. This completes the work and this project should be considered terminated.

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

This project is concerned with an overall interpretation of the hydrology of the karst region. Presently active facets deal with vertical shafts and with the morphological properties of caves considerd as solution conduits.

The systematic survey and description of vertical shafts and their drain complexes continued. Special attention was given to the abandoned shaft drain complex underlying Cammerer Hall. This complex is of importance because it lies under the protective caprock and is thus at variance with the usual interpretation of vertical shaft development.

The first aspect of channel morphology was an examination of the sinuosity of conduits and the relation of their meander bend spacings to channel width and a comparison of these relations with those for surface rivers. Most of the details of this project are in the 1967 report. During the current year, the project was completed, a manuscript was written, and has been accepted for publication by the American Journal of Science.

Numerous discussions and some preliminary planning have been done to instrument the big springs. Flow measurements in these springs have a high priority as the hydrology program enters a more quantitative stage.

Conceptual Models for Limestone Aquifers

Limestone aquifer systems are very diverse in their flow behavior. Progress in understanding these systems has been retarded by a tendency on the part of some researchers to lump all carbonate terrains together. In an attempt to spell out some of the hydrogeological variations in these aquifers, a paper has been written classifying limestone aquifers on the basis of the hydrogeology of the basin. This classification is given in table 1. The paper has been accepted for publication by the journal Groundwater.

Table 1

Types of Carbonate Aquifer Systems in Regions of Low to Moderate Relief

Flow Type	Hydrological Control	Associated Cave Type
I DIFFUSE FLOW	GROSS LITHOLOGY Shaley limestones Crystalline dolomites High primary porosity	Caves rare, small, have irregular patterns
II FREE FLOW	THICK, MASSIVE SOLUBLE ROCKS	Integrated conduit cave systems
A. PERCHED	Karst system underlain by impervious rocks near or above base level	Cave streams perched-often have free air surface
1. Open	Soluble rocks extend upward to land surface	Sinkhole inputs; Heavy sediment load; short channel morphology caves
2. Capped	Aquifer overlain by impervious rock	Vertical shaft inputs;lateral flow under capping beds;long integrated caves
B. DEEP	Karst system extends to considerable depth below base level	Flow is through submerged conduits
1. Open	Soluble rocks extend to land surface	Short tubular abandoned caves likely to be sediment-choked
2. Capped	Aquifer overlain by impervious rocks	Long, integrated conduits under caprock. Active level of system inundated
III CONFINED FLOW	STRUCTURAL AND STRATIGRAPHIC CONTROLS	
A. ARTESIAN	Impervious beds which force flows below regional base level	Inclined 3-D network caves
B. SANDWICH	Thin beds of soluble rock between impervious beds	Horizontal 2-D network caves

PROGRAM IN SEDIMENTATION, MINERALOGY, AND PETROLOGY

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

This project has not been active during the year. It was originally intended to be the PhD thesis research of the principal investigator but certain changes have made it impractical for this topic to be used. The project, for which most of the sampling and field work is complete, will be resumed at some later date but for the interim period will be considered inactive.

Cave Sediments of the Near East (Paul Goldberg, University of Michigan)

The principal investigator spent much of the summer in Israel with the University of Michigan Tabun excavations. In addition to sampling there, investigations and samples were made in two other caves, Qafzeh, near Nazareth and Iraq el-Barud (Sefounim) located in the western margin of Mt. Carmel. The advantages of studying these caves in particular is that they are from three different locations in Israel, each with its own microclimate. There is some hope that these caves will provide a record of late Pleistocene climatic changes in Israel.

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

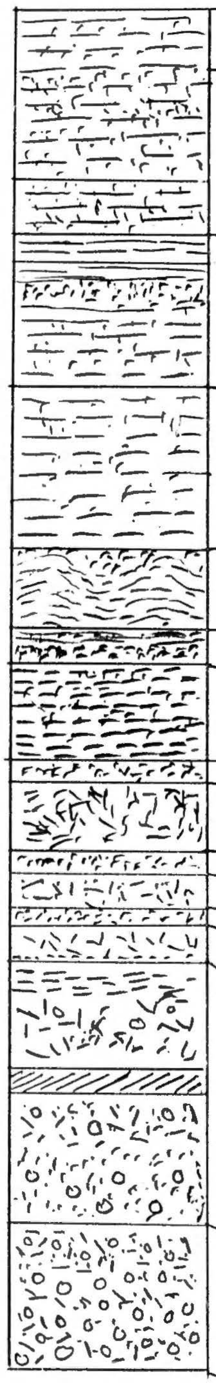
During 1968 a study of the sediments in Columbian Avenue was conducted and completed, resulting in a thesis for a BS degree at Ohio State University. The study involved removing cores from Columbian and making detailed descriptions of their contents. The study also involved size analysis of samples at selected levels in the cores to determine the feasibility of a correlation between size distribution and distance from the base level stream (Green River).

The cores were collected at approximately 300 foot intervals in the passage. Eight cores were taken. The cores were collected by digging a hole 4 feet by 2 feet down to the bedrock floor and removing a vertical sample in a metal trough 2 inches wide and 1 inch deep. This method removed the material in a relatively undisturbed state and gave enough quantity of material for sampling after description of the core. Sample 68-CH4 is typical core and description (fig. 1).

The size analysis showed a definite grading of sizes in the cores. All cores went generally from coarse at the bottom to fine at the top. No correlation could be found between size distribution and distance from either end of the passage. It is suspected that this is due to the distance between samples and the lack of "marker" beds in the cores. See table 2 for comparison of data.

Clay and silt were dominant in all samples. Sand became more prevalent towards the bottom of every core. Pebbles of sandstone (angular quartz in a matrix of iron oxide) and well rounded quartz were encountered regularly in the lowermost parts of all cores. Some pebbles were coated with manganese dioxide. X-ray diffraction of several samples was done using the size fraction <0.0039 mm. Quartz was the most dominant mineral in all samples, but each sample showed traceable amounts of kaolinite and illite. No significant difference was seen among any samples run.

SAMPLE 68-CH4



Interbedded v.f. sand and silt-clay layers; beds <1mm thick; general color 10YR 4/4, dark yellow brown.

Silt and v.f. sand layers interbedded; beds ~1mm thick; appears to be less clay than in unit above; light-dark interbedding very distinctive; layers very regular; dark organic layer 2mm thick, 8cm from bottom; general color 10YR 5/4, yellowish brown.

Reddish layers at top and bottom of unit ~7mm thick; rest of unit dark (organic?) layers interbedded with dark yellowish brown (10YR 4/6) layers; beds are pseudo-carved; 10mm v.f. sand layer 8cm from bottom; unit appears sandier towards bottom.

Interbedded light and dark layers of silt-clay and v.f. sand; layers 1mm thick; bedding very regular; light bands become thicker towards bottom of unit; color 10YR 4/4, dark yellowish brown.

Greenish unit with wavy bedding; 2.5Y 6/2, lt. brownish gray units interbedded with v.f. sand layers; beds 1mm thick; becomes sandier towards bottom.

Regularly bedded green, lt. red, brown, dk. brown, and gray beds; beds .5mm thick; distinct unit.

Interbedded v.f. sand and silt-clay; beds 2-3mm thick; center of unit clayier than top and bottom.

Sandy; 5YR 4/6, yellowish red; no bedding; distinct.

Silt and v.f. sand, no bedding apparent; color is very distinctive, 5YR 4/4, reddish brown.

Sandy; brown & red layers; 7.5YR 5/4; v.f. sand & silt.

Sandy at top, less sand towards bottom; no bedding.

Fine to v.f. sand layer; 10YR 5/6, yellowish brown.

Top 5cm silty clay, very little sand; beds ~.5mm thick; color appears purplish; 1cm sand layer at bottom of unit; color 5YR 5/8, yellowish red.

Top 3cm dk. brown beds ~.5mm thick; v.f. sand and silt-clay layers; appears purple, very distinctive; next 17cm 7.5YR 5/4, brown; no bedding; silt-clay w/ sand inclusions; 4cm dark organic layer; 8cm greenish layer; no bedding; v.f. sand and silt with organic inclusions; 14cm band much like 17cm layer above; few beds of white v.f. sand, 1-2mm thick.

Angular qtz sand pebbles 2-5mm diam; pebbles friable; yellowish color; several qtz pebbles 1 1/2 - 4cm in diameter; not bedded; matrix med. to coarse sand and silt.

Scale: 1/3" = 1cm

Conclusions were as follows:

1. The sedimentation system of Columbian Avenue is much more complex than first thought. Extremely rapid facies changes and passage gradients which are the reverse of what was expected make the interval of sampling used in this study useless for correlation of beds from core to core.

2. All sedimentation now occurring in Columbian Avenue is a result of silt and clay deposition by ponded floodwaters from the Green River. Field observations made in April, 1968 confirmed that the flood of March, 1968, had deposited a thin coat (<0.1 mm) of clay in the passage. There are no surface streams in Columbian Avenue and it is assumed that there is no deposition from up gradient at this time.

3. Sub-surface flow plays an important role in the transportation of water in Columbian Avenue. Cores 68-CH5, 6L, 6R, and 7 all encountered sub-surface flow in the lower 1 to .5 meters of each hole. An attempt to remove a core at the Columbian Avenue-Eyeless Fish Trail junction had to be abandoned at the 1 meter level due to excessive water flowage and flooding of the hole. The "water drains" which are located in the passage are suspected to play an important role in the transfer of water into the more permeable lower layers of sediment. It is interesting to note that the gradients of the passage generally grades down into these holes from both directions. Sand layers in the lower parts of all cores were very clean and appear to have been washed free of silt and clay. Perhaps these sub-surface waters are a means of erosion of fines from the cave.

PROGRAM IN KARST GEOMORPHOLOGY

Reviews of the Central Kentucky Karst

The general review paper being prepared under the authorship of W.B. White, R.A. Watson, E.R. Pohl, and R.W. Brucker was completed in first draft and was given a preliminary review by the American Geographical Society. The reaction was favorable and the final draft of the manuscript is now nearly finished and should be submitted before the end of the year.

A second review article emphasizing geomorphological relationships in the karst has been prepared by J.F. Quinlan. It has been submitted to the French journal, Mediterranee.

A third review paper was prepared by T.L. Poulson and W.B. White at the request of the editor of Science. This review, entitled "The Cave Environment," emphasizes the ecological aspects of karst research and relates biological and mineralogical problems to the unique character of the karst drainage net. It has been reviewed and will be accepted with some revisions.

Table 2

SAMPLE 5
68-CH4

SIZE IN mm	INDIVIDUAL %	CUMULATIVE %
2.0000	00.0	00.0
1.0000	00.0	00.0
0.5000	00.0	00.0
0.2500	00.0	00.0
0.1250	00.0	00.0
0.0625	00.2	00.2
0.0313	05.2	05.4
0.0156	15.4	20.8
0.0078	24.7	45.5
0.0039	04.2	49.7
0.0036	50.5	100.2

Sample taken at top of core 68-CH4

DESCRIPTION OF FRACTION >0.0625mm

Angular, white to colorless quartz sand; 1% dark minerals; 10% iron oxide staining on quartz; no calcite.

SAMPLE 9
68-CH4

SIZE IN mm	INDIVIDUAL %	CUMULATIVE %
2.0000	00.0	00.0
1.0000	00.0	00.0
0.5000	00.2	00.2
0.2500	01.5	01.7
0.1250	30.2	31.9
0.0625	27.3	59.2
0.0313	08.9	68.1
0.0156	11.1	79.2
0.0078	08.9	88.1
0.0039	01.1	89.2
0.0036	11.1	100.3

Sample taken in .4cm unit, 133cm down in core 68-CH4

DESCRIPTION OF FRACTION >0.0625mm

Angular to sub-angular, colorless to white quartz sand; secondary growth crystals on quartz; some jasper and iron oxide staining; 1% dark minerals.

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

Temperature data were collected routinely by survey parties throughout the year. The measurement program has now been in operation for about a year and a half, and seems to demonstrate that seasonal variations at any one station are very small. The next step in the program will be to devise mobile stations so that the spatial variation of the basic climatic parameters of the cave can be determined.

PROGRAM IN ECOLOGY

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

The results of terrestrial trapping near the Austin Entrance are in press (T.L. Poulson and D. Culver. 1969. Diversity in terrestrial cave communities. Ecology, 50). In this paper we categorize the hypotheses for explaining differences in diversity as primary, secondary, and tertiary level explanations. In the caves of the Mammoth Cave Plateau we can discard the primary level explanation that diversity is related to time available for cave adaptation or for movement between caves because the caves are pre-Pleistocene and the largest systems in the world. Climatic rigor (intensity of flooding, substrate moisture, and rate of evaporation), predictability, and variability are other possible primary level explanations. Habitat complexity and productivity are secondary level and both competition and predation are tertiary level explanations. In order of goodness of fit we report significant correlations of species diversity ($H = 1/N \log \frac{N'}{N_1'\ N_2' \ldots\ldots N_2'}$) with food supply (positive correlation with substrate organic matter), habitat complexity (positive correlation with substrate diversity), and climatic rigor (negative correlation with intensity of flooding).

This year visual census was used in passages with high densities of terrestrial organisms. In the past we have seen that visual census gives a better sample of fauna than trapping if food is not scarce and densities are high: apparently traps are most effective where food is scarce and both scavengers and predators travel widely in search of food. A comparison between Malott Avenue and Eyeless Fish Trail illustrates this point. Five 2-minute censuses in Malott yielded 61 Neaphaenops, 17 adult Hadenoecus, and 2 Plusiocampa whereas four trap days with 5 traps each yielded only 5 Neaphaenops but 156 Hadenoecus nymphs. This biased sample seems to be related to high concentrations of eggs and nymphs of Hadenoecus which Neaphaenops eats. In Eyeless Fish Trail conditions are not suitable for Hadenoecus to lay eggs and floods may require yearly repopulation of the area. In this case 15 randomly located 20minute censuses yielded 3 adult Hadenoecus, 2 Neaphaenops, and 1 Plusiocampa, whereas four trap days with four traps each yielded 68 Hadenoecus nymphs, 47 Neaphaenops, 6 Plusiocampa, 4 Pseudanophthalmus striatus, 5 Onychiurus, and 2 Tomocerus. Here the visual counts do not yield all of the species present but neither sampling method is biased on the basis of proportions of each species present. Presumably, organisms are superdispersed in Eyeless Fish Trail because food is scarce.

Russell Norton used the CRF base camp as a center of operations during his summer study of the Neaphaenops/Hadenoecus community in Mammoth Cave. This year's work was a feasibility study. It showed that there is a viable PhD thesis problem which Norton will pursue. He hopes to use life history and population structure data to get at community metabolism in the beetle/cricket community. The main work so far has been in Marion Avenue where there are about 3000 beetles and 3400 adult crickets per 1000 meters. A detailed survey and series of quadrats serve as the base for study of clumping, substrate characterization, etc. Among other data it appears that Hadenoecus spend 2 per cent of their time in copulo!

The data on Neaphaenops were obtained by direct census and penning; marking has been unsuccessful so far. Age structure (teneral, callow, and adult male/female ratios), rates of desiccation at different saturation deficits, and weight loss during starvation were the main data gathered.

The Hadenoecus studies centered on how it persists far from cave entrances. Specimens were taken for gut analysis and preliminary marking experiments at entrances showed that the supposed three-day feeding cycle is more apparent than real. Marking showed that crickets in Marion Avenue move from 0 to 250 meters per day.

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

The new census data are for six stream passages. Table 3 gives the data as number per 2-minute census for terrestrial and numbers per station for aquatic communities. The aquatic station consisted of a 1 m visual census. The places for census were selected randomly and included 6 to 15 areas along each stream. Data on habitat complexity were taken at each station.

Rank correlation showed significant positive correlations of species diversity with habitat complexity and negative correlations with rigor of the environment and predation. There was a marginally significant positive correlation with food supply. The correlation coefficients were about the same for terrestrial and aquatic communities in the passages examined.

Additional data were obtained on competition between Typhlichthys subterraneus and Amblyopsis spelaea. Historical records indicate that Amblyopsis is a native species in Mammoth Cave and that the present pattern of distribution in this area has not changed (see historical notes of CRF Christmas card for 1968). Where both species are found Amblyopsis is in deep, sandy, and food-poor rivers at or below base level whereas Typhlichthys is restricted to shallow, rocky, and food-rich streams that drain vertical shafts above base level. This pattern is now known from the Golden Triangle Room junction with Eyeless Fish Trail, the stream flowing north and north-east from the Colossal/Salts Link, lower Colossal River, the junction of Echo and Roaring River, and Cedar Sink north. Near entrances where food is very abundant, Chologaster agassizi may outcompete Typhlichthys or Amblyopsis (Echo and Styx Rivers and Cedar Sink south).

Until recently Amblyopsis spelaea was considered an introduced or rare species in Mammoth Cave. Its apparent rarity in Mammoth and absence in the area between Indiana and central Kentucky led to suggestions that it had been either introduced or decimated during the long period when

Table 3

Species Abundance Determined by Visual Census in Cave Communities

TERRESTRIAL

Stream Passage	hadenoecus	neaphaenops	onych-iurus	plusio-campa	Scoter-pes	arrhopalites	phalan-godes	pseudo anopthalmys striatus		rhagidia	anthrobia
Cedar Sink North	2.00	5.41	--	<.01	--	--	--	<.01	--	--	<.01
Wretched River	3.38	.43	--	--	--	--	--	--	--	--	--
Eyeless Fish Trail	.03	.02	--	.01	--	--	--	--	--	--	--
Candelight River	.01	.01	--	--	--	--	--	--	--	--	--
Colossal River	.46	.26	1.57	.28	--	.50	.03	--	.03	.07	--
South Lower Gravel Avenue	.51	.42	--	.13	.40	--	.11	.13	.07	--	--

AQUATIC

Stream Passage	typh-lichthys	orconec-tes	stygo-bromas	asellus	sphallo-plana
Cedar Sink North	--	1.15	--	--	--
Wret. River	<.01	.05	--	--	--
Eyeless Fish Trail	.06	.13	--	--	--
Candelight River	--	<.01	.55	3.13	--
Colossal River	.05	.35	.15	3.60	.20
South Lower Gravel Ave	<.01	.29	--	1.85	<.01

blindfish were sold as curios. The historical records and studies of the anatomy, variation, and distribution of the Mammoth Cave and northern Kentucky populations contradict both views. Most of the early records of blindfish from Mammoth are for Amblyopsis spelaea. One of the Bransford Brothers sold it to help buy his freedom from slavery and careful descriptions by Call around 1890 show that it was the dominant species in the Echo-Roaring River areas. It is still common, along with blind shrimp and crayfish in Roaring River and other large streams. The present rarity of Amblyopsis spelaea in Echo River is probably related to silting and flooding associated with deforestation, fires, and erection of the Brownsville Dam around the turn of the century.

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

The basic question I am considering is what are the major factors that influence diversity and structure of a simple community. The study area is the cave streams in the Greenbrier Valley of West Virginia. The species that I am considering are listed below:

1. Gammarus minus (Amphipoda)
2. Stygonectes spinatus (Amphipoda)
3. Stygonectes emarginatus (Amphipoda)
4. Asellus holsingeri (Isopoda)
5. Cambarus nerterius (Decapoda)
6. Gyrinophilus porphyriticus (Urodela)

These species occur in many combinations in the Greenbrier Valley. For this report, I will discuss only two aspects of this study. Niche separation between the amphipod species and the effect of spring high water on abundance of the various amphipod and isopod species.

Several simple laboratory experiments have been run in order to learn more about the nature of niche partitioning between the amphipod species. One animal was used for all trials in each experiment. The appropriate animal was put in a finger bowl covered with mud and containing one rock. All species significantly preferred the rock:

	under rock	on mud	P
Gammarus minus	10	2	.99
Stygonectes spinatus	18	6	.98
Stygonectes emarginatus	13	2	.99

The adaptive significance of this behavior is to secure a position against a current.

In a second series of experiments, two species were introduced simultaneously. Significance was tested using a 2 x 2 contingency table with the above experiment as the 'untreated group'. Only those cases where exclusion occurred are listed below:

	loser on mud	loser on rocks	P
G. minus excludes S. emarginatus	17	4	.99
G. minus excludes S. spinatus	17	16	.99
S. emargin. excludes S. spinatus	16	5	.98

It was possible to shift the entire dominance order by substituting a very small rock (approx. 10 mm. in diameter) for the larger one used in the other experiments.

For all species pairs tested one is excluded from the rock. In the field, this means that the 'loser' gets swept down stream and possibly injured. It is therefore not surprising that there is some zonation between the species in the cave. By virtue of its smaller size, S. spinatus occurs together with the other two amphipod species, but on smaller rocks which tend to be deeper in the stream bed. S. emarginatus and G. minus do not occur together, and S. emarginatus is usually found in small feeder streams with G. minus in the main stream.

One consistent pattern that I have found in sampling over the past year is a drop in mean number/sample at the time of spring flooding. The drop has been recorded for all amphipod species,but not for Asellus holsingeri. This is to be expected since isopods are much better at clinging to rocks than amphipods. The possibility that flooding controls amphipod abundance is attractive because it would explain why the Stygnectes species are so rare. These species are much poorer swimmers than G. minus and probably cannot maintain their position in the gravels as well. More intensive sampling during spring high water is planned. One piece of evidence that the amphipods are not food-limited is that no reduction in metabolic rate occurs in cave forms in comparison to closely related surface forms. Poulson has found that the reduction in metabolic rate among cave fish is related to the low food supply in caves. If amphipods are also food-limited, cave species might be expected to have a reduced metabolic rate; they do not.

Paleoecology of Lacustrine Bored Shells and Ultrastructural Diagenesis (Alan P. Covich, Yale University)

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

THE ARCHAEOLOGY PROGRAM

The final report on the 1963 Salts Cave Archaeology project was completed in early 1968. This is a monographic work containing all data collected during the project. It will be published by the Illinois State Museum.

The final design of a new archaeological program was completed in 1968. It involves more work in Salts Cave, surface exploration for possible village sites, a careful physiological examination of the Salts Cave Mummy (now stored at the Anthropology Museum of the University of Kentucky), and an inspection tour of various museums known to contain Salts Cave materials.

THE SOCIOLOGY, HISTORY, AND ECONOMICS PROGRAM

Social Forces in Cave Exploration (R.A. Watson)

The very activity of cave exploration and volunteer contributions of time and effort to cave research pose problems of considerable significance. Drafts of two papers have been prepared which examine the mechanisms by which such interactions take place. One, "Voluntary Associations in the Cave Research Foundation" examines the mechanisms by which CRF operates in terms of financial resources (limited) and human resources (extensive). It shows that a considerable accomplishment is possible if the volunteer personnel are highly motivated. The second, "Who is to Explore the Longest Cave...?" is a parallel study of the power structure necessary for small volunteer organizations to achieve their goals.

THE ADVISORY PROGRAMS

MANAGEMENT PROBLEMS

The Development of the Cave Research Foundation

A careful examination has been made of the Foundation's internal capabilities and it has been discovered that the programs are growing at a rate such that leadership capabilities are being overreached. Further, the work of the individual volunteer is seen as becoming more and more fragmented and his view of the overall purposes of the organization are less clear. The solution proposed for these problems is to institute a series of short courses and special training programs. Leadership training will emphasize a better knowledge of the Flint Ridge Cave System, of surveying techniques, and of the methods for conducting successful field work. Scientific training both by field demonstration and by lecture will be introduced to provide basic background knowledge in the cave-related sciences and to bring the field leaders and volunteers alike up to date on the scientific efforts associated with the Foundation's programs. Both of these training efforts will be initiated in 1969.

Management Problems in the National Parks (P.M. Smith)

An article has been prepared and published in National Parks Magazine concerning the problems faced by the National Park Service in face of dramatically changing responsibilities concurrent with a relatively fixed bureaucratic structure. The article concludes:

"I have sketched in only a general way four basic proposals for change in the organizational structure of the National Park Service. Past emphasis on the "natural" in parks may have had a tendency to lead to the techniques now utilized by the Service. The present proliferation of visitors to all areas of the National Park System regardless of category necessitates fullest attention to effective administration and management. The organization of the aerospace, defense, and automotive industries, however distasteful it may seem to the ardent conservationist and nature lover, is the best model for an improved Park Service. Parks are also big business. The time is long past when the park system could be managed with a combination of general knowledge and mystique. The management of natural, historical, and recreational lands today requires a systems-approach technology.

Commerce and industry continue to imprint changes on man's environment, on park lands, and park visitors. The challenge to develop necessary organizational improvements to meet these changes must be made explicit. The proposals in this article are for the purpose of opening serious discussion.

In the end it comes to this: National Park Service administrative and management techniques are outmoded and inefficient. The National Park System is now so large and diverse that a new organizational plan must be devised. The necessity for Service reorganization must be the subject of continuing constructive discussion. And there is no area, I firmly believe, in which individuals with executive experience in the private sector can be of more help. Implementation of their advice would be of benefit to the parks and their visitors."

WILDERNESS AND HUMAN VALUES

Wilderness at Mammoth Cave National Park

A preliminary fact-finding hearing on the future of Mammoth Cave National Park was held in May with many State and Community officials, conservation organizations, and interested citizens participating. Although the purpose of the hearing was supposed to cover all facets of the Park's future development, it, in fact, focused primarily on the issue of Wilderness and what areas, if any, of the Park should be given protection under the Wilderness Act of 1964. Opinion was sharply divided and the debate lively and often vociferous. Statements supporting wilderness were read by the President, and other statements were submitted in writing by the Chief Scientist and the Secretary providing supplementary information on various aspects of the geology and ecology of the Park with emphasis on the necessity for wilderness protection for these values.

Since the hearings provided a forum for confrontation between many diverse interests, the dialogue is a valuable historical and sociological record. The Foundation has purchased tapes of the entire proceedings for future research.

The Nature of Wilderness (R.A. Watson, P.J. Watson, and P.M. Smith)

A major effort was made during spring and early summer 1968 to complete two book-length essays on Wilderness and man's relation to it. "The Technology of Equilibrium" by Smith and Watson discusses the problems of conservation and human ecology on a broad scale. This book has been completed and has been sent to a publisher. "Man and Nature" by Watson and Watson is a treatment of man in relation to his environment from his origins to the present day. It also has been submitted to a publisher.

PUBLICATIONS IN 1968

PAPERS AT PROFESSIONAL MEETINGS

National Speleological Society (Springfield, Missouri, August)

William B. White, "Conceptual Models for Carbonate Aquifers"

TALKS, SEMINARS, AND SYMPOSIA

Roger W. Brucker: "Research and Exploration in the Flint Ridge Cave System," Louisville Chapter of the Sierra Club.

Thomas L. Poulson: "Caves as Models for Tropical Communities," Dept.'s of Physiology and Epidemiology, Yale University.

William B. White: "Problems in Karst Hydrology" and "Sedimentation in Caves", Dept. of Geography, McMaster University.
"Speleogenesis-A Modern View" Pittsburgh Chap. Nat. Speleo. Soc.
"Unsolved Problems in Karst Research" Geological Sciences Colloquium, Pennsylvania State University.
"Aspects of Karst Hydrology" and "New Research in the Central Ken-Karst," Dept. of Geology, University of Texas.

ABSTRACTS OF 1968 PUBLISHED PAPERS

Four articles were published in 1968. The abstracts of two of them are reproduced below. See master bibliography for complete citations of these papers.

Richard A. Watson, Philip M. Smith
Washington University, St. Louis, Missouri, Office of Antartic Programs, Washington USA

THE FLINT RIDGE CAVE RESEARCH CENTER, MAMMOTH CAVE NATIONAL PARK, KENTUCKY

The Flint Ridge Cave Research Center consists of 3 integrated laboratories, Flint Ridge, about 5 miles long and 1 and 1/2 miles wide containing 50 miles of mapped cave passages is itself a natural laboratory. Here are found at least 6 major surface and 9 major underground temperate zone environments for research work. Formal underground laboratory facilities at present are limited to portable equipment which can be utilized in Great Onyx and Floyd Collins Crystal Caves. Formal surface laboratory facilities at present are limited to 2 small buildings with water, electricity, and work space for portable equipment. Plans for development include the establishment of more permanent formal facilities. A distinctive feature of the Center will be the instrumentation of the 15 major environments with remote sensing devices. With information thus gained about the environmental parameters, cave conditions can be duplicated and varied in environmental control rooms for the conducting of controlled experiments.

William B. White
Dept. Geochem. Mineral., Pennsylvania State University, USA

SULFATE MINERALOGY IN SOME CAVES IN THE UNITED STATES

The sulfate minerals which occur in U.S. caves are principally gypsum, epsomite and mirabolite of which gypsum is the most common. $2Na_2SO_4 \cdot CaSO_4 \cdot 2H_2O$ has also been identified as a new mineral. Because of their similar crystallography all sulfate minerals exhibit similar morphological forms such as stalactites, curved acicular crystals, linear needles, fibers, and crystalline crusts. The petrography of each of these deposits is described. Three primary origins for the sulfate minerals have been distinguished: (i) solution and re-deposition of overlying evaporites, (caves in New Mexico and Western Oklahoma), (ii) bacteriogenic decomposition and oxydation of pyrite in overlying clastics followed by transport of sulfate ions and deposition of sulfate minerals by reaction with limestone wallrock (caves of the Central Kentucky Karst), and (iii) a primary origin in a fine-grained cave soil (Caves of the Cumberland Plateau). The chemical stability of the sulfate minerals will be discussed.

MASTER PUBLICATION LIST OF THE CAVE RESEARCH FOUNDATION

December 1968

Contributed Papers

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Supported Papers

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

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

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

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

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

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

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

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

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

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

Advisory Reports

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

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

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

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

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

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

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

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

Theses

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

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

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

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

Papers Given at Professional Meetings: 1957-1967 (Ref. to published abstract given in parenthesis)

1957

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

1960

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

1961

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

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

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

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

1962

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

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

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

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

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

1963

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

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

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

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

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

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

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

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

1964

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

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

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

1965

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

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

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

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

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

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

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

30. William B. White; Sulfate Mineralogy in Some Caves in the United States. 34d. Int. Congr. Speleo., Ljubljana, Yugoslavia.

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

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

1966

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

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

35. Denver P. Burns; Explorations in Flint Ridge. AAAS, Washington DC (NSS Bull. 29 114 1967)

36. Thomas L. Poulson; Biospeleology: Past, Present, and Future. AAAS, Washington DC (NSS Bull. 29 100 1967)

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

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

39. William B. White and Elizabeth L. White; The Speleological Approach to Limestone Hydrology. AAAS, Washington DC (NSS Bull. 29 113 1967)

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

1967

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

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

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

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

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

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

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

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

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