NINTH ANNUAL REPORT

of the

CAVE RESEARCH FOUNDATION

For the year ending

December 31, 1967

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Table of Contents

GENERAL INTRODUCTION: 1957-1967 3.

INTRODUCTION: 1967 8.

THE SCIENTIFIC PROGRAMS 9.

A. The Cartography Program
1. The Cartographic delineation of the caves of Mammoth Cave National Park 9.
2. Location of cave passages by instrumental methods 11.

B. The Hydrology Program
1. Hydrology Review 11.
2. Paleohydrology of Mammoth Cave and The Flint Ridge Cave System 11.
3. Hydrology of the Central Kentucky Karst 14.

C. Program in Sedimentation, Mineralogy and Petrology
1. Petrology of Mid-Mississippian limestones 19.
2. Dynamics of Cavern sedimentation 19.
3. Cave sediments of the Near East 19.
4. Base level sedimentation in Flint Ridge 20.
5. Water-soluble minerals from cave soils 20.

D. Program in Karst Geomorphology
1. Relation of joints and fractures to cavern development 22.
2. Review of the Central Kentucky Karst 26.
3. Measurement of the cave environment 26.

E. Theoretical Speleology
1. Statistical properties of the Flint Ridge Cave System 27.

F. Program in Ecology
1. Comparison of terrestrial cave communities 27.
2. Comparison of stream cave communities 33.
3. Cave crustacea from West Virginia 33.

G. The Archaeology Program
1. Excavations at the Salts Cave Site 36.
2. Action Archaeology 37.

H. The History and Economics Program 38.

THE ADVISORY PROGRAMS 38.

A. Management Problems
1. The Development of the Cave Research Foundation 38.
2. Management problems in National Parks 38.

B. Wilderness and Human Values
1. Wilderness at Mammoth Cave National Park 38.
2. The nature of wilderness 38.

PUBLICATIONS IN 1967 39.

A. Papers at Professional Meetings 39.

B. Talks, Seminars, and Symposia 39.

C. Abstracts of 1967 Published Papers 40.

MASTER PUBLICATION LIST OF THE CAVE RESEARCH FOUNDATION 41.

A. Contributed Papers 41.

B. Supported Papers 42.

C. Theses 42.

D. Papers Given at Professional Meetings 43.

Acknowledgements

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

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

GENERAL INTRODUCTION: 1957-1967

In 1967 the Cave Research Foundation marked its tenth anniversary. While many of those who organized CRF had begun working in Central Kentucky as early as 1947, it was not until much later, nearly a decade, that the catalyst for the organization of CRF was found. The catalyst was the discovery of the Flint Ridge Cave System. The possible interconnection of the several caves in Flint Ridge had been suspected for about 50 years. Hard evidence was nonexistent, however, and the known extent of the caves in the early 1950's was more or less what it had been to an earlier generation of explorers and cave geologists. A series of remarkable discoveries in 1954 and 1955 paved the way for the later integration of the caves into the Flint Ridge Cave System, and showed the need for an organization to continue and expand the work then in progress. The organization formed was the Cave Research Foundation.

Today CRF is the only organization in the United States devoted exclusively to the support of research in the cave-related sciences. Other organizations such as the National Speleological Society provide some support for cave study, but also have other goals such as membership for all those interested in speleology. At the outset the founding Directors of CRF elected to concentrate the activities of the new organization on the support of exploration and research in cave and karst areas, the interpretation of these features to the public, and the conservation of caves. While there are no limiting provisions in the CRF charter, two additional important decisions were made by the CRF founding Directors. Initially all work would be concentrated in Kentucky which had already been the scene of much work. No secondary objectives such as the publication of a journal would be supported. These basic guidelines are still being followed as the first decade of work draws to a close.

Of the goals enumerated, the pursuit of the first, the support of exploration and research in caves has received the greatest attention. Inherent in karst research everywhere has been the need to conduct much preliminary exploration and cartography so that the investigating scientists could portray their findings accurately. The lack of detailed maps had been a limiting factor in Kentucky for may years. With a newly discovered cave system of unknown extent, the need for accurate maps was all the more urgent. Thus much early support in CRF was given to cartography, a program that has continued over the ten year period.

The need for exploration and cartography and also the degree to which the program has been successful is shown in the two maps of Flint Ridge that accompany this introduction (figures 1 and 2.). Figure 1 shows the known caves in Flint Ridge in 1947 when the first work by the founding Directors of CRF began. The map in figure 2 shows the extent of the Flint Ridge Cave System in 1967. An early goal then, was building the organizational and personnel base for the cartography program. A forthcoming paper by the first two CRF Presidents Philip M. Smith and Richard A. Watson on the history of CRF details the organizational buildup. Here it is important to note only that a cadre of fifteen or twenty persons has grown into a group of nearly 200 workers.

These workers in the exploration and cartography program are largely volunteer, but they have developed into a professional force with the continuity and organizational experience necessary to carry the work forward indefinitely. The field program in Kentucky has as its only speleological parallel the work in Switzerland's Holloch, directed by Professor Alfred Bögli who is himself a member of CRF. Cartography will continue to be an important part of the CRF program.

Concurrent with the early attention to cartography, the CRF Directors gave attention to opportunities for research in the Central Kentucky Karst. A survey by a special committee resulted in "Speleological Research in the Mammoth Cave Region", the first advisory report issued by the Foundation. This study set the stage for CRF's support of research. From the start attention has been given to a broad program that concentrates on no single discipline. CRF support has been given in geology and hydrology, biology, archeology and history. Interdisciplinary opportunities have been followed where possible and are well illustrated in the series of archeological reports appearing since 1962. The diversity of CRF's present research interests is illustrated by the reports on the 1967 program that follow.

A number of administrative problems have developed over the years, and all have been successfully solved. For example, when the work began in 1957 there was no working agreement with the National Park Service and no existing arrangement used by the Service for the support of research met the needs at Mammoth Cave National Park. A memorandum of agreement for research was executed by the Service with CRF in 1959. It has been renewed and modified on two occasions, and the working relationships that have resulted are excellent.

Initially it seemed that adequate financial support would be the major problem in CRF;s continuing program. Adequate financing has been a problem and continues to demand considerable attention on the part of the CRF Directors. CRF faced the financial problems of any new organization. A second, continuing problem is that the cave-related sciences remain within an area of study generally called basic research. The work undertaken by cave scientists must compete with the generally limited funds for basic research in the

United States. A modest grant from the United States Steel Foundation for general program support over a three-year period provided the "seed" money for several CRF studies. The success of these studies will, it is hoped, attract further financial support.

One CRF program with many immediate implications is hydrology. Far from being a pursuit for mankind's "knowledge bank" the understanding of karst hydrology is important to the control of pollution in many industrial areas of United States and Europe, and important to the search for water in many arid lands. Attention to the hydrology of the Central Kentucky Karst has awaited production of base maps and completion of several geological studies. Hydrology will have increasing attention in future CRF support.

A problem that has proved more difficult than financial support has been the location of qualified investigators who have an interest in cave and karst research. The environmental and logistic difficulties of cave research are obvious. Even with many of these problems solved through the long CRF experience in Kentucky investigators have not been forthcoming. One solution has been to identify and support interested graduate students. At some point after these students are professionally established, there own interest might be expected to stimulate further research in caves and karst. That point of greatly accelerated interest is in the future. Meanwhile the scientific manpower problem continues.

A concern for the availability of future research opportunities in American speleology has resulted in two special CRF reports. "The Flint Ridge Cave System: A Wilderness Opportunity" recommended that the wilderness and research aspects of Flint Ridge be given careful consideration in the administrative planning for Mammoth Cave National Park. These thoughts were expanded in "The Mammoth Cave National Park Research Center". With the experience of ten years to assist in making a judgment, CRF places even greater emphasis today on the preservation of the natural cave environment. This is the most appropriate use of the Flint Ridge Cave System. Protection will insure the continued availability of the natural laboratory. Lan management in the Central Kentucky Karst has focused attention on CRF's interpretative and conservation goals and these are receiving greater attention than in earlier years.

Throughout the growth and development of CRF the presence of the Flint Ridge Cave System has been a dominating force. A true catalyst, it has remained. The immensity of the geographical problem has demanded new and sometimes unusual solutions in management and research. The prevading nature of Flint Ridge is seen in the reports of 1967 activities. Much future work can be expected in Flint Ridge even though programs in other karst areas will gain more attention.

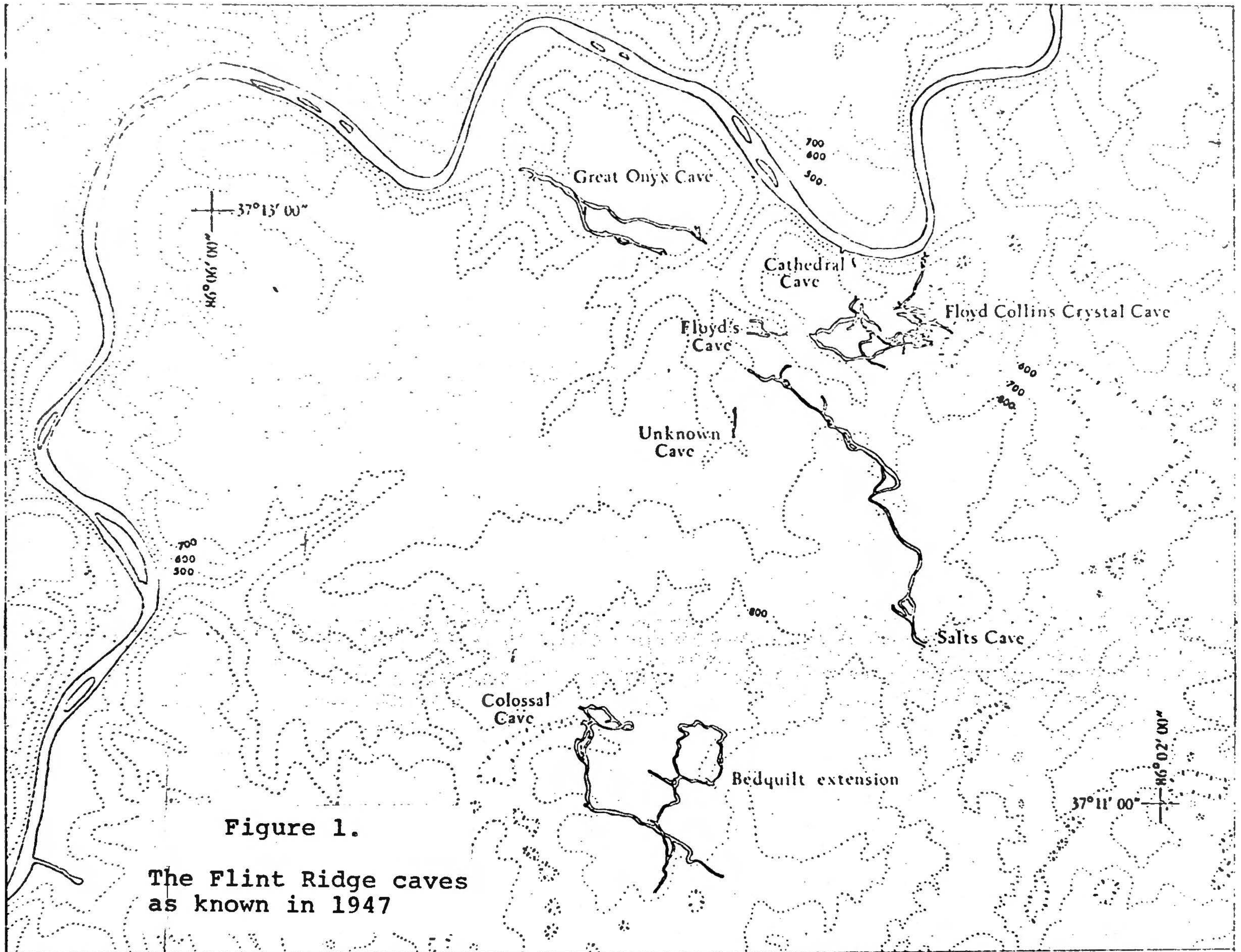


Figure 1.

The Flint Ridge caves as known in 1947

SURFACE TOPOGRAPHY FROM U.S. GEOLOGICAL SURVEY
7.5 MINUTE MAMMOTH CAVE QUADRANGLE, 1954

1000 0 1000 2000 3000 4000 5000 6000 FEET
Scale

Surface Contour Interval 100 Feet Datum MSL

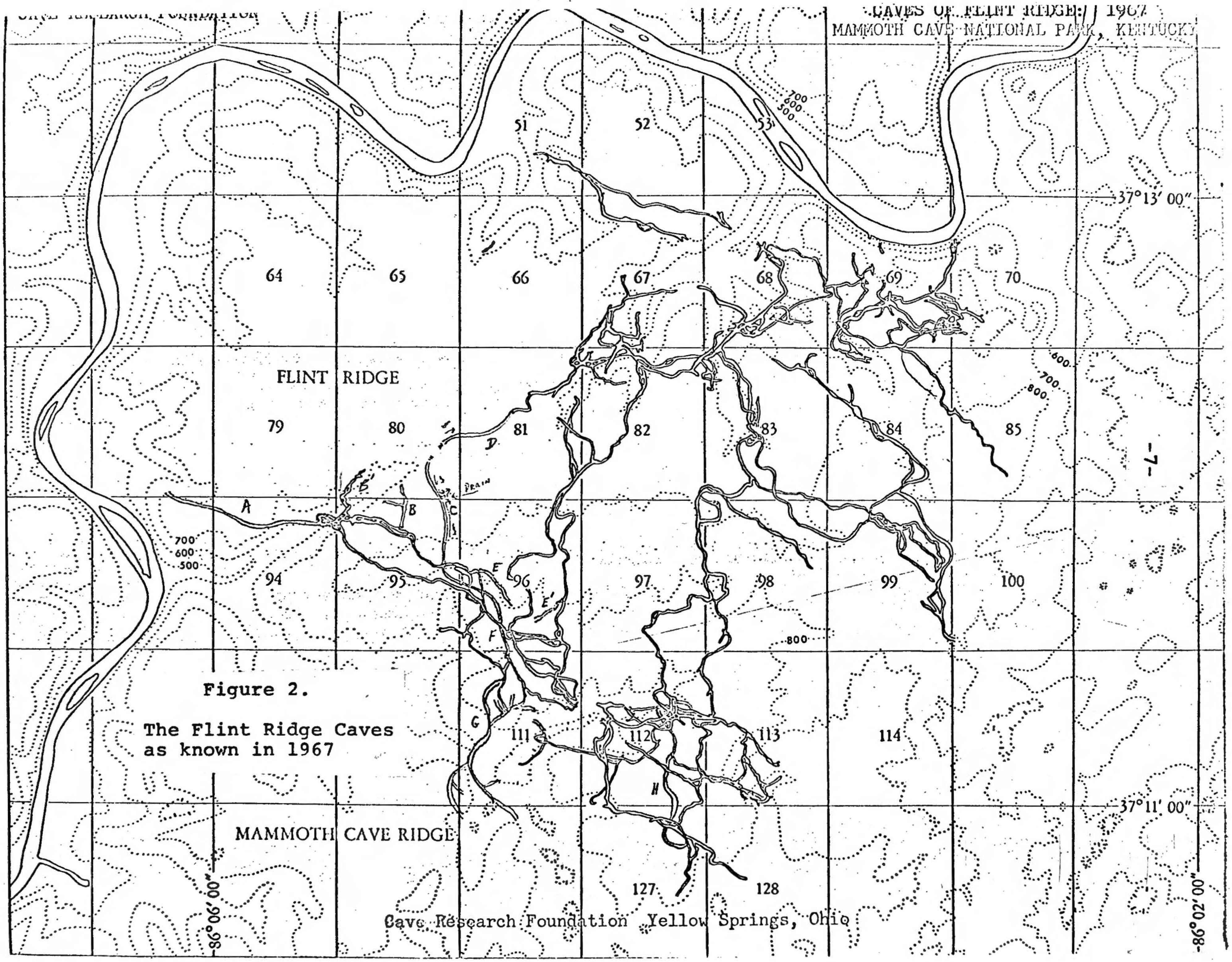


Figure 2.

The Flint Ridge Caves as known in 1967

INTRODUCTION: 1967

The Foundation continued a series of scientific programs in the Central Kentucky Karst and elsewhere during 1967. Some of the older projects have been completed and these appear appended to the list of publications at the end of this report. Highlights of all active research are given in the following pages. Those projects which were conducted in Mammoth Cave National Park have been assigned a project number by the Park Service and these numbers appear on the reports.

The Foundation awarded a fellowship for graduate study in the cave related sciences for the first time in 1967. The fellowship was awarded to Mr. David Culver of Yale University for his thesis research on "The Ecology of Cave Crustacea from West Virginia". A second applicant for the fellowship, Mr. Paul Goldberg of the University of Michigan was awarded a grant in partial support of his research on the cavern sediments of the Near East. These awards represent both a new mode for support of the cave-related sciences and an expansion of the Foundation's sphere of interest beyond the confines of the Central Kentucky Karst.

George H. Deike III, who has been pursueing a dissertation project on the geology of the Central Kentucky Cave Area was awarded a PhD in Geology by the Pennsylvania State University in September, 1967. The title of Dr. Deike's thesis is "The Development of Caverns in the Mammoth Cave Region".

The scientific program, "Hydrology of the Central Kentucky Karst" has been accepted by the United States National Committee of the International Hydrological Decade as an official part of the Decade Program.

The Foundation was well represented at the Symposium on Wilderness Planning for Mammoth Cave National Park. Several members participated in the discussions and others lead tours to give the Symposium members a sampling of the Flint Ridge Cave System Wilderness.

THE SCIENTIFIC PROGRAMS

THE CARTOGRAPHY PROGRAM

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

The cartographic descriptions of the caves of Mammoth Cave National Park proceeded rapidly in 1967. Caves in Flint Ridge and Joppa Ridge were examined and described. Tradionally the exploration and survey of the Flint Ridge Cave System has been cyclical, that is, some years few major passages are found and survey is mostly of passages within the known system. Exploration during other years results in the discovery of major or significant passages that extend beyond the limits of the system. 1967 was a year of discovery with five major areas of survey in Flint Ridge and one area in Joppa Ridge.

Below are described the principle discoveries and survey progress. Names assigned to the areas are for field reference and do not necessarily represent the names to be submitted for certification.

In the historic portion of Crystal Cave several leads around the Cigar Box Junction Room of Miller Trail were surveyed including one which ties to Denison Way giving a major survey loop including the following passages: Dyer and Thomas Avenues, Scotchman's Trap, Miller Trail, and Denison Way. Such loops provide a check of the accuracy of the surveys.

Grund Trail was surveyed its entire length between Gravel Avenue and the Mountain Room in Mather Avenue. This survey completes a loop including Mather and Swinnerton Avenues, Roebuck Trail, and Grund Trail. Several leads in a pit and canyon complex were discovered under the Mountain Room. The survey is still incomplete but traverses have been run at five levels in the Mountain Room area. The discovery includes 100-foot canyons extending southeast towards Colossal Cave and a stream draining to the northwest. This complex of passages is one of the few that occurs well under the caprock and its significance is not yet understood. It does demonstrate that complex sets of passages in addition to trunk passages can exist under the caprock.

The Southwestern Passage extends southwest along the axis of Floating Mill Hollow and then turns west. The survey terminates where the passage (a canyon) has several feet of water on the floor. Floating Mill Hollow truncated all of the upper level passages such as Swinnerton and Gravel Avenues and Penck Trail. Low level leads in the area have been methodically examined for several years as it was known that passages had to exist on the western side of Floating Mill Hollow. This past year a particularly low and wet passage was surveyed. It led to a pit, the ascent of which gave access to the Southwestern Passage.

The access passage, which passes under the axis of Floating Mill Hollow, can be flooded by an eight-foot rise in Green River. A complex of canyon passages off of the Southwestern Passage may lead to the truncated segments of Swinnerton and Gravel Avenues. Because of the rapid response of water levels in the access passage to stages of the Green River, it is believed that the pooled water at the end of the Southwestern Passage represents water at Base Level under Flint Ridge. More than one and one half miles of walking-height passage have been surveyed beyond the access passage.

Wretched River is an abandoned drain for the water falling into Colossal Dome. A river flows along the passage but the water source is not Colossal Dome. The water flows northwest to Colossal River.

Stairway Crawl in Great Onyx Cave represents a first significant discovery in Great Onyx in several years. The crawl goes northwest from the lake in Cox Avenue. Its length is now more than 1700 feet. Leads near the end of the survey may go to the cave passages known to underlie the northwest corner of Flint Ridge but not yet entered. Tehy may also go to the Storts Trail - Faust WAy area of Crystal Cave. Discovery of this passagge increases the length of Great Onyx Cave by about 15%.

All of the formerly commercial passage plus several crawlways and shaft drains have been mapped in Proctor Cave on Joppa Ridge.

New survey from November 1, 1966 to November 1, 1967 in the Flint Ridge Cave System totaled 6.03 miles. This was the greatest amount of new survey in several years and indicates both the increase in the number of survey parties and the significance of the passages discovered during the year. The total horizontal length of the Flint Ridge Cave System is now 63.18 miles. Holloch Cave (in Switzerland) is the second longest cave in the world with a length of about 57 miles.

A vertical control program was initiated in the Flint Ridge Cave System in 1967, with two major leveling surveys. One was a loop beginning at the entrance to Colossal Cave and passing through Grand Avenue, Bedquilt Route, Davidson Trail, and the River Route. The second leveling survey was from the intersection of Thomas and Collins Avenues in Crystal Cave to Floyd's Lost Passage.

Several passages in Flint Ridge totaling 2.57 miles were resurveyed to correct suspected errors and/or to record or upgrade information on passage detail.

Location of Cave Passage by Instrumental Methods (Alan Hill, CRF)

The effort to devise instrumental techniques for locating and measuring inaccessible parts of the cave system have continued. This years work has been concentrated on a theoretical study of the feasibility of acoustical holography as a technique to make 3-dimensional photography through solid limestone possible.

In brief an acoustical plane wave is introduced into the ground. Its complicated rebounds from cave passages and joints back to the surface are made to interfere with a second reference plane wave at a liquid-air interface. The nodal cavitation at the liquid-air interface then contains information of a holographic nature. By photographing the interface, this information may be reduced to a diffraction limited interference pattern on film. The actual 3-dimensional image of the cave may then be produced from the film as a hologram with the aid of a laser. The underlying difficulties are considerable and are being further investigated.

THE HYDROLOGY PROGRAM

Hydrology Review (William B. White and Elizabeth L. White, CRF and Pennsylvania State University)

A review paper is under preparation to compare the speleological approach to limestone hydrology with the more conventional hydrological techniques. Further literature review was undertaken during the present year.

The topic of principle interest was the application of of soil mechanics to the problem of catastrophic sinkhole collapse. This problem is causing considerable property damage and occasional loss of life in Florida and in several areas overseas. Collapse if often triggered by overpumping the groundwater reservoirs of the areas with resultant lowering of the water table and draining of formerly water-saturated soils.

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

This project, which has been active since the Summer of 1963, is gradually coming to a close. Its object has been to test the degree to which a cave system can be treated as a set of fragmented segments of an integrated drainage net and whether interpretable information on past flow conditions is recorded in the cave pattern and its solutional sculptering. The principle conclusions are summarized below:

i. Brucker's concept of a trunk drain appears to be valid. Nine major trunks can be traced in the Flint Ridge System and three in Mammoth Cave. Fragments of at least one additional trunk exist in Joppa Ridge.

ii. The role of the trunks was to carry water from the Sinkhole Plain to Green River. The terminal breakdowns against the Green River bluffs mark the locations of former big spring discharges. The spring locations seem to have shifted very little since the caprock was breached. Trunk gradients are very low. This implies a very flat water table in agreement with the flat water table which Cushman (USGS) determined from well data.

iii. Scallop measurements give at least a rough indication of past flow velocities which, in bed-rock-floored passages, permits an estimate of the paleo-discharge. The numbers are in the order of 10 to 20 c.f.s. for many trunks, a discharge which is quite reasonable in comparison to that of present day big springs.

iv. Hydrologic roles have been determined for some of the minor tubes and canyons. These include shaft drains which postdate the breaching of the caprock, piracy routes which are closely related to the sequence of trunk development, and residual canyons which downcut from a trunk after its major flow has been pirated into a lower route.

v. Some insight into the question of a "phreatic" versus a "vadose" origin for the trunks has been obtained by an examination of Robertson Avenue in Mammoth Cave. A 3000-foot reach of this passage alternates between a canyon cross-section with small (high velocity) scallops and an elliptical tube cross-section with large (low velocity) scallops. A carefully surveyed profile of this passage shows an undulating pattern with the canyon geometry on the high parts of the curve and the tube geometry on the low parts. It seems probable, therefore, that this trunk at least formed within a few feet of the water table.

The most recent conclusion is an explanation for the location of the big springs in terms of the structural geology of the area. This interpretation is based on the premise that trunk drains form along a path of maximum hydraulic gradient and minimum hydraulic resistance. Prior to the incision of the Green River Gorge into the limestones no discharge into the river is possible in spite of a considerable hydrostatic head from recharge onto the Sinkhole Plain. The average route of the Green is skewed to the regional structure so that in general the riverbed contact between the limestone and the caprock migrates downstream as the river downcuts. However, there are large

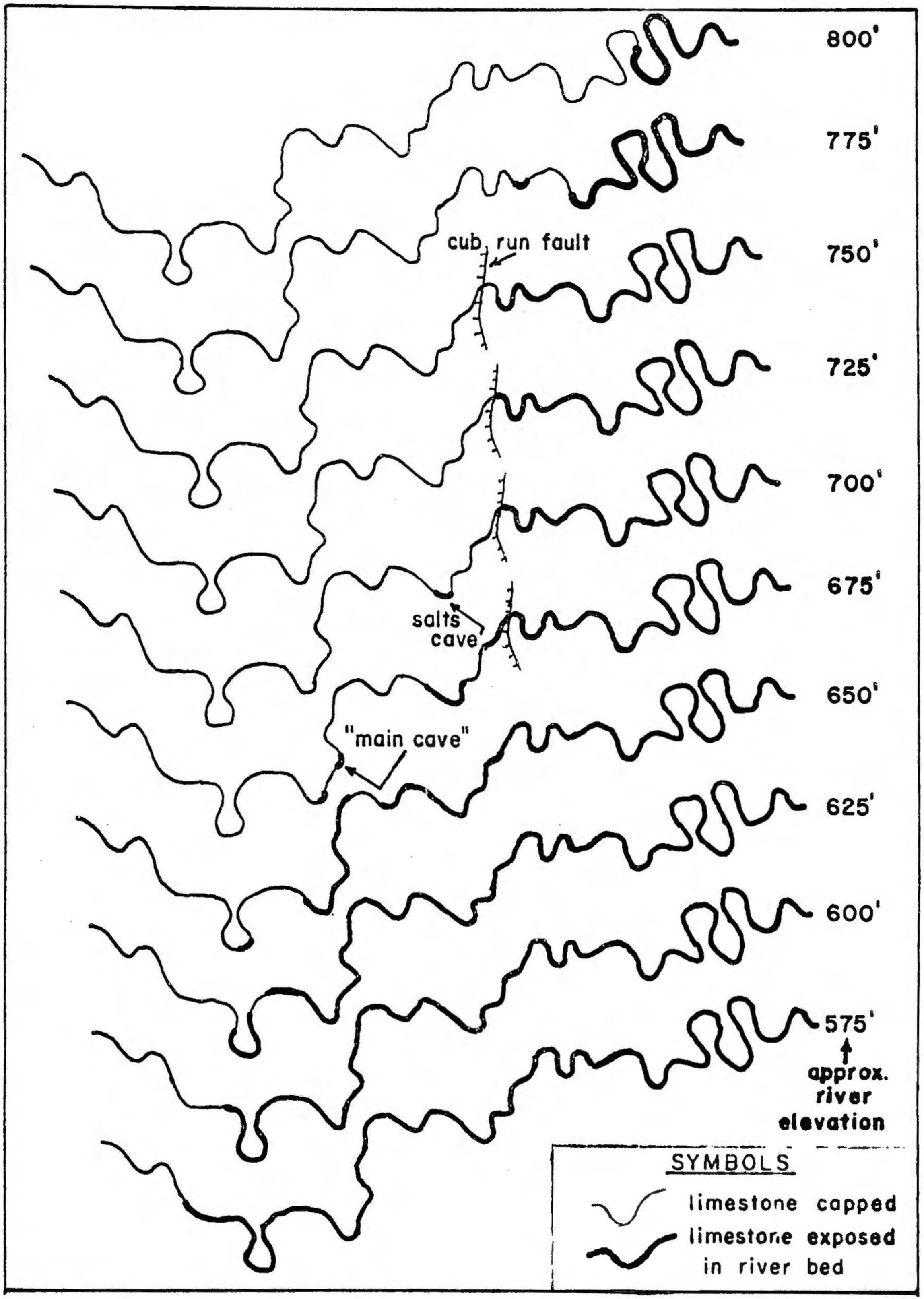


Figure 3.

Maps of Green River at successive elevations (and points in time) showing progress at exposing the limestone by cap breaching.

local irregularities in both the structure contours and the position of the river channel. The caprock breach has not migrated uniformly down river but has occasionally skipped to a point further downstream when a south-sweeping bend of the river touched the top of the limestone on the crest of minor anticlines. Other structural elements, particularly the Cub Run Fault, have also played a role in retarding the migration of the limestone contact. The situation is illustrated in figure 3. The first breaches of the limestone agree in great detail with the terminations of high level trunk conduits. These optimum points of discharge were the northern terminus of Salts Cave, close to the present location of Pike Spring, the western end of the Main Cave above the present day Styx River Spring (with another breach above the location of present day Echo River Spring), and at the Turnhole. It is argued that these break-points permitted the establishment of a trunk drain while the riverbed was floored with sandstone both up and down stream from the breach-point. The focal points of these major drainage lines seem to have been preserved until the present time with very little lateral migration.

MACA-N-12. Hydrology of the Central Kentucky Karst.

The Central Kentucky Cave Area is an outstanding example of a maturely karsted limestone aquifer. The U.S. Geological Survey geological mapping and groundwater studies in the area have provided an important source of background information. Other on-going CRF programs, particularly cartography, provide a more detailed picture of the drainage net than is available anywhere else in the United States. It was this optimum situation that lead to the establishment of a long term program with the aim of achieving a full understanding of the hydrological mechanisms operating in the area. The project has been accepted by the U.S. National Committee of the International Hydrological Decade as part of the United States official Decade program.

During 1967 two facets of the project were active: a continuing study of the hydrology of vertical shafts and a study of the sinuosity of limestone solution conduits.

Vertical shaft research: (Roger W. Brucker, CRF) In August Brucker investigated and mapped two canyon complexes, which are of interest because they contain many features common to vertical shaft complexes. The first was a horizontal and vertical survey of the canyon known as "The River" in Cox Avenue, Great Onyx Cave. The second began as an investigation of a vertical shaft located in Mather Avenue near Cammerer Hall. This shaft was described previously as one of the few vertical shafts located under the capping sandstone-shale beds. While the vertical solution features and general shape resemble a vertical shaft, the feature was found to be part of an intricate canyone complex. This was surveyed.

Certain features appear to differentiate vertical shafts from complex canyons. The main features seem to be a common orientation of multiple drains in canyons, while shaft drains appear to have divergent orientations. A second diagnostic feature is the orientation of input water. Vertical shaft water inputs appear to be entirely vertical while canyon water inputs appear to be horizontal streams.

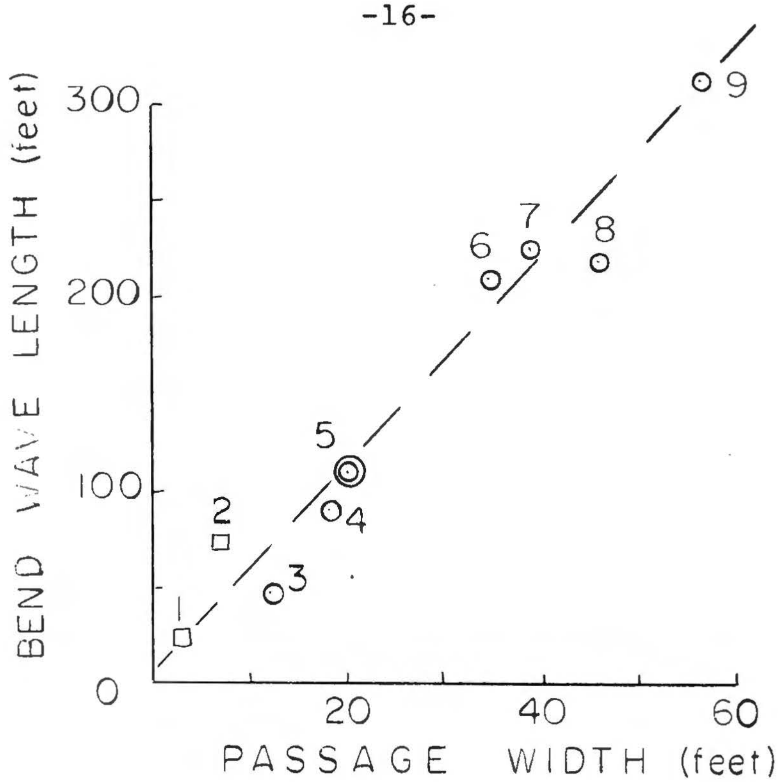
Sinuosity in Limestone Solution Conduits: (George H. Deike and William B. White, CRF and Pennsylvania State University) Many surface streams pursue a sinuous or meandering course over their alluvial floodplains. It has long been noticed that all rivers tend to look alike when they are drawn on maps--an observation which implies a near linear relationship between the size of the meanders and the width of the channel so that both values change in the same proportion as the scale of the map is changed. The relationship between the "wavelength" of the meander and the channel width has been reviewed by Leopold and Wolman*. They find a relation of the form:

$$L = 10.9W^{1.01}$$

Caves in flat-bedded limestones in the absence of other structural controls also exhibit a distinct sinuosity. Meandering curves are observed in canyons cut in trunk channel floors (where they would be expected by analogy with surface streams), in bedrock canyons, and also in the elliptical tube channels themselves. There are a number of complexities to the measurement and interpretation of the cave data. A sinuous pattern would obtain if a passage were developed along a hydraulic gradient diagonal to orthogonal regional joint sets. Some such influence is probably responsible for part of the scatter in the data in figures 4 and 5. Channel width is difficult to define in a cave in which solutional irregularities or breakdown modify the channel cross-section. Passage widths are merely sketched in most cave survey practice; therefore widths scaled from published maps are likely to be inaccurate.

The meander length-channel width relationship seems to dominate over these (and other) randomizing factors. Some data from Central Kentucky are shown in figure 4. These data were field checked personally and it can be seen that the scatter is rather small. The deviation from direct proportionality (i.e. a straight line on a linear plot) is not obvious.

* Luna B. Leopold and M. Gordon Wolman (1960) River Meanders. Bull. Geol. Soc. Amer. 71 769-794.



Index to Data Points

Point	Location	No. Bends Measured
1	Carlo's Way	6
2	Rose's Pass	3
3	Little Bat Avenue	7.5
4	Parker Cave	2
5	Long Cave (channel)	5
6	Gothic Avenue	4.5
7	Long Cave	2
8	Cleaveland Avenue	3.5
9	Main Cave	2.5

Figure 4.

Relation of cave passage meander length to passage width for various segments of Mammoth and other caves.

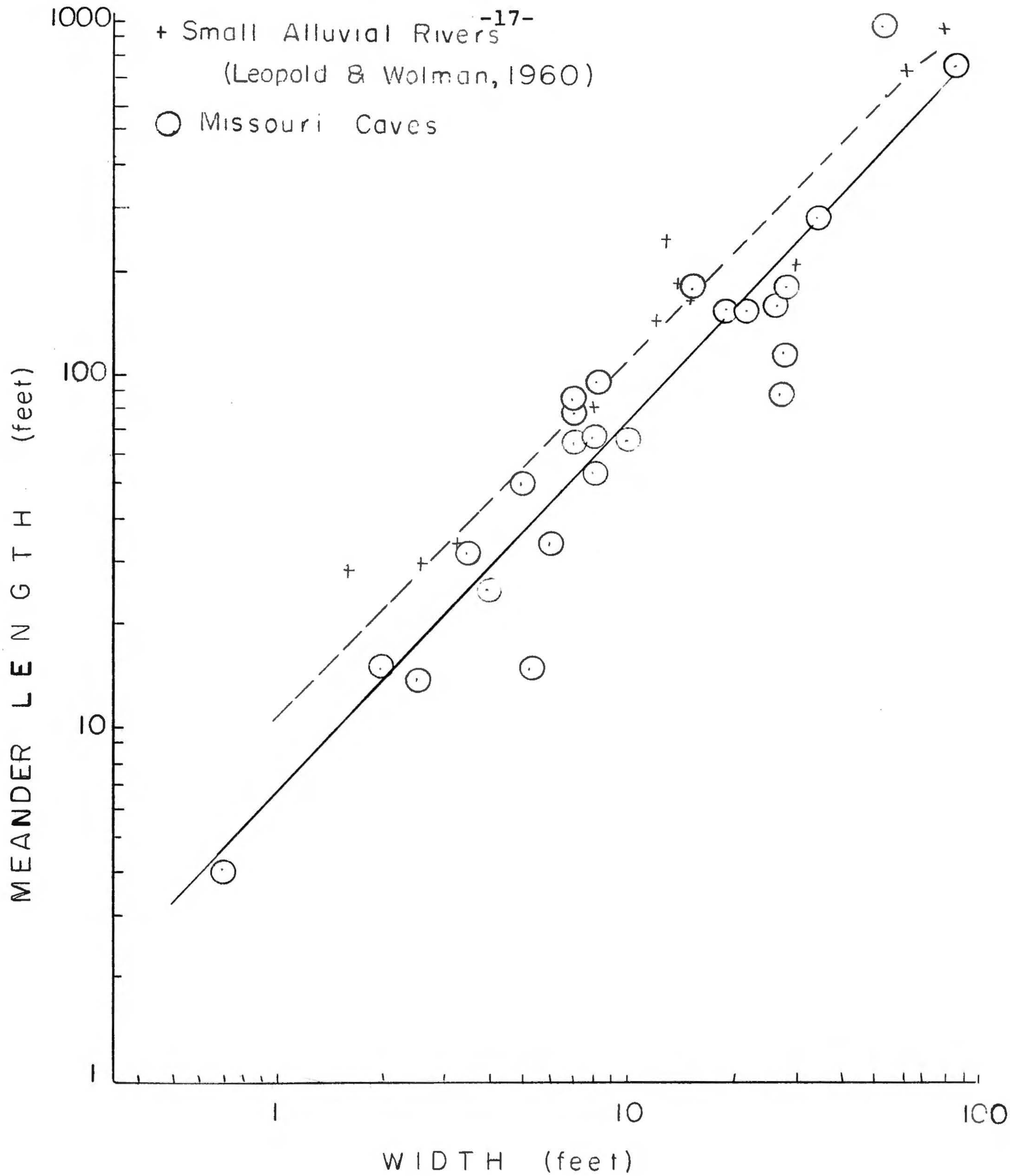


Figure 5.

Meander data for cave passages in Missouri

A selection of cave data from Missouri are shown in figure 5. The Missouri Speleological Survey enjoys a high reputation for the quality of its maps. The data in figure 5. are scaled directly from the maps published in various issues of Missouri Speleology. There is more scatter in the data but the correlation is still rather good. For camparison, Leopold and Wolman's data for small rivers are also plotted in figure 5. The offset in the curves appears to be real although they are still nearly parallel. Another set of data were obtained using a selection of cave maps from other parts of the United States and from Europe. These data, not reproduced here, give a plot similar to figure 5.

All of the meander length-channel width data can be expressed as a power function of the form:

$$L = KW^n$$

Comparisons of the constants of the equation for cave data with published values for these constants for river data are given in table 1.

Table 1.

Source of data	K	n
Missouri Caves	6.8	1.05
Kentucky + Other Caves	8.2	0.92
Leopold and Wolman (1960)	10.9	1.01
Inglis (1949) Indian Rivers	6.6	0.99

The scatter of the data are such that the deviations of the exponent from unity are probably not significant. However, the variations in the proportionality constant are at least partly real and of unknown significance. The discovery that meanders of cave channels follow the same equation as meanders in alluvial rivers is of considerable importance because it shows that the hydrodynamic forces responsible for meandering are sufficiently powerful to impose themselves on a conduit cut in bedrock. It also confirms a prediction made by Bagnold+ that some properties of sinuous channels should be the same whether the channel is a closed conduit or an open channel type of flow.

+ Ralph A. Bagnold (1960) Some Aspects of the Shape of River Meanders. U.S. Geol. Surv. Prof. Pap. 282-E 135-144.

PROGRAM IN SEDIMENTATION, MINERALOGY AND PETROLOGY

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

This project was started in 1963 with the object of describing the petrology of the limestones of the Central Kentucky Karst. Field work consisted of measuring six 200-foot sections and sampling the bedrock at 6-inch intervals. As a by-product of the sampling program, many details of the stratigraphy which had previously escaped notice became apparent. Irregular dolomite beds and chert horizons occur frequently. Many of the field aspects of the project are complete and were described in the Fifth Annual Report.

Some 1200 hand speciments of limestone were collected during the 1963 field season and many additional samples were obtained in 1966. A vast amount of laboratory work is necessary to describe these rocks and this effort has occupied most of the available time during the past year.

Dynamics of Cavern Sedimentation. (Elizabeth L. White and William B. White, CRF and Pennsylvania State University)

This is mainly a theoretical study of the fluid mechanics of sediment transport mechanisms by underground streams. A more complete abstract appears in the Eighth Annual Report. During the past year a manuscript describing the work was completed and has been submitted to the National Speleological Society Bulletin for publication.

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

New work has been started in 1967 on a comparison of the sediments of two caves in Israel with cave sediments of Southern Europe. Field work was started in Summer, 1967 with observa-tions in a number of caves in Southwestern France. This was followed by extensive excavations and sampling in the caves Et-TAbun and Qatzeh near Mount Carmel in Israel. The work in Israel was postponed until August due to the political situation there in June and July. The sediment samples obtained are being analysed for granularity, degree of weathering, iron and phosphate content and pH. This project will be continued during the coming year.

Base Level Sedimentation in Flint Ridge. (Roy Carwile and Edward Hawkinson, CRF and Ohio State University)

The sedimentation that occurs in the floodwater zone of both Mammoth Cave and the Flint Ridge Cave System has been the subject of much debate. Fresh sediments are built up each year on the commercial trails in the Echo River section of Mammoth Cave but it is still not clear whether these clays and silts are backflooded from the Green River, whether they come from the Sinkhole Plain by transport by underground streams, or whether they are merely local sediments reworked by the annual floods. The resolution of this question would seem to require a knowledge of the distribution of sediment types as a function of distance from Green River.

Earlier observations in Columbian Avenue in Flint Ridge revealed some obvious differences in grain size distribution along the passage. The Golden Triangle Room, the closest approach to the river at Pike Spring contains large sand bars. Considerable sand is also found along Eyeless Fish Trail. The lower reaches of Columbian Avenue contain thin layers of interbedded sand and clay. The sand lenses out in the upper reaches of Columbian Avenue and only very thin laminated clays remain. All of these observations, however, are qualitative and very spotty. The present study is a more quantitative approach to this problem.

What is needed is a comparison of the micro-stratigraphy of the passage sediment as a function of the distance from Green River. This can be obtained by coring the sediment at known intervals along the passage and measuring the relative thicknesses of sand and clay beds in the core. Preliminary observations in November confirm the earlier observations and further indicate that a coring project is feasible. Work on obtaining cores will begin in late 1967 or early 1968 pending approval of the project by the National Park Service.

Water-Soluble Minerals from Cave Soils. (William B. White and Craig S. Peterson, CRF and Pennsylvania State University)

During the field seasons of 1961 and 1962 a number of recconnaissance studies of many facets of cavern sedimentation were started. One of these was an investigation of the mineralogy of the clastic sediments from both of the big cave systems. The detrital fraction of the sediments has been investigated in some detail by Davies and Chao but the clay fraction and the water-soluble minerals have remained unknown. The field aspect of this earlier phase of the study consisted of collection a large number of soil samples from all principle passages in Mammoth Cave and the Flint Ridge Cave System. Time did not permit further work in 1962 but during 1967 attention was again turned to this collection of samples and the task of laboratory analysis was begun.

The objective was to determine the clay minerals and the water soluble minerals present in the soils. So far 83 specimens have been examined. All samples were slurried in water; the coarse grains were allowed to settle, and the muddy suspension was decanted off. The suspension was poured into evaporating dishes and allowed to stand in air until only a dry residue remained. In this manner both the very fine-grained clastic material and any water soluble material was separated from the coarse grained clastics. The dried residue was then powdered and analysed by x-ray diffraction techniques.

The results of these analyses are summarized in table 2. Each "x" indicates that a particular mineral was found in one specimen. The number of "x"'s in a particular column is only indicative of the number of samples taken in the passage, not of the relative abundance of minerals. The sulfate minerals which appear in the x-ray patterns are not the minerals which occur in the soils in the caves. The common form of sodium sulfate in the cavern environment is mirabilite, $Na_2SO_4.10H_2O$, which is unstable under laboratory conditions and so appears on the x-ray patterns as thenardite, Na_2SO_4, or one of the other anhydrous sodium sulfate polymorphs. Likewise the hydrate of magnesium sulfate stable in the cave is epsomite, $MgSO_4.7H_2O$, which under laboratory conditions loses one water of crystallization to become the mineral hexahydrite.

Table 2. contains a number of supprises. Clay is very rare and has definately been identified in only one sample. Quartz is ubiquitous. A very fine-grained quartz appears in nearly all samples. It varies considerably in crystallinity as evidenced by the width of x-ray diffraction peaks. Some diffraction patterns exhibit a diffuse background indicating the presence of an amorphous phase, perhaps amorphous SiO_2.

Magnesium sulfate appears to be fairly common as a constituant of the cave soils but has not yet been identified in any of the "gypsum flower" or stalactitic forms of the water-soluble sulfates. Sodium sulfate, on the other hand, which makes up the bulk of the water-soluble sulfate speleothems is uncommon the the soils.

Mammoth Cave was extensively mined for saltpretre a century and a half ago but nitrate minerals seem to be strangely absent. Soda nitre, $NaNO_3$, has been tentatively identified in one sample from Thomas Avenue.

A number of minerals appear in the form of unidentified peaks in the x-ray diffraction patterns. These are merely listed as "unknown" for the purposes of this report. During the coming year attempts will be made to complete these identifications. More than one mineral is represented in the unknown column.

Table 2.

Analyses of Water-Soluble Minerals

Location	Quartz	Clay	Na_2SO_4	$MgSO_4$	$NaNO_3$	Unknown
FLINT RIDGE CAVE SYSTEM						
Upper Salts	xxx		xxxxx			x
Thomas Ave.-Dyer Ave.	xxxx			xxx	x	xxxxx
Turner Ave.	xxx			xxx		xxxx
Grand Ave.	xxxx					x
Great Onyx	xxxxxxx			xxx		
Floyd's Lost Passage	xx					xx
Pohl Ave.	xxxxxxx					x
Columbian Ave.	xxxxxx					
MAMMOTH CAVE						
Main Cave-Ky. Ave.	xxxx	x	x			xx
Cleaveland Ave.	x					xx
Silliman Ave.	x					
River Hall-Echo River	xx					

PROGRAM IN KARST GEOMORPHOLOGY

Relations of Joints and Fractures to Cavern Development. (George H. Deike, CRF and Pennsylvania State University)

This project was completed during 1967 and the results form a portion of the PhD Thesis of the investigator. An abstract of the principle conclusions follows. A summary of the joint, fracture, and cave orientation data is given in figures 6, 7, and 8.

Joints in the Central Kentucky Karst are distributed in a planar northeast set, typically close-spaced in swarms but of limited extent, and a rough northwest set usually wider spaced, and of greater horizontal and vertical extent. The photo-geologic fracture traves in the region are most strongly developed parallel to the northwest joint set.

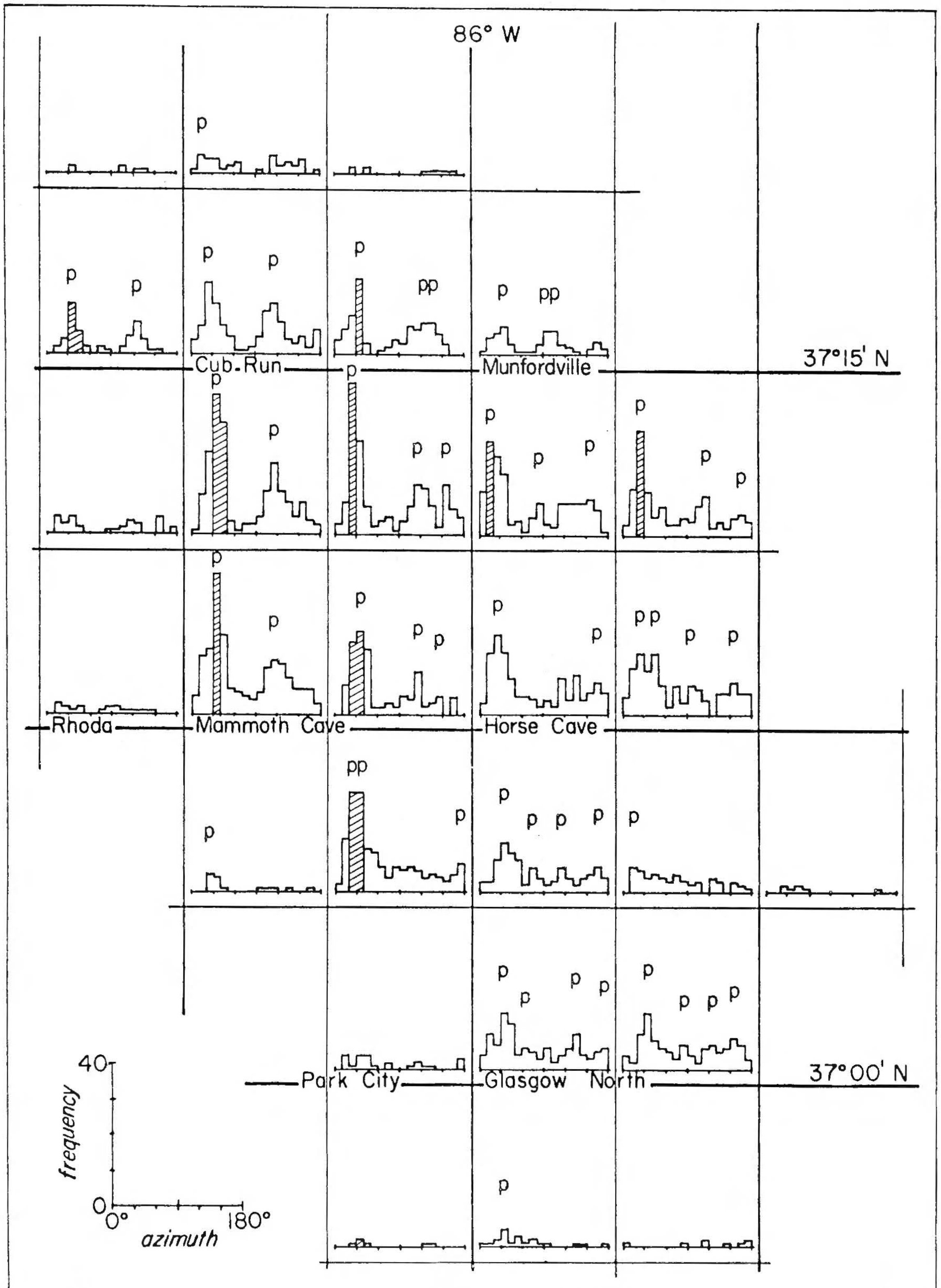


FIGURE 6.

JOINT ORIENTATION HISTOGRAMS

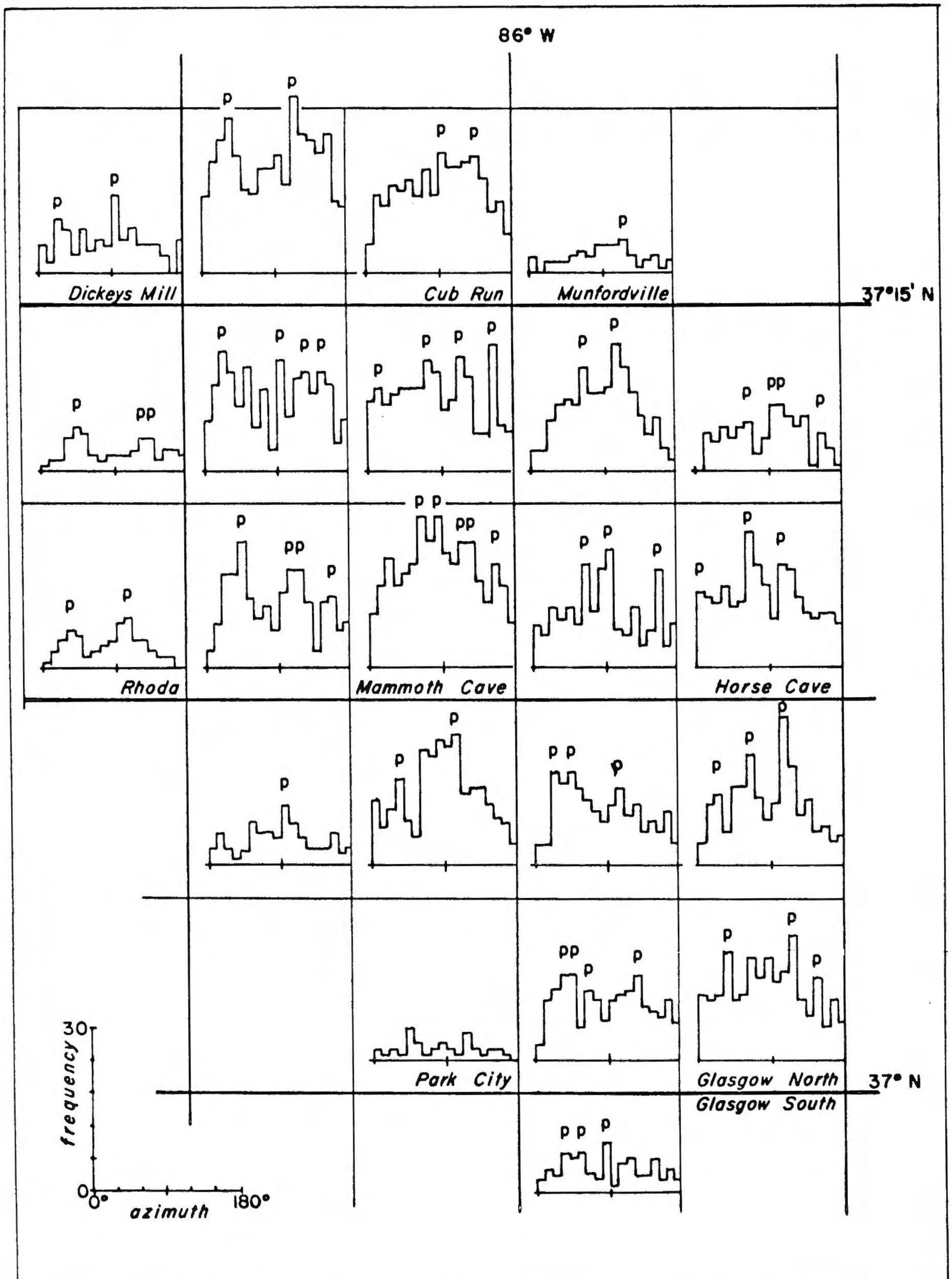


FIGURE 7.

FRACTURE TRACE ORIENTATION HISTOGRAMS

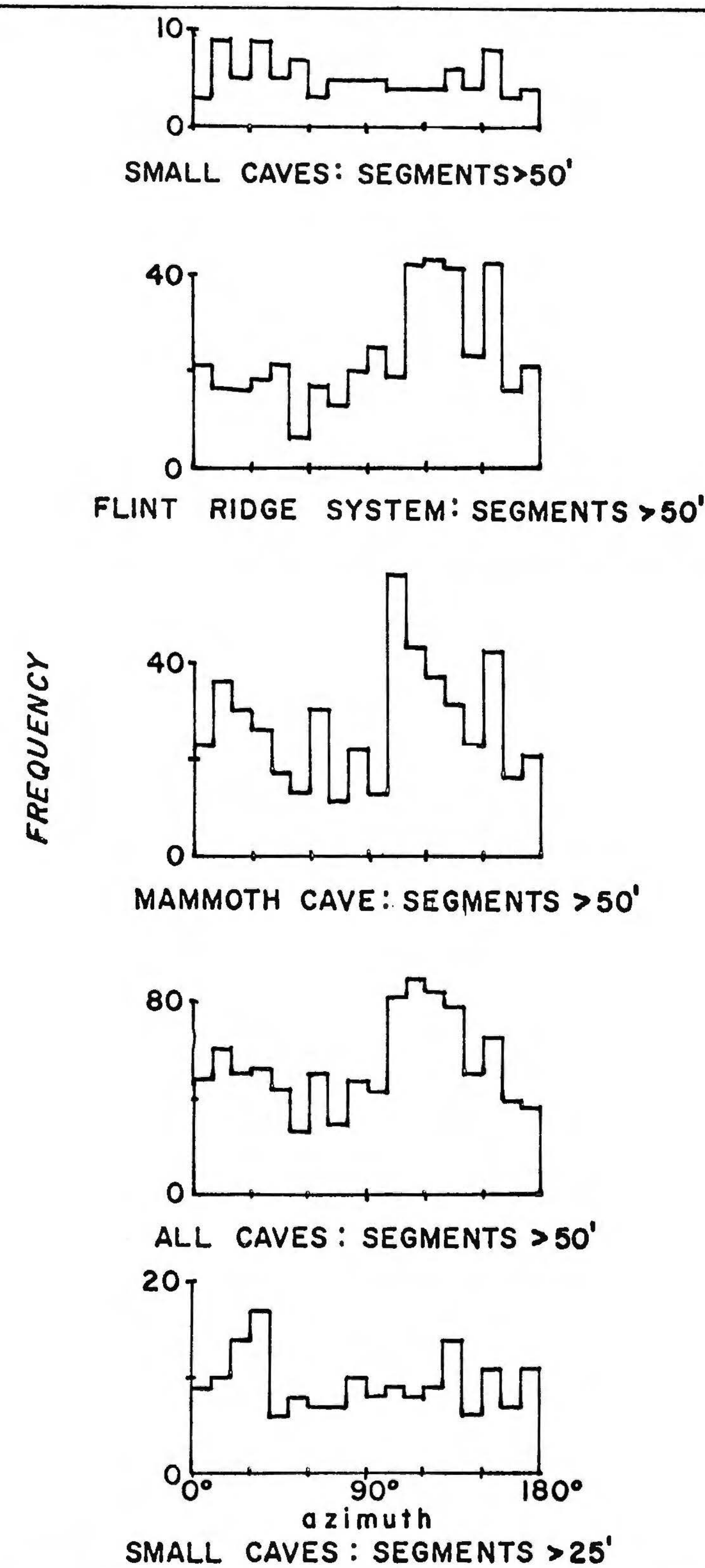


FIGURE 8.

ORIENTATION HISTOGRAMS FOR STRAIGHT CAVE SEGMENTS

Cavern passages show straight segments on maps and/or field evidence of following fractures in only about 40% of their length. This proportion of passages parallels the joint sets, with variations depending on dip direction and other factors.

The joint-influenced part of a passage has the same over-all trend that is shown by the entire passage, indicating that other directional factors select the joints which are utilized.

Disconnected joints, sometimes in en-echelon groups, direct parts of tubular passages along bedding planes, and permit changes of stratigraphic horizon as integrated passage systems develop horizontally close to base level in spite of dipping structures. Joint influence on later stream-eroded canyons cut from tubular passages is very limited.

Hydraulic factors are prominent in shaping the plans of non-fracture influenced passage segments.

The mean amount of straight, fracture controlled cave passage for a variety of other karst regions is 75%. The limited control exhibited in the Central Kentucky Karst is ascribed to the short, disconnected nature of the joints present.

Review of the Central Kentucky Karst. (Richard A. Watson, CRF and Washington University, William B. White, CRF and Pennsylvania State University, and E. Robert Pohl and Roger W. Brucker, CRF)

This long manuscript reviewing the background geology and geomorphology of the Central Kentucky Karst underwent a final revision in 1967. Some progress has been made on the preparation of figures.

MACA-N-10. Measurement of the Cave Environment. (Michael F. Ehman, CRF and Pennsylvania State University)

In the 1967 Field Season in Mammoth Cave National Park, six data collection stations were utilized and maintained to monitor the cave environment in selected sections of the Flint Ridge Cave System. The areas under observation were: two stations in Pohl Avenue, one at Austin Entrance, and one near Black Onyx Pit. Two stations were also placed at Brucker Junction, one at its connection with Pohl Avenue, and the other at its connection with the higher levels at Turner Avenue. Two additional stations were placed in Turner Avenue.

A summary of the temperature data are given in table 3. One factor which stands out in the data is the 0.2°C. gradient between the air temperature and the wall temperature. A second observation which developed is the apparent increase in temperature in the higher levels of the system which also have a reduced relative humidity. There appears to be a larger fluctuation in temperature in these regions. However, this is also a function of the frequency of observation. The sampling of data presented are representative of only the first year of the project and may not be statistically meaningful.

In the 1968 field season it is planned to expand the number of stations to approximately ten, particularly to examine the climatic variations in Pohl, Turner, and Columbian Avenues.

THEORETICAL SPELEOLOGY

Statistical Properties of the Flint Ridge Cave System. (Rane L. Curl, University of Michigan)

This project concerns the invention of stochastic models for various relationships observed in the Kentucky cave systems. One analysis was made of the distribution of angles of intersection of cave passages with present-day topographic contours. The analysis showed that there is no relationship between the orientation of cave passages and present-day topography, a conclusion in agreement the hypothesis that the major cave passages were formed prior to the breaching of the caprock and the creation of the present surface topography.

PROGRAM IN ECOLOGY

MACA-N-14. Comparison of Terrestrial Cave Communities. (Thomas L. Poulson, CRF and Yale University)

Last year's work on "Terrestrial fauna in relation to entrances" was expanded to include study of six additional factors that might affect community complexity. Complexity is defined by the diversity per individual,

$$H = \frac{1}{N} \log \frac{N!}{N_1!\, N_2! \ldots\ldots N_s!}$$

which is derived from information theory and is determined from the distribution of numbers of all species sampled in a community. The community in our case is defined by all organisms censused in a 100 m^2 area and all organisms caught in a baited trap placed at the center of the 100 m^2 area. Thirty-eight such communities were studied for 216 trap days in 1966 and 1967 (table 4.).

Table 3.

Mean Temperatures (°C.)

Location	Surface	Air	Wall
Austin Entrance:			
December	0.8°	11.2°	11.0°
April	9.0°	12.2°	11.8°
June	17.2°	12.2°	11.8°
August	19.0°	12.0°	11.8°
October	15.8°	12.0°	11.8°
Pohl Avenue (near Black Onyx Pit):			
December		12.0°	11.8°
April		12.0°	11.8°
June		12.0°	11.8°
August		12.0°	11.8°
October		12.0°	11.8°
Brucker Junction (bottom):			
December		12.0°	
April		12.4°	
June		12.6°	
August		12.2°	
October		12.0°	
Brucker Junction (top):			
December		12.2°	12.0°
April		12.6°	12.4°
June		12.6°	12.4°
August		12.4°	12.2°
October		12.2°	12.0°
Turner Avenue (Grandfather Formation)			
December		12.2°	12.0°
April		12.4°	12.2°
June		12.6°	12.4°
August		12.6°	12.4°
October		12.6°	12.4°
Turner Avenue:			
December		14.0°	
April		14.0°	
June		14.2°	
August		13.8°	
October		14.0°	

Table 4

Diversity in Terrestrial Organisms

Zone/Diversity/Sites	Organisms	No./Trap-day
Dark, constant temp.	Ubiquitous:	
Div. = .442 (.089-1.047)	Hadenoecus subterraneous (cave cricket	1.227
30 sites, 180 trap days	Neaphenops tellkampfi (carbid beetle)	0.744
	Plusiocampa nearctica (dipluran)	0.144
	Regular but spotty:	
	Ptomaphagus hirtus (catopid beetle)	0.155
	Pseudanophyhalmus striatus (carabid beetle)	0.044
	Tomocerus (collembolan)	0.033
	Rare:	
	Onychiurus (collembolan)	0.028
	Anthrobia mammouthi (cave spider)	0.011
	Scoterpes copeii (millipede)	0.011
	Phalangodes (harvestman)	0.011
	entomobryid (collembolan)	0.006
		2.414
Twilight, fluctuating temperature.	Hadenoecus subterraneus (cave cricket)	21.900
Div. = .246 (0 - .612)	Ceuthophilus (cricket)	2.900
3 sites, 20 trap days	Anthrobia mammouthi (cave spider)	0.550
	Meta menardii (spider)	1.100
	phorid (fly)	6.100
	heliomyzid (fly)	1.450
	Quedius (scavenger beetle)	0.600
		34.600
Just outside entrance Div. = 1.432 (1.02-1.63) 4 sites, 16 trap days	12 orders, 28 species (3 species common with twilight; 1 species common with dark	16.500

Cave communities offer special advantages for study of community complexity because factors known to affect complexity in other habitats are held constant. The general advantage of caves is in slight or no seasonal change of temperature, lack of light, and simplicity of the community. The special advantage of the large Flint Ridge System is that communities in very different habitats are available and these have been interconnected for so long that differences in communities can not be the result of genetic isolation.

Community complexity, H, is being rank correlated with 9 factors in 3 catagories to determine which factors are responsible for differences in complexity between habitats. The first category is "diversity of the habitat". This is measured both by relative proportions of wall-ceiling-floor at the trap site and by relative proportions of different substrates in the 100 m^2 census area around the trap. The second category is "physical factors determining rigor of the microclimate". Potential evaporation rate is determined by measuring saturation deficit and estimating air movement. Susceptibility of a site to heavy and unpredictable flooding is measured by past records of Green River flood crests and by sediment profiles. Soil moisture content is measured by direct weighing before and after desiccation at 100°C. The third category is "food". Actual food supply is estimated by burning dried substrate samples at 550° C. to obtain per cent organic content by weight. Predictability of food supply is estimated by predictability of flooding and by spatial relation of the site to areas where bat, cricket, or cave rat activity result in a seasonal import of organic matter.

The 1967 field data are not all analysed but completed analysis of the 1966 data and examination of the 1967 data allow us to draw some general conclusions. The kinds of data which lead to these conclusions are illustrated in tables 4 to 7.

Table 4 summarizes the species of organisms trapped and censused in the area of the Flint Ridge System bounded by the Austin Entrance, Malott Avenue, Union Shafts, Eyeless Fish Trail, Golden Triangle Room, and Columbian Avenue.

The data in Table 4 show that the twilight zone may have unique species and that it has more individuals but a lower diversity than just outside the entrance or in the dark, constant temperature zone. The 1967 data from Cathedral Cave, still to be analysed, should clearly show if the twilight zone is a distinct community.

Several sorts of data bear on the explanation for the negative correlation between food supply and complexity of the community. Table 5 shows that exogenous pollution, resulting from flushing of the Job Corps sewerage lagoons in the summer of 1967, reduced the complexity of the cave community as seen under unpolluted conditions in 1966. It also reduced numbers of organisms trapped per trap day by more than ten-fold. The pollution was indexed by a "high-tide line" of blue green algae like that associated with foam and coliform pollution in Keller Shafts. The two stations compared are near the head waters of Eyeless Fish Trail. There

Table 5.

Organism populations at Polluted and Unpolluted Sites

Site	Organic Content	Community Complexity	Hadenoecus subterraneus	Neaphenops tellkampfi	Plusiocampa nearctica	Pseudan-ophthalmus	Tomocerus sp.
Unpolluted, 1966							
a.	1.23%	0.795	0/36	0/26	0/1	0/3	0/0
b.	1.05%	1.037	0/16	1/15	0/3	0/1	0/2
Polluted, 1967							
a.	3.06	0.000	1/2	0/0	0/0	0/0	0/0
b.	2.44	0.347	1/1	1/1	0/0	0/0	0/0

Numbers are number censused/number trapped at site.

Table 6.

Beetle Movements on Different Substrates

Substrate	Food		Beetles			
	Organic Content	Cricket Egg Laying Index	Free Path cm/min	Movement Rate cm/min.	Numbers per 100 m^2 per 2 min.	Numbers per Trap Day
Wet mud	1.23%	0	188.4	282.7	0	2.50
Mud over siliceous sand	2.50%	1	140.0	185.5	18	0.80
Gypsum sand	----	4	89.6	39.5	33	0.25

are not enough data to tell whether this is a mortality effect or a decrease in mean free path of the organisms and thus a decrease in trappability. However, comparison with areas not trapped in 1966 and with areas trapped in 1966 and not polluted in 1967 shows that these changes are not due to "trapping out" the Eyeless Fish Trail sites in 1966.

Table 6 shows that a cave beetle, *Neaphenops tellkampfi* travels fastest and farthest when in areas of low food supply. The data are consistent with the hypothesis that beetles are most often trapped in areas of low food both because they are "hungry" and because they must have a longer mean free path in order to find the scattered concentrations of food. Ten beetles were followed for 2 minutes on each of three substrates.

A corollary is that beetles will only invade depopulated areas slowly if there is a high food supply. This was shown by a removal census in a small part of a gypsum sand area where *Neaphenops* occurred at a density of about 0.3/m^2. Successive "removals" yielded 27, 8, 3, 1, 0, 0, and 0 beetles (incidentally showing that few hide under rocks). Three days later only four adults were found in the area (three newly hatched beetles were also present).

Another major result is that community complexity is low where intensity and unpredictability of flooding or evaporation rates are high. Data from paired trap sites, 25 meters apart, illustrate this point (table 7.).

It is also clear that there is no correlation between community complexity and diversity of the habitat as measured either by relative proportions of wall-ceiling-floor or by relative kinds of substrate around a trap site.

Table 7.

Comparison of Community Complexity with Microclimate

Site	Microclimate Flooding	Microclimate Evaporation	Food %organic	Complexity H
Union Shaft	2	2	2.45%	.411
Head of EFT	1	1	1.70%	.795
Pohl Avenue	1	3	4.25%	.167
Columbian at Pohl	1	1	4.45%	.807

MACA-N-15. Comparisons of Cave Stream Communities. (Thomas L. Poulson, CRF and Yale University)

Several projects from 1966 were lumped under the present project. These are bioenergetics, the question of whether *Amblyopsis spelaea* is native, changes in faunal populations at base level, and comparisons of stream communities that have differing food supplies. The last item forms the focus of the work currently active. The project has been broadened to answer the general question, "what factors influence diversity and population structures of cave stream communities?" This year data were gathered on organic content of substrates and on plankton. The data for food supply as indexed by organic content are analyses but the plankton samples are not. Three new stream censuses were made and two others were repeated. Furthermore an area was found where *Typhlichthys* and *Amblyopsis spelaea* co-occur. In this area classical competitive exclusion was observed with *Amblyopsis* restricted to the deep food-poor areas and *Typhlichthys* restricted to the shallower areas with rocks and more food.

Next year it will be necessary to get quantitative data on isopods, amphipods, and planarians. At the same time more precise data on habitat heterogeneity will be obtained. Only then will it be possible to give a mathematical definition of community and habitat diversity. Though this study is not completed some general patterns are emerging. The relevent data are detailed in figure 9. First, community diversity is positively correlated with habitat diversity (habitat diversity was indexed by the proportion of stream that was backwater pool, flowing pool, stream and riffle while substrate was categorized into muds, sands, gravel, rock, and bedrock). Second biomass of standing crop as determined by substrate weight loss after ignition at 550°C. is positively correlated with standing crop of food. Also the sizes of the organisms and size at first reproduction are greater where there is more food. The absence of small size classes in the Gravel-Candlelight-Bretz complex could be due to intensity of flooding and to the possibility that this area is a sump fed by a number of streams having reproducing populations in them. This will be explored next year.

Cave Crustacea from West Virginia. (David Culver, CRF and Yale University)

In 1967 approximately eight weeks were spend in Greenbrier County, West Virginia. Two objectives were pursued:

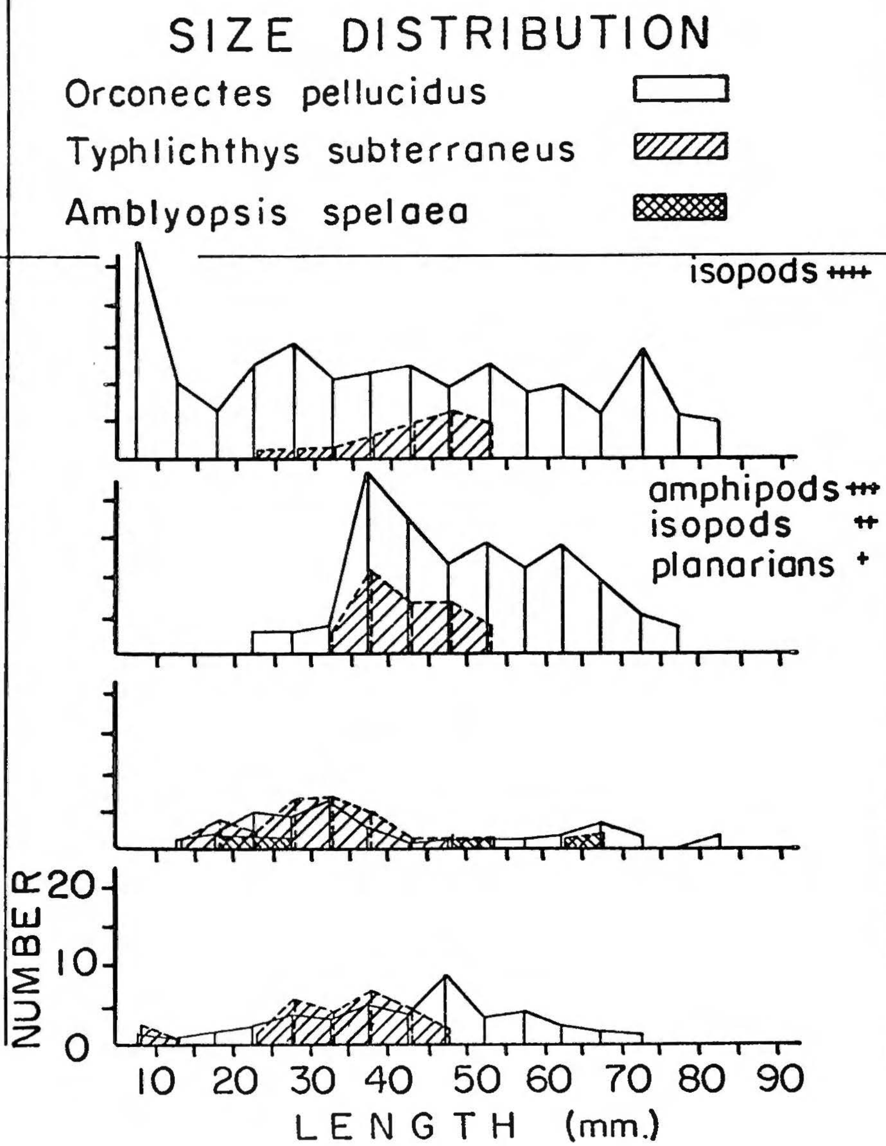
i. Faunal lists for a large number of caves in the area.

ii. Intensive sampling of seven caves on a regular basis.

Table 8 lists the fauna from 25 caves in the area. Almost every possible species combination has been found. The presence of any one species is neither negatively nor positively correlated with the presence of any other species. With the exception of the depauperate fauna in caves that severely flood, there was no correlation of diversity with various environmental parameters.

Figure 9.

A summary of work on aquatic cave communities in Mammoth Cave National Park, Kentucky. The pppulation data are adjusted to equivalent areas of 5000 m^2 so they can be compared directly. The table shows that community diversity is correlated with habitat deversity whereas biomass is determined by food supply.



SITE COMMUNITY COMPLEXITY	FOOD organic content of substrate %	FOOD predictability	FLOODS intensity	HABITAT COMPLEXITY stream substrate
Colossal River 4	2.2-4.2	34	2	5 (4) 3
Gravel-Candlelight-Bretz Rivers 5	1.2-3.5	3.4	3	3 (4) 5
Roman River 3	0.5-1.0	4.5	1	2 (2) 2
Eyeless Fish Trail 2	1.2-1.6	3.4	2	1 (1) 1

Table 8.

Species Combinations in West Virginia Cave Stream Communities

Cave	Stygonectes spinatus	Stygonectes emarginatus	Gammarus minus	Asellus holsingeri	Cambarus spp.
Fox	?	?			
Greenbrier		x	x	x	
Court Street	x	x		x	
Benedict"s	x	?	x	x	x
The Hole	x	x	x	x	
Fuell's Fruit		x		x	
Levisay	x	x		x	
Upper Marthas	x	x			
Lower Marthas			x	x	
Bransford's	?	?			
Bone-Norman	x		x		x
Grapevine	x	x	x		
McClung's			x		x
Ludington's			x		x
Peck's			x		
Coffman			x		x
Higginbothem 1			x		
Fuller			x		x
McLaughlin-Unus					x
Marten's			x		
Blue Springs	x		x	x	
Wade's		x	x		x
No. 219					x
Tub			x		

Closer examination of several cave streams reveals a more complex situation, but one in which more meaningful questions can be asked about the control of community structure and diversity. The following four species are characteristically found on or under gravels in moving water:

1. Gammarus minus
2. Stygonectes emarginatus (Amphipoda)
3. Stygonectes spinatus
4. Cambarus spp.

Only one species, Asellus holsingeri, is characteristically found in gravel bottomed pools. Since caves with good isopod and crayfish fauna have only recently come to be noticed, most of the data are for the amphipod species. Surber sampler data indicate only the following two of the four possible species occur in a small area:

1. Stygonectes spinatus and Stygonectes emarginatus
2. Gammarus minus and Stygonectes spinatus

It is interesting that these two species combinations are those in which there is a considerable size descrepancy in the species involved. Preliminary data suggest that size differences are important in controlling the depth in the gravels at which the species lives, rather than differences in feeding.

In all caves where Gammarus minus is found, it is the most important component of the total biomass. This is surprising since it is the least cave adapted, thus apparently violating the principle of "jack of all trades and master of none". One reason that high densities are possible for G. minus is that it displays less intraspecific agressive behavior than the other amphipod species. Work is continuing on this problem.

THE ARCHEOLOGY PROGRAM

Excavations at the Salts Cave Site. (Joseph R. Caldwell, Illinois State Museum, Robert Hall, Illinois State Museum, Patty Jo Watson, CRF, and Richard Yarnell, Emory University)

Most of the work in 1967 was tidying up various details and preparing a monographic final report. A summary of the new work follows:

Sampling of debris from possible nut caches inside Salts was undertaken by Yarnell. We were especially interested in a big heap of acorns hidden in the breakdown near the Iron Gate because other evidence for utilization of acorns by Salts aborigines is very scant. However, none of the possible caches could be said to be definitely a human rather than a pack-rat accumulation. In other words, it is quite possible (and in most cases, likely) that pack-rats are responsible for the accumulated items rather than human beings.

An extremely well-preserved slipper was found in Upper Salts by John Bridge. It was measured (some 8 inches long) and described but left in the cave.

Observations of Indian debris and traces of mining were made in Upper Salts "Basement" (lower part of the breakdown) and in various parts of Middle Salts. The cultural items scattered about are always of the same types, just as in Upper Salts, and in general our earlier impressions were confirmed; the preColumbians crawled and wiggled into nearly every available opening, passage, or room in the breakdown and in Middle Salts. We did explore one part of Middle Salts (?) where aboriginal debris was nearly absent, however. This is a narrow, twisting, double-totriple-decker canyon passage between the south end of Wilson's Accident and the Iron Gate Room. The passage has just a trace of water in it, a tiny trickle along the floor. It is probably wetter in the Winter.

Identifications of pollen and other items found in eight of the paleo-feces from Salts were obtained from William Benninghoff (Dept. of Botany, University of Michigan). He found pollen of cucurbit (squash/gourd), chenopod, and composit plants as well as wood ash and animal skin.

Some of the mites in the paleofeces were identified by William Bruce (Ohio State University) as Proctolaeps sp. This work will be pursued because many mites are highly specific to certain plants and hence may provide further clues to the ancient vegetation in the area around Salts Cave.

Detailed observations were made of the footprints in mud in the Upper Crouchway of Crystal Cave. There are two sets of prints (bare feet) clearly showing that two people went out the passage, and then returned, walking calmly. One person had a larger foot than the other (10 1/4 inches compared to 9 3/4 inches) and he put more weight on the inside of his foot and big toe. If these prints are indeed aboriginal they presumably represent two explorers who managed to get through the Link from the P-13 end of Indian Avenue to Unknown Cave and the pits at the end of the Upper Crouchway. We found no other signs of aboriginal remains, however, except two tiny pieces of charcoal and one cane torch smudge.

Action Archeology. (Patty Jo Watson, CRF)

Experiments with baking gypsum crystals from Salts shows it readily turns white and becomes dry and crumbly when heated (an oven was used, but this could be done by just throwing the crystals into a campfire). It can then be pulverized. When the resulting powder is mixed with water, plaster or a white pigment (the latter is a very bright white, but flakes off or washes off very easily) can be produced depending on the proportions of water to powder.

Further experimental burning of cane torches outside the cave confirms our earlier estimates of 45 minutes to 1 hour burning time for a standard cane torch (3-5 canes, each 1/2 to 1 inch in diameter and about 3 feet long). Ragweed stalks burn well, though somewhat more erratically than cane and considerably faster (nearly twice as fast according to one trial). Both dry weed torches and dry cane torches burn quite well without the addition of fat or grease.

THE HISTORY AND ECONOMICS PROGRAMS

These programs were inactive during 1967. They were the subject of considerable discussion by the CRF Directors at their annual Board meeting and several new approaches are to be launched in 1968.

THE ADVISORY PROGRAMS

MANAGEMENT PROBLEMS

The Development of the Cave Research Foundation. (P.M. Smith and R.A. Watson)

An article has been written to appear in Studies in Speleology. It describes the gradual evolution of the Cave Research Foundation, its goals, and some of the management, research, and financial problems that have been faced and solved over the decade of the Foundations existance. Much of the material in the introduction to this report is abstracted from the article.

Manpagement Problems in National Parks. (Philip M. Smith)

Investigation of National Park Service management problems continued, and the manuscript for an article on changes in the organizational structure of the Service was completed. The study draws on the experience of industry in systems management, and examines the origins of the Service's present "line" and "staff" management. Publication is expected in 1968.

WILDERNESS AND HUMAN VALUES

Wilderness at Mammoth Cave National Park.

Various members of the Foundation participated in the Symposium on the Application of the Wilderness Act as a means of Preserving the Surface and Underground Features of Mammoth Cave National Park. A statement was read by the President supporting the position of several conservation groups that the Flint Ridge Cave System should be classified as underground wilderness and that other major tracts, particularly those which contain major karst features should be considered for protection.

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

Two book-length documents have been prepared. "The Technology of Equilibrium" by Smith and Watson discusses the problems of conservation and human ecology on a broad scale. "Man and Nature" by Watson and Watson is a treatment of man in relation to the physical environment from his origins to the present day. It is an anthropological essay in human ecology. Arrangements for publication have been made with Harcourt, Brace and World.

PUBLICATIONS IN 1967

PAPERS AT PROFESSIONAL MEETINGS

Society for American Archaeology (Ann Arbor, Mich., May, 1967)

Richard A. Yarnell and Patty Jo Watson, "The Prehistoric Utilization of Salts Cave, Kentucky"

National Speleological Society (Birmingham, Ala., June, 1967)

Alan E. Hill, "Possible Application of Acoustical and Holographic Techniques to Locate and 3-Dimensionally Photograph a Cave from the Surface"

Alan E. Hill, "The Physics of Underground Radio Communication and Practical Tranceiver Design Implications"

Craig S. Peterson and William B. White, "Water-Soluble Minerals in the Cave Sediments of the Central Kentucky Karst"

American Association for the Advancement of Science (New York, Dec.)

David Culver, "Structure of Some West Virginia Cave Stream Communities"

George H. Deike, "Limited Influence of Fractures on Cave Passages in the Central Kentucky Karst"

George H. Deike and William B. White, "Sinuosity of Limestone Solution Conduits"

Thomas L. Poulson, "A Review of Cave Adaptation"

Thomas L. Poulson and David Culver, "Diversity in Aquatic and Terrestrial Cave Communities of Flint Ridge, Mammoth Cave National Park"

TALKS, SEMINARS, AND SYMPOSIA

Thomas L. Poulson: Seminars on the Diversity of Cave Communities at the University of Washington, The University of California at Berkeley, and The University of Rhode Island.

Philip M. Smith: "The Wilderness Review at Mammoth Cave", D.C. Grotto, NSS

Patty Jo Watson: "Salts Cave Archaeology", Mound City Archaeology Society, Clayton, Mo.

Richard A. Watson: "The Preservation of Wilderness Karst in Central Kentucky, U.S.A." at the Symposium on the Application of the Wilderness Act as a means for preserving the surface and underground features of Mammoth Cave National Park, Kentucky, U.S.A.

William B. White: "The Future of Recreational Caving in the Appalachians" at the annual meeting of the Mid-Appalachian Region, N.S.S.

"Research on Limestone Hydrology" at the informal conference on "Methods for Research on Hydrology of Limestone TErrains", Tuscaloosa, Ala. in Sept.

Richard A. Yarnell: "Paleoethnobotanical Aspects of the Salts Cave Archaeological Site" at the Louisiana State University

ABSTRACTS OF 1967 PUBLISHED PAPERS

Three articles were published in 1967. Two were advisory documents. An abstract of the other is reproduced below.

Underground Solution Canyons in the Central Kentucky Karst, U.S.A.

By Richard A. Watson[1])

With 4 figures in the text

SUMMARY

Solution canyons are underground voids 1 to 15 + meters wide, 3 to 45 + meters high, and 30 to 300 + meters long. Floors are stepped, ceilings level. Size increases downstream. Their course is sinuous, with some angularity. They occur parallel to and directly under or slightly offset from the thalwegs of re-entrant valleys tributary to major karst valleys. A section across a re-entrant and underlying solution canyon shows a rough hour-glass shape. Solution canyons are related genetically to solutional vertical shafts, forming where removal of the impermeable sandstone caprock permits the vertical descent of water through jointed limestone. Surface runoff concentrates along re-entrant thalwegs where a large quantity of water goes underground. This water, plus subsurface water flowing over the caprock breached by the valleys, follows the easiest route to baselevel down major vertical joints oriented parallel to the thalwegs. Solution by water seeping down these joint planes forms solution canyons.

MASTER PUBLICATION LIST OF THE CAVE RESEARCH FOUNDATION

December, 1967

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)

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)

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.

<u>Papers Given at Professional Meetings: 1957-1966</u>
(Ref. to published abstract given in parenthesis)

<u>1957</u>

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

<u>1960</u>

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

<u>1961</u>

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

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

5. Roger W. Brucker; Truncated Cave Passages and Terminal Breakdown. NSS, Chatanooga, Tenn. (NSS News <u>19</u> 96 1961)

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

<u>1962</u>

7. Bro. G. Nicholas; Nocturnal Migration of <u>Hadenoecus</u> <u>subterraneus</u>. NSS, Custer, S.D. (NSS Bull. <u>26</u> 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. <u>73</u> 262 1963)

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

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

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

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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)

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

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

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

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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; Archeological 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; Archeological Investigations in Salts Cave, Mammoth Cave National Park, Kentucky. 3rd. Int. Congr. Speleo., Ljubljana, Yugoslavia.

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

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

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

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

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

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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, D.C. (NSS Bull. 29 114 1967)

36. Thomas L. Poulson; Biospeleology: Past, Present, and Future. AAAS, Washington, D.C. (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, D.C. (NSS Bull. 107-109 1967)

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

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

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