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BATS... a symposium

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BATS AS A PUBLIC HEALTH HAZARD — A Symposium presented at the 1979 NSS Convention (Pittsfield, Massachusetts, 6 August).

In 1953, Charles Mohr stated that little had been discovered of Man's role in the demise or survival of bats. Research since that time has demonstrated strong relationships between pesticides and bat mortality, between caving pressure on hibernacula and bat mortality, and between public fear of rabies and political pressure to exterminate bat colonies.

This symposium was especially timely, in view of the release earlier in the summer of the bat horror movie, "Nightwing." Over 300 scientists, cavers, and members of the general public attended. The publication in this issue of *The NSS Bulletin* of several papers related to the symposium expresses the commitment of The National Speleological Society to increasing public appreciation of the uniqueness and benefits of bats and to the husbandry of our remaining bat populations.

The panel discussion which concluded the symposium (see abstracts in *NSS Bulletin* 42:23) posed questions, suggested answers, and staked out positions on bat-related issues. Brochures and other educational materials on bats, and information on cooperating with the Bat Subcommittee of the NSS Conservation Committee, are available from the NSS Office.

Thomas M. Lera
coordinator

Ladd, E.R. (1980)—The Fish and Wildlife Service Bat Program in Southern New England: *NSS Bulletin* 42: 63.

THE FISH AND WILDLIFE SERVICE BAT PROGRAM IN SOUTHERN NEW ENGLAND

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THE FISH AND WILDLIFE SERVICE bat program in southern New England is primarily one of extension service. We try to provide effective and safe information to persons, industries, and agencies that have a need for it. This involves keeping up on new information and techniques, sorting out what seems applicable, and passing the information on to others in the form of recommendations.

Problems encountered vary from a single bat in a home or small colonies in individual buildings to several hundred bats in warehouses and storage buildings. These have resulted in terrified housewives, loss of production in plants, and the tripping of burglar alarms.

We realize that bats and people are not always compatible and that bats in close contact with humans may cause problems. In most cases these problems, because of the emotions involved, cannot be ignored.

Our position is that bat control should be on a non-lethal basis, except where a proven danger to human health exists. We believe that it is better physically to separate the bats naturally than to force an immediate evacuation of the bats. The summer months may be better put to use defining the problem: the colony location, size, and entry points.

When the bats have left naturally, it is possible safely to do an extensive bat-proofing program. If it becomes necessary to use a lethal method to control bats, the method should be selective to the offending bats only. It should avoid scattering bats over a wide area, and it must be non-hazardous to people. No matter what type of control is used, bat-proofing is essential to prevent recurrence of the problem.

1. We need better educational materials for the general public. In addition to current methods of eliminating problems, they should deal with reducing the emotional reaction people have toward bats: *i.e.*, moving to motels, selling houses, sheer panic.
2. We need to improve our ability to determine why bat/building problems exist. What makes a particular building attractive to bats? With this information, perhaps true prevention and control could be undertaken: *i.e.*, remove the cause of attraction, thus removing or preventing the problem.
3. For those situations where immediate action is needed, some means (either mechanical or chemical) should be developed to repel bats from buildings. This would make the use of various live traps more practical, make immediate bat-proofing more practical and safer, and perhaps reduce the need for lethal methods of control.

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Trimarchi, C.V. (1980)—Bat Rabies in the United States: *NSS Bulletin* 42: 64-66.

BAT RABIES IN THE UNITED STATES

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INTRODUCTION

SINCE the first bats were found infected with rabies in the early 1920s, there has been much controversy about the extent to which bats are a public health problem and a reservoir for rabies in other animals. The results of investigations of rabies in bats have been used to support contradictory conclusions — that the problem is greatly exaggerated or does not exist, and that extermination of bats is justified as a means of controlling rabies. I would like to summarize the known facts on bat rabies in the United States as a basis for this afternoon's panel discussion.

INCIDENCE

Bat rabies was first identified in a fruit-eating species in South America in 1921 (Haupt and Rehaag, 1921). During the next decade a paralytic disease of livestock and man in Trinidad, associated with the bites of vampire bats, was identified as rabies (Pawan, 1936). Today rabies in vampire bats continues to be an important economic and public-health problem in Central and South America (Constantine, 1970).

Not until 1953 was the first North American insectivorous bat confirmed rabid. Since that time the disease has been reported from all 48 contiguous United States and all provinces of Canada, except the Maritimes. Some unconfirmed cases have been reported from Europe and Asia but bat rabies appears to be a significant problem only in New World bats (Baer, 1974). In 1977 (the latest year for which national data are available) 43 states reported a total of 637 cases; this was 100 fewer than in 1976 but 17% higher than the annual average for the preceding 5-year period. California reported the most cases (166), followed by Colorado (56), Texas (51), New York (33), and New Jersey (28) (CDC, 1978). Each year 10 to 15 states, generally in the Northwest and along the Eastern Seaboard, report cases exclusively in bats.

The reported number of rabid bats in the United States has risen steadily each year since the early 1950s to a high of 737 in 1976 (Fig. 1) (CDC, 1978). Although this rise in reported cases is often regarded as evidence of an increasing problem, it is more likely due to increased recognition. In New York State, while the number of rabid bats diagnosed each year has risen fairly steadily since the early 1970s, the number of bats examined has risen nearly proportionately (Fig. 2). In fact, the percentage of rabid bats among all bats examined has slowly *decreased* during that period. Constantine's data (1967a) from 1960 to 1965 in California show the same trend.

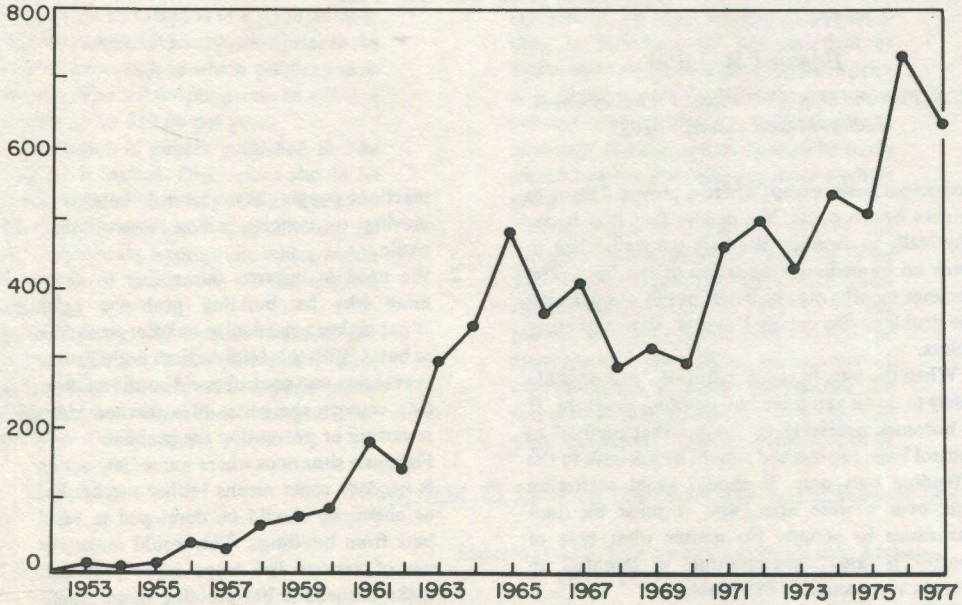

Figure 1. Reported cases of bat rabies in the United States (data prior to 1960 from USDA; subsequent data from PHS, CDC).

The incidence of rabies in bats submitted for examination generally ranges from 3 to 10% (Trimarchi and Debbie, 1979). Most of these bats, however, are submitted for testing because they had been in contact with humans or pets or had been otherwise behaving abnormally. Therefore these values probably overestimate the actual incidence of rabies infection and instead approximate the proportion of rabid bats among all sick (behaviorally abnormal) bats. In contrast, the prevalence of rabies virus in bat populations revealed by random sampling at roosts is generally reported to be a fraction of 1% (Constantine, 1970). This figure is likely to be an underestimate, as rabid bats are frequently behaviorally affected and are commonly active during the day away from their roosts.

Rabies virus has been isolated from virtually all species of North American bats that have been adequately sampled. Migratory species account for roughly 40% of the reported cases. As might be expected from known activity patterns, most cases of rabies in nontropical bats have been reported during the summer (Baer, 1974).

Data from New York State suggest that, among house bats, Big Brown bats are more commonly infected than are Little Brown (Table 1). In collections at selected nursery colonies, 2.9% of Big Brown and 0.3% of Little Brown bats were found to be rabid. In the last 5 years, 5.2% of Big Brown bats and 1.2% of Little Brown bats submitted for examination were rabid.

TRANSMISSION

Rabies is a viral infection of the central nervous system (CNS). The pathogenesis of the disease in bats is generally similar to that in other mammals. The virus, usually transmitted by the bite of a rabid animal through its saliva, remains at the site of exposure for a brief period and then

Table 1. Rabies incidence in upstate New York, 1974-1978. Number rabid/Number examined (%)

Year	Big Brown Bat	Little Brown Bat
1974	12/201 (5.9)	1/99 (1.0)
1975	16/280 (5.8)	2/198 (1.0)
1976	16/335 (4.8)	2/196 (1.0)
1977	16/320 (5.0)	3/237 (1.3)
1978	29/573 (5.1)	5/319 (1.6)
Total	89/1709 (5.2)	13/1049 (1.2)

progresses toward the CNS via nervous-tissue pathways. The period from infection to the first appearance of the clinical signs of rabies is called the incubation period. During this time the animal is not capable of transmitting the disease.

As the virus proliferates in the CNS, signs of rabies appear, including changes in behavior (such as agressiveness) and paralysis (Trimarchi, 1978 and unpublished data). The clinical period generally lasts 3 to 7 days, although in bats it may be longer than in other mammals, reportedly lasting up to 10 days (Bell, Moore, and Raymond, 1969). Concommitant with proliferation in the brain of the infected animal, the virus is disseminated to other organs, including the salivary glands (Debbie, 1974). Although an animal can transmit the disease actively only during the clinical period, the virus remains infectious in the carcass of an animal that died of rabies until decomposition is well advanced (Lewis and Thacker, 1974).

Early reports of bats as asymptomatic carriers of rabies have not been substantiated for insectivorous species (Bell, 1975). In observation and examination of thousands of Big and Little Brown bats, the virus has been demonstrated only in animals that eventually died of the disease, and it has not been found in their salivary glands without also being found in their brains (Baer, 1974).

Aerosol transmission of bat rabies virus has been reported. Two human deaths from rabies occurred in Texas in the early 1960s, apparently the result of exposure to airborne rabies virus in a cave populated by millions of free-tailed bats (Constantine, 1969). Constantine (1967b) has demonstrated that under certain natural conditions this mode of transmission is possible. An outbreak of rabies among laboratory-confined wildlife was caused by an artificially produced aerosol of bat rabies virus (Winkler, Baker, and Hopkins, 1971). Rabies virus has been demonstrated in the respiratory epithelium and urinary tract of naturally infected bats (Trimarchi, 1973). However, the high animal densities and very high infection rates necessary for aerosol transmission are most unlikely to be encountered among North American temperate bats. Overwintering populations of bats in caves are not a significant hazard to spelunkers because any activity of rabies virus in these animals is greatly depressed during hibernation (Sulkin, *et al.*, 1960).

Naturally occurring antirabies antibody has been demonstrated in 5 to 20% of Big and Little Brown bats in colonies where recent rabies virus activity was documented (Trimarchi and Debbie, 1977). A recently developed blood test, the microvolume serum-neutralization test, may allow assessment of rabies virus activity in bat populations with no need to destroy the animals examined (Andrulonis, *et al.*, 1976). Appearance of this antibody may be explained by recovery from rabies, or by exposure to the virus without infection , or possibly by the activity of a related virus which cross-reacts serologically with rabies. Further investigation is necessary to correlate antibody levels with the recent rabies history of a bat population.

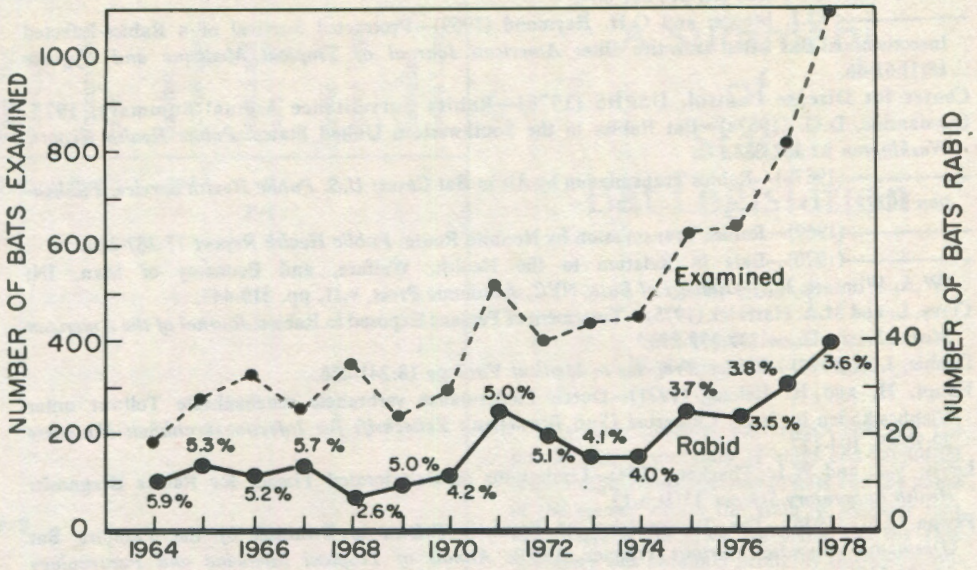

Figure 2. Bat rabies in New York State (excluding NYC). Percentages on solid curves indicate number rabid/number examined. Although numbers of each increase, percent rabid decreases.

HUMAN EXPOSURE

Although most rabid bats are behaviorally affected in some manner, the number of confirmed attacks on humans is actually quite small. Human deaths due to rabies transmitted by bats are also rare (a total of 11 in North America reported to date). The public health significance of bat rabies lies in the large number of persons requiring prophylaxis each year after exposure to potentially rabid bats. Although the development of new vaccines promises some relief, the treatment is still a long and unpleasant experience. It currently includes a single dose of human rabies immune globulin and 23 doses of Duck Embryo Vaccine (DEV). Two doses are administered each day for 7 days, then one dose a day for the next 7 days, and then booster doses 10 and 20 days later.

Preexposure immunization is available for persons with vocations or hobbies resulting in frequent contact with bats or other wildlife. This procedure requires a series of two or three doses of DEV given at weekly or monthly intervals, plus a single booster given at 3 or 6 months (Corey and Hattwick, 1975). The patient's blood should be tested after the initial immunization and periodically thereafter to confirm protection and to determine the need for booster doses.

The hazards associated with bats encountered in their normal habitat are minimal. However, a sick bat or any bat acting abnormally — for instance, flying around during the daytime or encountered on the ground — should be treated as rabid. In the event of a bite, the wound should be promptly washed and medical attention sought immediately. The animal should then be submitted to the local health department for examination.

CONCLUSIONS

The vast majority of bats are not infected with rabies. Their contribution to our environment, even beyond their important role in controlling insect populations, cannot be estimated. They also continue to be important subjects of basic and medical research which has led to significant technological developments. For almost all persons who work with these creatures for any length of time, bats also become esthetically pleasing. It would be very unfortunate if unreasonable fears of rabies led to policies which resulted in attempts to reduce our bat populations.

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Conroy, Carol (1980)—A Summary of State Bat Legislation: *NSS Bulletin* 42: 67.

A Summary of State Bat Legislation

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	Cave Laws	Endangered Species Laws	Hunting Laws	Collection Laws	Dept. Nat. Resources	Conservation Laws	Habitat Access Laws	State Land Laws	Public Health Dept.	Pesticide Board Laws
Alabama		F			P/I	P/I	P			
Alaska			NP/S	I				P/I		
Arizona	P		NP/S	I						
Arkansas		F	P/I	I						
California			P/I	I					L	
Colorado			P/S	I					L	
Connecticut		F								L
Delaware									L	
District of Columbia									L	
Florida		F								
Georgia	P	F								
Guam		A	P/S	S						
Hawaii		St			P/S					
Idaho			NP/I							
Illinois		F				A				L
Indiana		St			P/S					
Iowa		St	NP/I				A			L
Kansas	P									
Kentucky		St								
Louisiana		F	NP/I	I						
Maine		A	P/I	I						L
Maryland	P	F/St			A			P/I		
Massachusetts		F	P/I				P	P		L
Michigan		F		I						L
Minnesota			NP/I							
Mississippi		P		I						
Missouri	A	F		I		P/S	P			
Montana		A					P			
Nebraska			NP/I	I						
Nevada										
New Hampshire		A	NP/I							L
New Jersey		F	P/I						L	
New Mexico		St	A							
New York		F	NP/I						L	L
North Carolina		F	P/I	I		A				L
North Dakota			NP/I							
Ohio		St			P/I					
Oklahoma	P									
Oregon									L	
Pennsylvania		F	NP/I							
Puerto Rico	A									
Rhode Island										
South Carolina		F	NP/I							
South Dakota			P/I	I						
Tennessee	A	F	P/I	I			P			
Utah					P/I					
Vermont		A	NP/I				A			
Virginia		F								
Washington			P/A							
West Virginia	P		P/I	I						
Wisconsin		F								
Wyoming			NP/S							

KEY: P-protected, A-anticipated protection, F-federal endangered species, NP-not protected, I-bats by interpretation, St-state endangered species, L-laws for bats, S-bats mentioned.

This table provides bat researchers and the public with a summary of state and territorial laws or regulations applying to bats and the name of the agency within the state or territory that administers the laws. Information for this summary was obtained primarily through correspondence, begun in 1972 and continuing up to the present, with agencies that administer or are concerned with bat legislation.

While some states have laws specifically mentioning bats, either providing or denying protection, many states have legislation applying to bats only by interpretation. Under such laws, bats may be viewed as non-game wildlife or indigenous state mammals. In some cases, the legislation is so nonspecific that its effect depends entirely on interpretation, which varies depending on the interests of the interpreter. Some state regulations which offer protection for bats appear to be designed in the interest of public health. These regulations view bats as vectors of disease rather than mammals needing protection. Although some states presently do not have any legislation concerning bats, they anticipate developing bat protection legislation following increases in non-game wildlife funding, public interest, or bat research. Some bat species have state protection through endangered species laws, but the same state may offer no protection for other species of bats within the state. Without enforcement or public awareness programs, legislation may not accomplish its goal of protecting bats.

Laws or regulations pertaining to bats may accidently not have been included in the summary table. This may be due to lack of response of state agencies, changes in legislation, misinterpretation by the agency or myself, or accidental deletion. Anyone with additional information or seeking further informatin on specific states is encouraged to write.

I thank Dr. Robert L. Martin (University of Maine at Farmington), who originated this project, for his help and support.

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Kurta, Allen (1980)—Notes on Summer Bat Activity at Michigan Caves: *NSS Bulletin* 42: 68-69

NOTES ON SUMMER BAT ACTIVITY AT MICHIGAN CAVES

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SUMMARY

Bat populations at Michigan caves were surveyed during the summers of 1978 and 1979. **Myotis lucifugus** ***was the most common species at Bear Cave, Berrien County, while*** **Myotis keenii** ***was relatively more abundant at a number of small caves in Mackinac County.*** **Myotis lucifugus** ***and*** **Myotis keenii** ***showed similar temporal patterns of activity at Bear Cave.***

ALTHOUGH VARIOUS AUTHORS have described the geology of Michigan caves and karst (Davies, 1955; Winkler and Van Besien, 1963; Curl, 1978; anon., 1977) there is apparently no report concerning the fauna of these caves. Also, except for short natural history notes, only one field study involving Michigan bats has ever been published (Stones and Fritz, 1969). Because of this lack of information, I decided to visit known Michigan caves during the summers of 1978 and 1979, in order to determine what species of bats were using these caves and for what purpose.

BEAR CAVE

The first study site was Bear Cave, located 5.5 km north of Buchanan, Berrien County, in the southwestern corner of Lower Michigan. Bear Cave consists of approximately 50 m of passage in a Pleistocene tufa deposit (Davies, 1955; Winkler and Van Besien, 1963). The cave is commercialized, with human visitors entering through a small store. The bats, however, apparently utilize a small crevice (0.2 m by 0.6 m) toward the eastern end of the cave.

On 2 nights in September 1978 and 5 nights in September 1979, I monitored the nightly activity of bats at Bear Cave. Mist nets in 1978 and mist nets and a bat trap (Tuttle, 1974) in 1979 were placed in front of the small opening and to either side. Nets were checked at a maximum of 20-minute intervals throughout the night; the trap was emptied at the end of each hour. Time of capture, species, and sex were noted for each animal. In 1979, all bats were punch-marked (Bonaccorso and Smythe, 1972), and most were released immediately after marking.

Out of 356 different bats captured at the cave in 1978 and 1979 (Table 1), 75.0 percent were little brown myotis (*Myotis lucifugus*). Keen's myotis (*Myotis keenii*) made up 24.4 percent of the total, while less than 1 percent, only 2 individuals, were red bats (*Lasiurus borealis*). Males made up 73.5 percent of all Keen's myotis caught and 66.3 percent of the little brown myotis; both red bats were male. Only 15 of 216 little brown myotis and 3 of 54 Keen's myotis that were punch-marked in 1979 were ever recaptured.

The number of *Myotis* captured per hour is shown in Figure 1. Activity peaked within the third hour after sunset and again during the sixth hour. The pronounced dip in activity within the fifth hour after sundown does not seem related to ambient temperature, relative humidity, or precipitation. Fenton (1969) observed a slightly different pattern at an Ontario mine where little brown myotis were captured "at a more or less continuous rate until 2:00 or 3:00 a.m."

This pattern of activity, along with the predominance of males, the low recapture rate, and the abundance of *Myotis* in an area of Michigan where it is a rare summer resident (Kurta, unpublished data), indicates that Bear Cave is a "swarming" site. Swarming, according

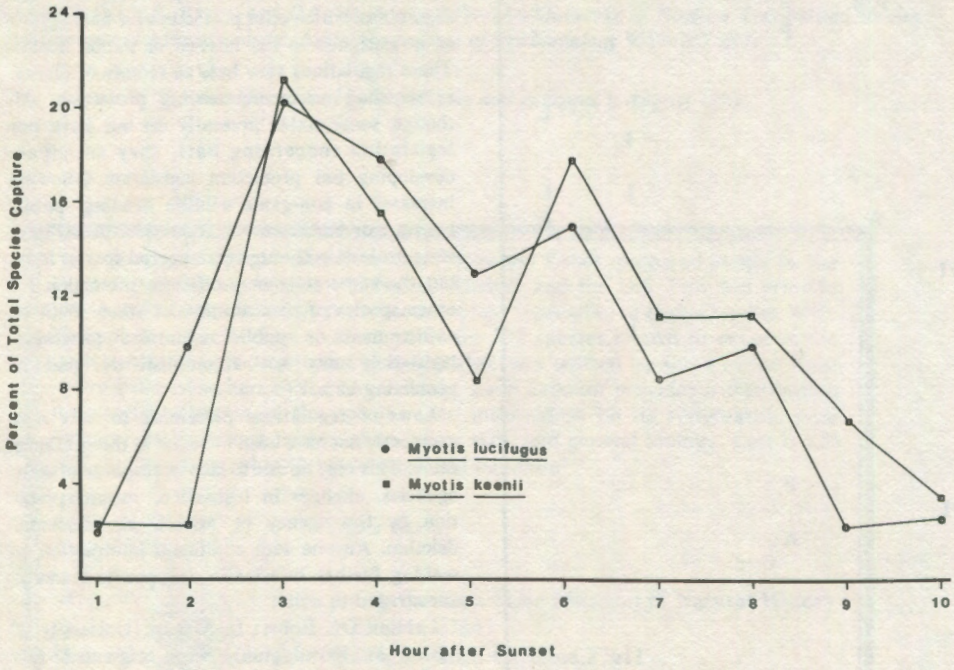

Figure 1. Bat swarming at Bear Cave in 1978 and 1979. Data points represent the percentage of the total species capture obtained within each hour after sundown. *Myotis lucifugus*, N=282. *Myotis keenii*, N=90.

to Fenton (1969), "refers to the flight of bats through hibernacula in the late summer and early fall." This activity brings males and females together for copulation and, possibly, introduces the young to potential hibernation sites (Fenton, 1969). As at other swarming sites (Hall and Brenner, 1968; Fenton, 1969), most bats caught at Bear Cave were probably migrants, moving from summer roosts in Michigan to cave hibernacula in southern Indiana or perhaps Kentucky. That some bats may hibernate at Bear Cave is suggested by a male *M. lucifugus* (Andrews University Museum of Natural History #146) taken there by L.H. Fisk on 10 December 1965.

In addition to monitoring swarming behavior, I made daytime visits to Bear Cave in order to look for roosting bats on 6 June, 12 July, and 7 September 1978 and on 5 September 1979. Only on 7 September 1978 did I detect any bats; 2 *Myotis* were flying in the cave and another bat could be heard inside a small crevice. The owners of the cave, however, stated that from 1 to 3 bats frequently disrupted cave tours throughout the summer. Bear Cave is apparently used as a day roost for a few bats, probably adult males, in early summer and, possibly, by transients of both sexes in late summer and early fall.

MACKINAC COUNTY CAVES

Other than shallow, wave-cut caves along the Great Lakes, Michigan's only limestone caves are formed within the Hendricks Formation of the Burnt Bluff Group, a Middle Silurian deposit (Curl, 1978 and personal communication; anon., 1977). These caves are located near Rexton, Mackinac County, in the eastern Upper Peninsula, about 500 km N of Bear Cave. Quarry Cave and the aptly named Bad Breath and Disgusting caves range in length from 12 m to 40 m and have passage heights generally less than 1 m. Kochab and Hendrie River caves are approximately 250 m and 350 m long respectively. Hendrie River Water Cave has passages that frequently exceed 3 m in height while those of Kochab are generally less than 1 m.

Activity at these caves was also investigated by placing mist nets or a bat trap in front of the entrances. Procedure was similar to that at Bear Cave, except that the nets and the trap were watched for only 5 to 7 hours each night; the trap then was left unattended until dawn. Nets or the trap were placed at 1 to 3 caves each night; each cave was monitored on 1 to 4 nights on 28 July, 25 to 28 August, or 12 September 1979.

Out of 82 bats captured at these caves, 81.7 percent were *M. keenii*, and the rest were *M. lucifugus* (Table 1). Males made up 82.1 percent of the Keen's myotis captured and 86.7 percent of the little brown myotis. Only one individual, a male *M. keenii*, was recaptured.

The most interesting aspect of these caves is the predominance of *M. keenii*. In most swarming studies, Keen's myotis represents only a small percentage of the total catch (Hall and Brenner, 1968; Fenton, 1969; Whitaker and Mumford, 1971). Mills (1971), however, does report a similar preponderance of *M. keenii* swarming at a "small" cave in Adams County, Ohio. Perhaps Keen's myotis is able to use shorter caves with smaller passage volume than can its congener, *M. lucifugus*.

In addition to capturing swarming bats at cave entrances, I also made from 1 to 4 daytime visits to each cave between 2 June and 12 September 1979. The only live bat found was a torpid, adult male *M. lucifugus* discovered on 2 June in Kochab Cave. This individual may have still been in hibernation, since winter torpor in northern Michigan can last into June (Stones and Fritz, 1969). Eight little brown myotis and 1 Keen's myotis, dead and partially decomposed, were also found in Kochab on that date and may be individuals that did not survive the long period of hibernation.

In addition to the bats at Kochab Cave, I did observe a *Myotis* leaving Hendrie River Water Cave near sundown on 27 July 1979. On 26 August 1979, about 25 minutes after sunset, a juvenile female *M. keenii* was found in the bat trap at Hendrie River Water Cave; this bat may have been caught while leaving to forage. As is Bear Cave, some of the caves in Mackinac County are apparently used on occasion as summer day roosts.

ACKNOWLEDGEMENTS

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Table 1. Number of bats captured at Bear Cave in September 1978 and 1979 and at Mackinac County caves in Summer 1979, excluding repeat captures.

Cave	Number of nights netted or trapped	*Myotis lucifugus*	*Myotis keenii*	*Lasiurus borealis*
Bear	7	267	87	2
Quarry	4	4	16	0
Bad Breath	4	4	21	0
Disgusting	3	4	18	0
Hendrie River Water	1	3	12	0
Kochab	1	0	0	0

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NOTES ON THE DETERMINATION OF BAT POPULATIONS USING PHOTOGRAPHIC MEASUREMENTS

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SUMMARY

Bat population counts during the 1960's were based upon visual impressions rather than upon counting individuals and were rather inaccurate. Photographic bat population investigation, then a relatively new technique, is based on periodically counting individual bats revealed in photographs and extrapolating that count by means of a mathematical formula.

INTRODUCTION

BOTH COMMON methods of counting bats in caves are unsatisfactory for measuring large populations such as are found in the American southwest. One method requires the observer to visually observe the entire bat flight from a point outside the cave and to estimate the number of bats seen. A better procedure is to estimate the number of bats roosting within a measured area and then extrapolate this figure to the estimated total roost area; such estimates are often difficult in the large Free-Tailed Bat caves of Texas, because the roosts are usually 20 or more feet above the observer, because the bats are in constant motion (*i.e.*, crawling over one another), and/or because the bats have been observed clinging to one another up to three deep. Several methods of counting bat populations are discussed by Fenton (1970), Hall and Brenner (1968), and Humphrey (1971).

While both traditional methods have their advantages, a third method, photographic counting, may be more accurate. Photographic counting involves taking pictures of a bat flight at intervals during the evening exodus from a cave, counting the number of bats in each photograph, and extrapolating from the photographic time to the total flight time.

PREPARATION

The equipment necessary for a bat-counting project includes a camera and tripod, a long tape measure, two brightly colored poles at least 6 ft long, a stop watch, and another watch with a second-hand.

One day and evening should be spent making preparations and observing the flight; *i.e.*, noting the time the flight commences, whether the bats rise from level flight immediately upon leaving cave entrance, the direction the bats take upon leaving, and their speed. A place for the camera must be found as close as possible to the entrance. No bushes, trees, or hills should obstruct the view or the background, so that pictures can be taken perpendicularly to the line of flight. In addition, it is important not to direct the camera lens toward the setting sun; this may not seem important when the sun is relatively high in the sky, but will prove disastrous later. When the sky becomes too dark for individual bats to be seen, a flash situated beyond the flight (from the camera) and which does not shine directly into the lens will permit continued photography.

Two brightly colored poles must be positioned so that they will appear at each side of every photograph. These poles should be placed as nearly parallel to each other as possible, perpendicular to both the aim of the camera and the direction of the bat flight, and centered on the bat flight. To make estimating easier, the poles should be so spaced that the bats will cover the distance from one to the other in one second (assuming constant flying speed).

Finally, because the last part of the flight will be in total darkness, the observer should learn to recognize flight sound changes, as these announce changes in the number of bats exiting the cave.

TEST DAY

When the actual count day arrives, the equipment should be set up and ready about an hour before the flight starts. As the flight begins, note the initial starting time and the time that the flight reaches full intensity. Note should also be made of the time and duration of any slackening in the flight and of the time the flight ends.

Photography should begin as soon as the flight reaches its peak and continue at regular intervals until the flight ends. The more frequent the photographs, the more accurate (but the more costly) the experiment. I think that 10-minute intervals are optimum.

The photographs should be enlarged and each bat image marked with a red grease pencil as it is counted. Care should be taken to count only those bats occuring between the poles, laterally. Black-and-white photographs are preferable to color.

FRIO CAVE EXPERIMENT

To my knowledge, a full-scale photogrphic count has never been made. However, during the first week of September, 1961, I travelled to Frio Cave, near Uvalde, Texas, accompanied by Ruben Gonzales, to test the feasibility of this method and to see if it would produce plausible results.

Upon arriving, we discovered that I had forgotten to bring a stopwatch, and we were compelled to use the sweep hand on my wrist watch. Our poles were made from the limbs of nearby trees.

Frio Cave has four entrances, the largest of which is 60 ft by 20 ft and faces north (Fig. 1). The other three entrances generally face north-by-west. The bats use the largest entrance for their exit flights, possibly because of a desire to leave in a body.

Immediately beyond the entrance is the entrance room, 225 ft by 80 ft and 20 ft high. The bats gather here before leaving the cave. The main body of the cave is a large room, 300 ft by 300 ft and 40 ft high. The roost is in this room (Reddell, 1961).

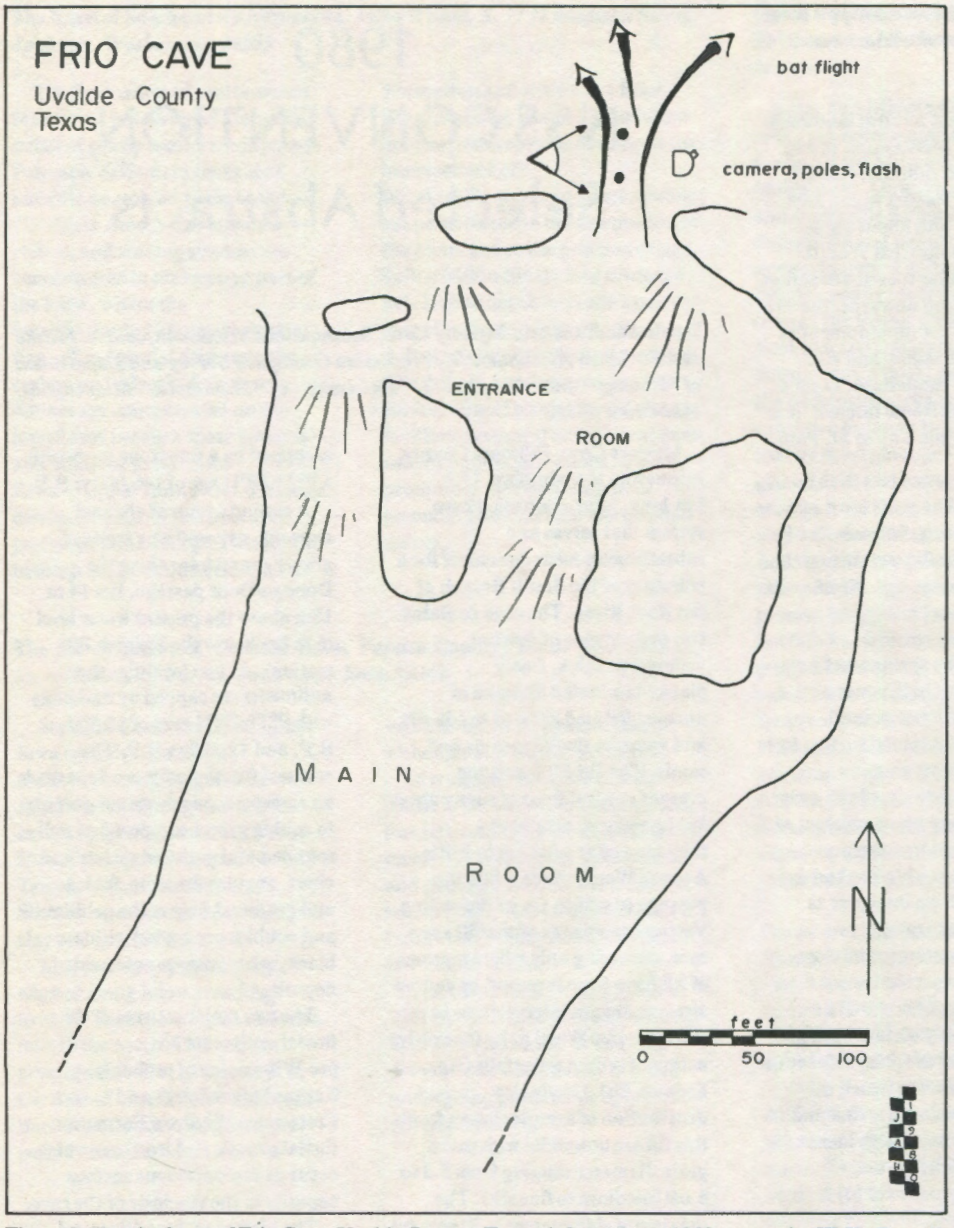

Figure 1. Sketch of part of Frio Cave, Uvalde County, Texas (after a June, 1960 survey by W.H. Russell and others).

On the day of the experiment, the entrance room became filled with flying bats moving counterclockwise. This continued from 6:05 PM until about 6:25, when the flight began. The flight sound reached its greatest intensity within 5 minutes. We recorded the "begin" time as 6:30.

Because my flash was inoperable, we took photographs only during daylight. Two of the four pictures taken were later found not to include the poles.

The average flight speed was 20 ft/sec (4 measurements: 19 ft/sec, 18 ft/sec, 20 ft/sec, and 22 ft/sec). We placed the poles 20 ft apart.

The flight sound continued at the same intensity until 8:00, when it suddenly ceased. We were startled at this interuption of the flight, but could find no reason for it. The flight resumed at 8:15 and continued until 9:15 without change, at which time it ended. The total flight time was 2 hours and 30 minutes.

CONCLUSIONS

The accuracy of the photographic counting method is proportional to the number of photographs taken. We counted 343 and 376 bats, respectively (average:360), in our two useable photographs. Since the flight time was 2½ hours (9000 seconds), the total number of bats leaving the cave was estimated to be 3,240,000 (9000 times 360). Our results contain a very large potential error, being derived from only two photographs. However, I feel that the photographic counting method is feasible and is capable of producing highly accurate information.

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1980 NSS CONVENTION Selected Abstracts

Carver's Cave—An Enduring Landmark on the Upper Mississippi River. *Allan R.* and *Nancy L. Woolworth, Woolworth Research Associates, 3719 Sun Terrace, White Bear Lake, Minnesota 55110*

Carver's Cave has the distinction of being one of the earliest caves to be investigated and described in the United States. The explorer and trader, Jonathan Carver, voyaged to the Upper Mississippi River in the fall of 1766 and made reasonably detailed observations on this natural wonder. His popular *Travels* was first published, in London, in 1778 and has been reprinted in more than 50 editions. Thus, Carver's Cave became well known and was long considered the most prominent natural landmark on the Upper Mississippi. It was visited by most military, literary, and scientific visitors to the area between 1806 and about 1870. Shortly before the Civil War, it became a popular tourist attraction. From about 1869 onwards, the cave suffered from the development of industry in the region and was damaged and vandalized. Long a local topic of extreme interest, it is now owned by the City of St. Paul, Minnesota.

Quantitative Fluorometric Dye Tracing in Fillmore County, Minnesota. *Eric Mohring* and *E. Calvin Alexander, Jr., Minnesota Geological Survey* and *Department of Geology and Geophysics, University of Minnesota, Minneapolis, Minnesota 55455*

Since September, 1979, we have used rhodamine wt in conjunction with a sensitive fluorometer to conduct quantitative tracing tests of underground water flow in the karst of Fillmore County, Minnesota. The procedure involves (1) injecting a known quantity of dye at the point where surface water sinks underground, (2) periodically monitoring the dye concentration in the water at one or more resurgences, and (3) measuring the flow rate at the spring (which, since April, has been done using the fluorometer and dye dilution techniques). The resulting data allow the calculation of underground transit times, Dispersion along underground flow paths, and dye budgets (*i.e.*, the fraction of the injected dye resurging at the springs and how the flow divides in the case of multiple resurgence points).

The results obtained to date have revealed (1) dispersive underground flow, in which water that sinks at one point resurges at 3 separate springs in 2 surface drainages, (2) double-peaked dye pulses -- which we interpret as evidence for separate, independent underground flow paths, (3) unexpected transit time relationships, where the dye arrives at geographically distant springs before it arrives at springs closer to the sink, (4) cases in which the transit times between a sink and its resurgence increase with increasing flow from the spring, and (5) cases in which the opposite of (4) is true.

Wastewater Stabilization Ponds in Karst Regions — A Delicate Balancing Act. *Lawrence J. Landherr, Route 3 Box 63A, Rochester, Minnesota 55901*

A 3-cell wastewater stabilization pond system was constructed in Altura, Minnesota in 1974. The instability of the underlying bedrock was observed during construction and a detailed hydrogeologic investigation of the site was made to assess the potential impacts of construction and operation of this system on the local groundwater. The ponds became operational in 1975. In April, 1976 a major leak developed in the bottom seal of the 11-acre secondary cell when a series of 4 subsidence voids opened, apparently over an underlying fraction zone in the Oneota dolomite. The failure of the pond bottom seal after an extensive site review process demonstrates the need for developing sophisticated predictive hydrogeologic techniques which can more accurately define potential hazard areas in the site evaluation phase of similar construction projects.

Detrital Sediments in Mystery Cave, Southeastern Minnesota. *Jodi A. Milske* and *E. Calvin Alexander, Jr., Minnesota Geological Survey* and *Department of Geology and Geophysics, University of Minnesota, Minneapolis, Minnesota 55455*

Mystery Cave, Fillmore County, Minnesota is a complex, 17.6 km-long, joint-controlled cave system that serves as a subterranean meander cutoff for a tributary of the South Branch of the Root River. The cave contains two major types of detrital sediments: thick, finely planar-laminated deposits of unconsolodated silt and sandy silt, and younger fluvial gravels and sands. The silt fill forms the present natural floor of many upper level passages, attaining a thickness of at least 3m in Fifth Avenue West, where it fills the passage to within 1m of the ceiling. Vertical exposures of the fill are rare, occurring only where sections of fill have been removed by vadose streams at joint intersections (*e.g.*, Fifth Avenue West) or by the erosive action of ceiling waterfalls (*e.g.*, Enigma Pit). Grade size distribution of samples taken from this fill are unimodal with mean grain diameter ranging from 5.3 to 6.6Ø (medium to fine silt). The maximum clay content is 20 percent by weight.

A vertical section exposed at Enigma Pit contains both types of detrital sediments. Here, the finely laminated silt is overlain by 1.7 m of inter-layered gravelly sand lenses and ripple-bedded sandy silt. These sediments appear to be the deposits of a meandering stream that flowed 20 to 22 m above the present average water level in the cave. The coarsest size fraction of the sand lenses is a granule to fine pebble gravel composed primarily of friable white siliceous limestone fragments leached of carbonate, with lesser amounts of quartz, chert limonite, feldspar, and granite. The section is capped by a flowstone layer with a $^{230}Th/^{234}U$ age of 146,000 yr B.P.

A second group of channel deposits, exposed as a series of gravelly sand bars along the Door-to-Door passage, lies 14 to 15m above the present water level (6 to 8m below the Enigma Pit section). At two localities the sediments are capped by flowstone with $^{230}Th/^{234}U$ ages of 12,500 yr B.P. and 12,600 yr B.P. The coarsest fraction of these deposits is an extremely poorly sorted granule to cobble gravel composed of well rounded and polished quartz and chert, angular limonite, feldspar, and granite. Many of the pebbles and cobbles are coated with a black, sooty, manganese oxide deposit.

The two major sources of the fluvial sediments are pre-Wisconsinan (probably Kansan) glacial drift and Cretaceous Windrow Formation fluvial gravels and iron ores which occur as discontinuous surface deposits in the vincinity of the cave.

The history of deposition and erosion of detrital sediments in Mystery Cave has been primarily controlled by the incision of the Root River. The uniformity, thickness, and laterally continuous planar bedding of the massive silt deposits suggest deposition in slow moving water in nearly or completely water-filled passages. The process of valley incision gradually drained the cave and initiated a network of high gradient vadose streams by at least 146,000 yr B.P. Several major channels developed in the upper levels of the cave were later abandoned, perhaps the result of stream piracy by flow paths at lower levels.

The Karst of Southeastern Minnesota. *Mike Wopat, S. 2127 Madison Street, Spokane, Washington 99203*

The fluviokarst of southeastern Minnesota is developed along the strike of gently southwest-dipping Paleozoic carbonate rocks that underlie an upland plain in the "Driftless Area". Caves, blind valleys, and sinking streams are concentrated in the western part of the karst, where the easterly-flowing allogenic streams flow off the glacial drift onto the carbonate bedrock. Solution dolines are concentrated on the interfluves between these streams and adjacent to the Root River—Upper Iowa River drainage divide. The Karst features are preferentially developed within the outcrop of the Ordovician Galena Formation and within the Root River drainage basin. The solution dolines preferentially develop at the intersections of solutionally-enlarged joints. Doline shape is related to the orientation of the joints and to the position of the doline within the surface drainage net. Doline depth depends upon the rate of sediment delivery to the doline relative to sediment removal. The dolines are clustered because surface runoff pirated by a doline facilitates removal of sediment from nearby joint intersections, thereby promoting the development of secondary dolines near the original doline.

The Development of Sowards Cave, Fayette County, Iowa. *M.J. Bounk, Iowa Geological Survey, Iowa City, Iowa 52242*

Sowards Cave, Fayette County, Iowa includes 3 levels of shallow-phreatic origin. The middle level, through which the cave is entered, consists of about 55m of passage developed in the Tete des Morts formation of Silurian age. It ends upstream in a clay and gravel fill.

This passage, normally dry, is aligned along joints trending towards Turkey River, about half a mile to the north. This implies groundwater flow to the north at the time of cave development and, thus, restricts cave origin to the period after Turkey River was established in its present course, although at a higher elevation.

In contrast, the upper level, which is developed in the Blanding formation of Silurian age, displays much less directional development and does not trend toward the north. Thus, this level was formed before the Turkey had established its modern course.

The lower level, which is in the Tete des Morts formation, is an active streamway at or near the present-day watertable. It is still undergoing phreatic or epiphreatic development.

Some Factors Influencing Phreatic Cave Development in the Silurian Strata of Iowa. *M.J. Bounk, Iowa Geological Survey, Iowa City, Iowa 52242*

Initial evidence shows that stratigraphically controlled variations in solubility, primary porosity, and permeability have influenced phreatic cave development in the Silurian strata of Iowa. This is best seen in the *Cyclocrinites* zone of the Hopkinton formation, which contains too large a number of caves to be explained by chance intersections with the watertable. Additional data indicate that the Le Claire facies of the Gower formation is another zone of exceptional cave development, although of lesser importance because of its relatively restricted outcrop area.

In many caves within the Silurian strata, passage morphology is related to jointing and to the local hydraulic gradient. These relationships can be seen at Dancehall Cave, a joint-influenced cave in the *Cyclocrinites* zone in Jackson County. In some instances, joints are not apparent in the caves, but regional joint trends still influence cave development and orientation.

Caves and Karsts of the Late- and Middle-Ordovician Carbonate Rocks of Southeastern Minnesota. *Ronald C. Spong, 1772 Ashland Avenue, St. Paul, Minnesota*

Late- and Middle-Ordovician rocks are represented in southeastern Minnesota by the Maquoketa, Dubuque, Galena, and Platteville formations. These limestones and dolostones include approximately 430 ft of sediments dipping gently southwestward toward the Forest City basin. Post-glacial topography is cuestaform. Fluvial denudation of the carbonate rocks produced extensive uplands truncated on the east by escarpments. Overlain by glacial drift and loess, the uplands emerge from thick soil covers near major drainageways.

Extensive karstification (coeval, relict, fossil, and rejuvenated) is present on upland margins. Surface karst forms are predominantly soil-covered, and subsidence dolines appear frequently where soils are less than 35 ft thick. Collapse dolines are common where soil cover is 10 to 25 ft thick, where subjacent karst has developed beneath sandstone caprock, and where thin- to thick-bedded carbonate rock with interbedded shale overlies limestone, dolostone, or sandstone caverns. Maturely karsted uplands commonly posses sinking streams, but surface drainage capture is more subtly defined by streamsieves in less well-developed karsts. Karst groundwater recharges deeper bedrock aquifers in upland divides and reappears in springs and seeps along upland margins, especially where these expose the Decorah shale.

More than 450 caves and pits have been discovered to date in southeastern Minnesota. Although many speleogenetic processes are represented, corrosion of limestones and dolostones by aggressive groundwaters in the vadose, epiphreatic, and phreatic zones predominates. The majority of the caves and pits are simple in plan and profile, being confined to a single level or rock formation. The more complex cave and pit systems resulted from the integration of underground drainage.

Caves and Karsts of the Prairie du Chien Group, Minnesota. *Ronald C. Spong, 1772 Ashland Avenue, St. Paul, Minnesota*

The prairie du Chien Group is comprised of Lower Ordovician dolostones and sandstones. It is the uppermost indurated rock over about 30 percent of southeastern Minnesota and is present beneath nearly 90 percent of the area. Caves are present where erosion has partially removed mantles of glacial drift and loess. Caves of vadose, epiphreatic, and phreatic origins are present, and retiform, ramiform, and rectiform patterns are observable where cave systems are integrated. The extent of karstification in the Prairie du Chien Group is dependent upon a number of factors, including thickness of soil mantles, local groudwater levels, and stratigraphic and structural controls. Karsted landscapes include paleokarsts, parakarsts, and mantled karsts. Karstification may be shallow or deep. Mantled karsts predominate; subsidence dolines are the most frequently observed surface feature.

Mammoth Cave of Illinois, A Brief History. *Larry Cohen, 3244 No. Lakewood, Chicago, Illinois 60657*

Mammoth Cave of Illinois (aka. Illinois Caverns, Little Mammoth, Burkesville Cave, Egyptian Caverns) near Waterloo, Illinois has operated on and off as Illinois' only commercial cave venture since before the 1904 St. Louis world's Fair. Today, the cave remains in a semi-commercial state under the caretaking of Armin Krueger, a farmer and long-time spelunker in the area. Born in 1914 and raised just a few hundred yards from the cave entrance, Krueger reflects a fascinating 60-year coexistence of man and cave. A detailed exploration and survey of the cave has been in progress since early 1979. The total length of the survey is now 5 miles.

A Preliminary Report on a Low-Altitude Glaciated Karst in Door County, Wisconsin. *Michael J. Barden, 826 Ottawa Trail, Madison, Wisconsin 53711*

Karst landforms in Door County, Wisconsin are developed on gently dipping (1° to 2° SE), thin-to massive-bedded, dolomitic carbonates of the Alexandrian and Niagaran series (Silurian) which crop out between the less resistant units underlying Green Bay and Lake Michigan. The region was strongly affected by the Woodfordian and Greatlakean (Late Wisconsian) glaciations, and calcareous till overlying the bedrock surface has inhibited post-glacial solution. Karst features are controlled by rock structure, commonly major joint planes. Lithologic variations also appear to be important to cave conduit morphology. The influence of glaciation on karst development has resulted in karst landforms which can be considered predominantly glaciokarstic.

Large kluftkarren are present throughout the area. Pavements are developed where over-burden is thin (<1m). Solution dolines, in the form of shafts up to 10m deep, are common features, and collapse dolines occur as "karst windows" above near-surface caves. Speleogenetic development is along bedding planes. Caves commonly exhibit up to 20m of vertical development. Cave passages are dominantly of phreatic orgin, with some vadose modification, and contain significant accumulations of surface-derived clastic sediments and few speleothems.

Karst drainage is well developed along solutionally enlarged joint planes and bedding planes. Infiltration of surface runoff is rapid through ponors and kluftkarren which channel water downward to bedding-plane conduits. Resurgence occurs as numerous semiartesian and gravity springs.

The age of the karst landforms is problematic, owing to a complex regional geomorphic history, however, some features are known to predate the Twocreekan (11,800 yrs BP).

Groundwater Quality in the Karst Region of Southeastern Minnesota. *Michael Osterholm, Rexford Singer,* and *Conrad Straub, Environmental Health Program, School of Public Health, University of Minnesota* and *Acute Disease Epidemology, Minnesota Department of Health, 717 Delaware Street, Minneapolis, Minnesota*

Water quality of 21 wells in the karst area of southeastern Minnesota was studied from February, 1977 to May, 1979. The wells were located within a single township and were chosen for study by type of construction and by aquifer(s) in which they were completed. Eight wells were finished in the Galena Aquifer (surface aquifer), three in the St. Peter, three in both the St. Peter and the Shakopee-Oneota, six in the Shakopee-Oneota, and one in the Jordan. Thirteen routine and 6 runoff samples were collected from each well during the study and were examined for 18 biological, physical, and chemical parameters.

Water quality of wells finished in the Galena was most variable. Total coliform and nitrate nitrogen concentrations exceeded recommended limits for drinking water in 68 and 72 percent of the samples, respectively. Generally, the median routine concentrations of all parameters studied were lower than the median runoff concentrations. There was evidence that the chemical quality of water of the deeper aquifers supposedly protected by a major aquaclude was affected rapidly by surface runoff.

The best indicators of surface water contamination in the aquifers were: bacterial counts (total coliform, fecal coliform, fecal streptococci), nitrate nitrogen, turbidity, conductivity, sulfate, chloride, phosphate, total organic carbon, and sulfate/chloride and nitrate nitrogen/chloride ratios. This study reveals an urgent need to initiate a groundwater monitoring program in southeastern Minnesota to determine short- and long-term trends in water quality.

The Northern Midwest Regional Aquifer-System Analysis Project in Minnesota. *D.G. Woodard* and *J.H. Mossler, U.S. Geological Survey* and *Minnesota Geological Survey, 702 Post Office Bldg., St. Paul, Minnesota 55101*

The U.S. Geological Survey has begun a new series of hydrologic investigations, the Regional Aquifer System Analysis (RASA) program, to provide groundwater information on a regional scale. These regional studies are designed to provide (1) geologic, hydrologic, and geochemical information on ground water flow systems, (2) predictive capabilities for evaluation of alternatives for ground water development, and (3) a perspective of the groundwater system on which local, more specific, investigations can be based.

The Northern Midwest project will evaluate aquifers primarily of Cambrian and Ordovician ages that constitute the major aquifer system in most of Wisconsin and Iowa, northern Illinois, North-western Indiana, southeastern Minnesota, and northern Missouri. The study encompasses about 161,000 mi² and is scheduled for completion in September, 1982.

Aquifers to be investigated in Minnesota include the Mount Simon-Hinckley, Ironton-Galesville, Prairie du Chien-Jordan, St. Peter, Upper Carbonate (Cedar Valley-Maquoketa-Dubuque--Galena), and the drift.

The Minnesota Geological Survey is participating in the investigation by preparing maps showing (1) variations in altitude of the tops of the 5 bedrock aquifers and 4 intervening confining beds, (2) variations in the thicknesses of the bedrock aquifers and confining beds, (3) topography of the bedrock surface, and (4) variations in thickness of the drift. In addition, the State Survey is preparing several geologic sections of the bedrock units and overlying drift in southeastern Minnesota.

The principal source of data used to compile the maps and sections is existing driller's logs of water wells. The State Survey field-checks the location and altitude of each well used to compile the maps and geologic sections. The stratigraphy of the geologic units recorded on the logs is identified, and all pertinent data on well location, altitude, stratigraphy, water level, construction, and depth are entered in System-2000 format for computer storage and retrieval.

Design and Application of an Automated Fluorescence Filter Spectrograph for Underground Water Tracing. *Stephen D. Maegerlein, P.O. Box 60, Williams, Indiana 47470*

An inexpensive fluorescent dye detector has been designed for recording both time and dye concentration as well as differentiating between dyes used for ground water tracing. The automated fluorescence filter spectrograph (AFFS) is a waterproofed, battery-powered, automated time-lapse movie camera controlled by a series of timing circuits which also synchronize other unit components. The unit includes a water sediment precipitator and filter, centrifugal water pump, Pyrex flow cell, electronic flash with ultraviolet primary band pass filter, optically coupled light emitting diode time display mounted in the spectrograph slit, and secondary light filters in front of the film frame for distinguishing between dyes. A filtered water sample is analyzed every ten minutes by recording the blue, green and orange fluorescences plus the time on high speed black and white movie film. The film is sensitive to the fluorescence of a few parts per billion of dye. Stand solutions of fluorescent dye are analyzed by the AFFS to calibrate the film before placing the unit in the resurgence. The AFFS will operate underwater for seven days on a fully charged battery pack and measure the fluorescence of over 1000 water samples. A microphotometer is used to measure film percent transmission after the film is developed. Calibration curves are prepared for determination of fluorescent dye concentrations.

Photogeologic Technique for Monitoring and Predicting Sinkhole Collapse. *Ramesh Venkatakrishnan, 231 W. Lauder, Apt. A-11, Moscow, Idaho 83843*

Air-photograph characteristics of surface-karst landforms are helpful in detecting and monitoring potential land-failure sites in the karst regions of southeastern Minnesota. The land area occupied by sinkholes near the town of Fountain in Fillmore County ranges from 10 percent to 50 percent in a mi^2; sinkhole density here ranges from 60 or 70 per km^2 to almost 300.

Time-sequential black-and-white aerial photophaphs (scale: 1:20,000) are analyzed and areas containing sinkholes, sinking streams, and other indicators of potential land failure are annotated. Changes over time in the size, number, and shape of such areas and of individual features within them are determined.

Areas of thin to very thin regolith, outcrop areas of carbonate bedrock, photo-lineaments related to joints in the bedrock, and areas of intensive land use are associated with piping and other karst-related land failures.

Locating Solution Conduits with the Tri-Potential Method of Resistivity. *Albert E. Ogden, Department of Geology, University of Arkansas, Fayetteville, Arkansas 72701* and ***Paul S. Eddy, Jr.,*** *Exploration Section, Gulf Oil Company, New Orleans, Louisiana*

Tri-potential resistivity surveys were conducted over caves and fractures within the Mississippian Boone-St. Joe limestone aquifer of northern Arkansas. The following relationships were found between the investigated caves and the different arrays:

Water-filled caves: The response in the arrays varies according to the depth to the top of the cave, the radius of the cave, and the a-spacing change. In general, the apparent resistivity decreases for the cppc and cpcp configurations and increases for the ccpp configurations. At shallow depths, the three peaks form; the center and lowest peaks (highest in the ccpp configuration) are located all over the cave. At greater depths, it becomes impossible to differentiate between a water-filled fracture and a water-filled cave.

Air-filled Caves: The responses in the different arrays will vary with the depth to the cave, the cave radius, and any a-spacing changes. As the traverse crosses an air-filled cave, the apparent resistivity for all three configurations increases.

Hydrographic Analysis of Karst Stream Capture in Sinking Valley, Kentucky. *Percy H. Dougherty, Department of Geography, University of Cincinnati, Cincinnati, Ohio 45221*

The subterranean drainage patterns of Sinking Valley, Kentucky have been identified by fluorescein tracing and by mapping. Field inspection has revealed 3 surface drainage basins which are not identifiable on topographic maps; these are older than modern Sinking Valley surface streams and orthogonal to them.

Sinking Valley is located in south-central Kentucky, on the western edge of the Cumberland Plateau where Buck Creek has become entrenched in Upper Mississippian and Lower Pennsylvanian sediments dipping 5 to 8 m/km to the southeast. The hilltops consist of basal Pennsylvanian clastics ranging from cross-bedded conglomerates to siltstones, shales, and coal. The lowlands, composed of Newman and Borden limestones, are marked by numerous dolines and solution valleys, of which Sinking Valley is a good example.

Modern Sinking Valley drains from north to south. It is roughly 13 km long by 7 km wide and is 88 km^2 in area. Subterranean drainage patterns are structurally controlled. Trend surface reconstruction shows the paleo-drainage to have consisted of consequent streams that flowed southwestward before the development of the present Cumberland Plateau escarpment.

Water Tracing in Karst Areas with Dissolved Uranium Isotopes. *J.K. Osmond, Department of Geology, Florida State University, Tallahassee, Florida 32306*

In contrast to the situation in rocks and minerals, where each of the members of a radioactivity series has the same level of radioactivity (equilibrium), extreme disequilibrium is observed in many aqueous environments. Differential solubility is not the complete explanation, inasmuch as the two isotopes of uramium, ^{234}U and ^{238}U, also exhibit disequilibrium; in ground waters, the activity ratio (AR) of $^{234}U/^{238}U$ is usually high. Apparently, mobilization of the daughter ^{234}U is promoted by the alpha decay process, probably by nuclide recoil during alpha emission. Low AR's are often observed in karst regions, especially in waters of high concentration (1* ppb). This may by the result of sudden (geologically speaking) solution of previously immobile uranium. In any case, the great natural variation in dissolved uranium concentration and AR from one local aquifer to another provides a valuable natural tracer for water migrations. For example, the mixing proportions from various sources can be calculated for several large karst springs.

Alpha Radiation in Caves. *Richard Lively, Minnesota Geological Survey, 1633 Eustis Street, St. Paul, Minnesota 55108* and ***Tom Aley,*** *Ozark Underground Laboratory, Protem, Missouri 65733*

Articles about radiation in caves due to radioactive decay of radon and its daughter products have been published in *The NSS News, The NSS Bulletin,* and elsewhere since about 1976. These articles have provided evidence that many caves have ambient radon levels which reach or exceed the present standard in the mining industry of 0.3 working levels. As alpha radiation in mines have been correlated with an increased likelihood of lung cancer, the radiation found in caves has caused concern about the potential hazards of alpha radiation, resulting from the decay of radon and its daughter products, to cave exployees and the visiting public. This concern has led to the development of monitoring programs at some National Park Service caves and to guidelines and regulations which would limit radiation exposure. As of 1978, National Caves Association members have adopted and ratified a set of precautionary standards for employees and the general public. The NPS has developed a large set of draft guidelines concerning radiation exposure and the study of radiation in caves, but has not yet formally implemented them.

Differences exist between NCA and NPS concerning the degree of regulation and the protection measures called for in the standards and guidelines. These differences in part result from the NPS viewing radiation in caves in the same light as radiation in uranium mines, while the NCA sees cave radiation and uranium mine radiation as separate and distinct issues, which should not be subject to the same type of regulation. These differences could become very important in terms of limiting cave access if rules are adopted and enforced which treat cave radiation exposure in a similar manner to uranium mine radiation exposure.

Why is there a Ballad for Floyd Collins but none for Lindsay B. Hicks? *Richard L. Breisch, 110A Dibb, China Lake, California 93555*

It was 3 days before rescuers found the man who had been trapped underground. It was not hard to get food to him, but extracting him presented difficult problems. The initial estimate of 4 days to perform the rescue was overly optimistic. Newspaper coverage made the incident a national event, and promoters would later set up tours to exploit the public's interest in the rescue. Fifteen and one-half days after being trapped, Lindsey B. Hicks was rescued from a tunnel near Bakersfield, California. This incident is very similar to the entrapment of Floyd Collins which would occur 18 years later.

Mineralogy of Rohrer's Cave, Lancaster County, Pennsylvania. *William B. White* and *Barry E. Scheetz, Materials Research Laboratory, The Pennsylvania State University, University Park, Pennsylvania 16802* and *Dale Ibberson, 445 Hale Avenue, Harrisburg, Pennsylvania 17104*

Rohrer's Cave, developed along the contact between the Cambrian Vintage dolomite and Kinzers shaley limestone, was opened by a sinkhole collapse in 1979. The cave's 900+ft of passages are floored with a recent mud overlying an intricately layered sequence of white, yellow, brown, and black sediments. In place of the usual calcite speleothems, there occurs a bizarre collection of white and black soft mushy coatings and hanging forms much resembling pinecones. There are also stalactites and stalagmites of red flakey material. A boxwork-like form occurs, as do small patches of blue-green coating.

The white, black, and red speleothems do not diffract X-rays, which indicates that they are not crystalline. Whether or not they can be called minerals is a point of semantics. The speleothems were investigated by infrared spectroscopy and with a scanning electron microscope with energy dispersive X-ray attachment for chemical analysis.

The red stalactites and stalagmites are relatively pure iron oxide hydrates. There is no evidence for other heavy metals. Their near-infrared reflectance spectra are similar to the spectra of goethite, although the cave deposits do not exhibit the goethite X-ray diffraction pattern. The black coatings consist of manganese oxides with exceptional concentrations (about 20 wt%) of other heavy metals: nickel, cobalt, copper, and zinc in various but approximately equal proportions. The white opalline or moonmilk-like coatings consist, at least in part, of non-crystalline aluminum phosphates and hydrated silicates. The silicate material is rather pure and might be described as a silica gel. A more rare blue-green material found in a few patches in the cave is hydrated silicate material containing a few percent copper.

Diamond Craters, Oregon, A Proposed Outstanding Natural Resource Area. *Ellen M. Benedict, Biology Department, Pacific University, Forest Grove, Oregon*

Called "a museum of basaltic volcanic features" by Bend, Oregon volcanologist Bruce Nolf, this six-mile diameter shield volcanic area was recommended on 21 November, 1979, by the Natural Area Preserves Advisory Committee of the Oregon State Land Board to be designated as an Outstanding Natural Area. This relatively small area contains an unusual diversity of volcanic features: a graben, a maar, large and small craters of diverse volcanic origin, vents, spatter cones and driplet spires, cinder cones and cored bombs, pressure ridges and toes of flows, pahoehoe and aa surfaces, tiny surface tubes and lava caves with walking passage and interesting linings, as well as 50-ft deep earth cracks with permanent ice. Although the area was known to cavers as early as 1961, the "first recorded speleological investigation" occurred in 1973 when Patty Silver and Ellen Benedict explored North and South Lava Pit caves. Surprise Cave was "discovered" in 1974 and Stu's Cave was mapped in 1976. In cooperation with the Burns District of BLM, cavers of the Oregon Grotto have conducted extensive field studies during 1979, resulting in the mapping of Spatter Cone Cave, and the discovery of Bacon, Block, Creep, Juniper, Littlefield, and Harter caves, and Wingo Cave System, and the 50-ft deep Earth Crack Ice Caves. Although none of these caves are large, they are especially significant in the light which they shed on lava cave speleogenesis. To quote Russ Harter, "Diamond Crater is speleologically significant because it has caves, and caves are a geological anomaly!" Large portions of the Craters still remain unexplored for caves.

Crystal Morphology and Crystal Growth of Gypsum Speleothems in Caves. *William B. White* and *Barry E. Scheetz, Materials Research Laboratory, The Pennsylvania State University, University Park, Pennsylvania 16802*

Gypsum, $CaSO_4 \cdot 2H_2O$, is deposited in dry caves by precipitation from microscopically thin moisture films saturated with calcium sulfate. Only rarely is gypsum observed crystallizing from dripping, flowing, or ponded water. Gypsum appears as crusts, curved "flowers," needles, and long fibers. Examples of these well-known macroscopic forms have been examined by polarized light microscopy and by scanning electron microscopy. Gypsum needles are either single fish-tail twins or are multiply twinned. The re-entrant at the end of the needle provides a continuous growth site, eliminating the need for a two-dimensional nucleation step. Gypsum flowers are polycrystalline, and their curved petals are formed by more rapid growth near the center of the flower. Gypsum fibers are single crystals, elongate along the fast (001) growth direction.

Cave-in-Rock Cave, Hardin County, Illinois: Paleo-Spring or Floodwater Spur? *Ernst H. Kastning, Department of Geosciences, Murray State Univeristy, Murray, Kentucky 42071*

Cave-in-Rock Cave is a solution cave that opens onto a 10m-high bluff on the north shore of Ohio River in Cave-in-Rock State Park, Hardin County, Illinois. The cave lies within the upper member of the St. Louis limestone and consists of a linear passage 50m in length, 12m in width, and 3 to 4m in height. At the rear of the cave are a parallel but shorter passage branching to the northeast and an enlarged joint opening to the surface, forming a 15m shaft entrance. Passages are oriented parallel to bedrock strike in rocks that locally dip 1.3° northeast. Excavation occurred along a prominent set of joints, oriented N42° W, that are numerous and closely spaced in strata in the basal part of the passage section but diminish in frequency and extent in overlying strata.

Previous interpretations have suggested that (1) the cave is a remnant of a once much longer master conduit within the phreatic zone that drained a large area of dolines north of the Ohio, and (2) the continuation of the passage at the rear of the cave exists as an hydraulic lift-tube, presently occluded by sediments. On the contrary, passage morphology, internal solution features, and position of the cave within the flood zone of the Ohio indicate that enlargement may be largely due to backflooding by river water. Evidence for this includes (1) concordance of passages with bedding planes and preferential enlargement along strata containing relatively little chert, (2) abrupt horizontal termination of the cave in bedrock, (3) numerous joint spurs, (4) enlargement of passage cross section at the rear of the cave, and (5) an entrenched channel in the bedrock floor that is at grade with Ohio River, suggesting some excavating by return flow.

Preliminary Report on Biota of Harlansburg Cave, Pennsylvania. *J. Philip Fawley, Westminster College, New Wilmington, Pennsylvania 16142*

Harlansburg Cave, Pennsylvania was accidently opened with the construction of a road cut during the summer of 1950. Prior to this time, the cave apparently was filled to a considerable depth with water, and few if any dry entrances existed. The cave consists of approximately 3.5 km of maze passages in an area of 200 m^2.

Numerous bacteria, fungi, and protozoa have been preliminarily classified. All appear to be typical ground water varieties or types easily introduced by explorers.

A few hundred bats inhabit the cave. Most are found in the northwest quadrant of the cave's southern section. Scattered individuals can be found in other areas.

Numerous 'coon tracks and droppings have been observed in the cave. Several species of salamanders have been collected.

Glacial Origins of the Bahamian Karst. *Dennis Williams, Box F931, Freeport, Bahamas.*

The geological history of the string of shallow-water carbonate banks that stretches southeast from Florida 1400 km to the island of Hispanola is tied to the repeated changes in sea level that resulted from the alternate storage and release of great quantities of water in glacial ice. The northwestern Bahamas consist of two large, flat-topped banks (Great Bahama Bank and Little Bahama Bank) that were flooded near the end of the melting cycle of the most recent glacial period. The present-day Bahama Islands are the exposed margins of these banks. They represent less than ten percent of the total area of the banks.

In islands of adequate size, and in the entire bank when a lowered sea level permits it, a fresh-water lens forms by displacing sea water that has entered the aquifer laterally. Rain is the source for this fresh water, and a distinct halocline is maintained by density and temperature gradients. This fresh water lens has been responsible for extensive solutional activity within the Bahama Banks. Over the last million years, this lens repeatedly oscillated vertically over a range exceeding 100m as it rode the gross changes of sea level due to glaciation, producing a karst of remarkable complexity.

Lucayan Caverns. *Dennis Williams, Box F931, Freeport, Bahamas.*

Divers have explored a submerged cave on Grand Bahama Island for over 6 km. Nine surface openings have been found, but the fact that they are clustered within radius of 300m has necessitated swims of over 700m horizontally from air to reach the presently known limits of the cave. In this system, the primary limitation to exploration is air supply, with all air being carried by the diver. There are no air bells or dry chambers.

A typical exploration dive consists of a 50-min swim into an area where virgin cave is suspected to exist, 10 to 15 min of exploration and surveying, a 50-min swim out, and 20 to 40 min of decompression before resurfacing. Exploration is also complicated by the quantity of speleothems in the system; many passages contain sufficient numbers of stalagmites to require slow, careful swimming.

Karst and Caves in the Gunong Mulu National Park, Sarawak, East Malaysia. *Michael J. Day, Department of Geography, University of Wisconsin-Milwaukee, Milwaukee, Wisconsin*

Much of the surface limestone of the Gunong Mulu National Park is deeply fissured, highly irregular, or traversed by steep ridges of extreme sharpness. Elsewhere, large, steep-sided enclosed depressions pit the surface; one such depression, named Sendirian, has a vertical entrance drop of 150m. The deeply etched nature of the surface is climaxed by the development of the Pinnacles —spectacular spires rise up to 35m through the forest-covered slopes of Gunong Api and Gunong Benarat. Limestone towers protrude through the alluvial lowlands, and incised gorges traverse the limestone massif.

Outstanding among the caves of Mulu are Deer Cave (Gua Payau) and Clearwater Cave (Gua Terangair). Deer Cave is basically a single passage about 1 km in length, but it is nowhere less than 100m high and wide. At its downstream end, the passage is 190m wide and nearly 140m high. The roof contains 35m-diameter avens in its upstream half.

Clearwater Cave is perhaps the most important yet discovered in the Park area. Over 25 km of passages have been explored.

Age and Paleoclimate Studies of Speleothems from Vancouver Island Caves. *Mel Gascoyne, Department of Geology, McMaster University, Hamilton, Ontario L8S 4M1, Canada*

Four fossil flowstones collected from Cascade Cave, Pt. Alberni have been dated by the $^{230}Th/^{234}U$ method. Seventeen age determinations show that the deposits grew during the Mid-Wisconsinan interstadial, approximately 70,000 to 30,000 years ago. No older deposits were found. Two of these flowstones were deposited in isotopic equilibrium with their seepage waters (determined by analysis for ^{13}C and ^{18}O along growth layers) and their overlapping axial profiles of changes in ^{18}O content can be interpreted in terms of a paleotemperature record for this period. Results show that mild conditions existed from 65,000 to 55,000 years ago and that temperatures steadily decreased to about 0°C by 35,000 years ago. Speleothem growth ceased shortly afterwards. Good agreement is found with local Quaternary stratigraphic sequences which have been dated by ^{14}C, showing onset of full-glacial conditions about 25,000 years ago.

Sex Differences in Caving Styles, Motivations, and Personality. *Carol Vesely and Dave Bunnell, 745 Camino Del Sur, Apt. 5, Goleta, California 93117*

A survey questionnaire was distributed to all persons attending the 1979 NSS convention. Nearly a 50% return (n=273) was obtained, with males comprising 70% (n=191) and females 30% (n=82). The questionnaire was designed to assess five major areas: (1) demographic/biographic background; (2) involvement in caving activities (*e.g.*, frequency, type, and length of trips, and other spelean pursuits; (3) importance of caving to the individual; (4) motivations for caving; and (5) relevant personality factors as assessed by Zuckerman's Sensation Seeking Scale (SSS) and measures of Activity and Sociability Temperments.

Women had gone on significantly fewer trips, to fewer different caves, and in fewer different states than men. Women reported a higher preference for horizontal and survey trips, while men preferred vertical, photographic, biological, and exploration trips to a greater extent than did women. Caving was significantly less important in the lives of the women than of the men. Males and females also differed in their reasons for caving: "beauty of the cave environment" was a more important reason for caving amongst women, whereas "personal glory" and "exploring the unknown" were more important reasons for men than for women. The majority of these results remained significant even when part correlations were performed to control for such sex differences as number of years in caving and importance of caving. Women were also more likely to be married, and their spouses were more likely to be cavers. Cavers married to non-caving spouses tended to be older than those married to another caver. While there was no difference in the number of trips they took, those people with non-caving spouses went on significantly more sport trips than did those woth caving spouses, who went on a greater percentage of survey trips.

Exploration of the Organ Cave System, West Virginia. *Paul Stevens, 5964 Seabright road, Springfield, Virginia 22152*

The Organ Cave System is located in southern Greenbrier County, West Virginia. While accounts of the cave date back to the late 1700's, exploration by modern cavers did not begin until 1948. Much of the initial modern exploration was conducted by members of the Charleston Grotto and of the West Virginia Association for Cave Studies. Since 1970, exploration and mapping of the cave system has been conducted primarily by members of the District of Columbia Grotto. Over 36 Miles of cave passage have been mapped.

Munson, P.J.; P.W. Parmalee; and J.E. Guilday (1980)—Additonal comments on the Pleistocene Mammalian Fauna of Harrodsburg Crevice, Monroe County, Indiana: *NSS BULLETIN 42*: 78-79.

ADDITIONAL COMMENTS on the PLEISTOCENE MAMMALIAN FAUNA OF HARRODSBURG CREVICE MONROE COUNTY, INDIANA

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SUMMARY

The Pleistocene faunal samples reported by Parmalee, et al. *(1978) and by Volz (1977) were both recovered from Harrodsburg Crevice and are probably Sangamonian in age. Two additional small samples of teeth and bones from this deposit have subsequently come to our attention and are herein described; measurements of the* Canis *cf.* dirus *and* Smilodon fatalis *teeth are presented.*

IN OUR INITIAL STUDY (Parmalee, *et al.*, 1978), we noted that "persons unknown" had removed approximately 10 cubic feet of bone-bearing deposits from Harrodsburg Crevice sometime after October 1974. This individual was Steven A. Volz; through a series of unfortunate coincidences his identity to us (and ours to him) was not discovered until the nearly simultaneous publication of his paper that dealt with the identification of materials he had recovered (Volz, 1977) and ours. One purpose of this note is to point out that, although the faunal samples were different, both publications refer to the same cave site. Other reasons for this note are to provide supplemental descriptions (measurements) of the large feline and dire wolf remains recovered by Volz, to record two small collections that were removed from the deposit prior to September 1974 which only recently have come to our attention, and to comment further on the nature of deposition and the dating of the site.

SABERTOOTH CAT

When we prepared our initial paper on Harrodsburg Crevice, only a lower jaw fragment of a juvenile sabertooth cat containing the deciduous M_4 was known to us. It was identified as *Smilodon* cf *floridanus* (Leidy) because dental measurements fell within the range of specimens of this species from Rancho La Brea (Merriam and Stock, 1932). Six isolated teeth recovered by Volz (1 left, 1 right P^4; 1 left, 1 right P^3; 2 incisors), all possibly from one individual, now allow us to assess the size characteristics of an adult animal. Measurements of the length of the P^4, when compared to other *Smilodon* material (Table 1), fall below the range of those for *S. fatalis.**

Length and width of the Harrodsburg premolars are presented in Table 2. Volz (1977) identified these speciments as *S. fatalis,* and we concur. In light of this, we will now suggest that the juvenile speciment that we previously identified as *S.* cf. *floridanus* is also probably *S. fatalis.*

The geological range of *S. fatalis* embrances Illinoian through early Wisconsinan times (Slaughter, 1963; Kurten, 1965), the species being succeeded by the larger *S. floridanus* (=*S. californicus* Bovard) in mid-to-late Wisconsinan times (Webb, 1974). Although it is hazardous to attempt a specific identification on the basis of such a meager sample, the small size of the P^4, as well as the association of a large *Platygonus* (larger than the typical Wisconsinan *P. compressus*), suggests that the deposit is pre-Wisconsinan in age.

*Merriam and Stock (1932, Table 6) also list a measurement of "a 33.4 mm." for *S. floridanus.* As suggested by the prefix "a," the measurement was an approximation, possibly from a broken specimen. They list no catalogue number, and the specimen is here discounted.

ADDITIONAL COLLECTIONS

In the spring of 1974 Greg A. Corwin, then a student at Purdue University, removed a small sample of teeth from the Harrodsburg Crevice deposit. Mr. Corwin donated this collection to the George C. Page Museum (Rancho La Brea), Los Angeles, where it was ultimately brought to our attention. During the summer of 1974 Thomas P.

Table 1. Measurements (mm) of length of P^4, various *Smilodon*.

Taxon	Site and Catalogue Number	$\bar{X}$	O.R.	N
S. fatalis (Leidy)—Type*	Hardin Co., Texas AMNH 10395	33.5.		1
S. fatalis (Leidy)	Harrodsburg Crevice	35.2	35.1-35.3	2
S. floridanus (Leidy)**	Rancho La Brea, California	40.5	37.5-46.0	22
S. cf *floridanus* (Leidy)***	First American Bank, Nashville, Tennessee (field no. 74)	40.3		1

*Kurten, 1965; **Merriam and Stock, 1932; ***Guilday, 1977

Table 2. Tooth measurements (mm) of *Smilodon fatalis* from Harrodsburg Crevice.

Tooth	Length	Width	Catalogue no.
P^3, right	15.2	8.0	IUPC 14627-55
P^3, left	15.2	8.1	" 14627-54
P^4, right	35.1	15.7	" 14627-51
P^4, left	35.3	15.7	" 14627-50

Table 3. Tooth measurements (mm) of *Canis* cf. *dirus* from Harrodsburg Crevice: specimens from the Volz, Corwin, and Basa collections.

Measurement	N	O.R.	$\bar{X}$
P^1, length	1	7.0	—
P^1, width	1	5.5	—
P^4, length	1	31.2	—
P^4, width	1	14.5	—
M^1, length	2	17.9-19.1	18.5
M^1, width	2	22.3-24.4	23.35
M^2, length	2	10.5-10.7	10.6
M^2, width	2	16.0-17.0	16.5
P_1, length	1	8.0	—
P_1, width	1	5.0	—
P_2, length	3	14.9-15.0	14.93
P_2, width	3	6.7- 7.2	7.0
P_3, length	4	15.4-16.1	15.8
P_3, width	4	7.0- 8.0	7.5
P_4, length	3	18.2-19.0	18.6
P_4, width	3	8.7- 9.4	9.1
M_1, length	1	33.5	—
M_1, width	1	12.6	—
M_2, length	5	12.9-14.6	13.8
M_2, width	5	9.5-11.2	10.2
M_3, length	3	6.9- 8.1	7.4
M_3, width	3	6.1- 7.1	6.6

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Basa, Bloomington, Indiana, also recovered a small sample of teeth and bones from the deposit. This collection was brought to the Department of Anthropology, Indiana University. Both collections are now housed in the Ethnozoology Laboratory, Department of Anthropology, Indiana University, Bloomington. Identifiable specimens from these collections are as follows:

Family Canidae

Canis cf. *dirus* Leidy—Dire Wolf

Material: 1 incomplete right *C*, 1 left P^4, and 2 M_1s; 1 complete right M^1 and 1 left M_3.

Canis sp.

Material: 12 tooth fragments.

Family Tayassuidae

Platygonus cf. *cumberlandensis* Gidley—Peccary

Material: 2 cheek teeth; 1 right *C*.

Platygonus sp.—Peccary

Material: Fragments of 14 cheek teeth and 4 canines; 1 carpal; 1 phalanx; 1 sesamoid.

DIRE WOLF

Measurements of *Canis* cf. *dirus* teeth in the Volz, Corwin, and Basa collections are presented in Table 3. These measurements do not differ significantly from those presented in our previous paper, but they do increase the sample size as well as provide measurements for P^1, P_2, and M_3, that were not recovered in our initial sample.

DEPOSITION AND DATING

Volz (1977) suggested that the bulk of the faunal accumulation at Harrodsburg Crevice was the result of a natural trap situation. We argued, on the contrary, that the crevice had once been a horizontal cave which had been utilized as a lair by carnivores and possibly peccaries. Given the physical characteristics of the crevice and its deposits, the species composition, and the high ratio of juvenile animals, we hold to our original interpretation.

On the basis of the identification of the sabertooth cat as *S. fatalis* and a radiocarbon age determination of greater than 34,460 radiocarbon years BP (Geochron, no laboratory number given), Volz (1977) argued for a Sangamonian or early Wisconsinan age for the deposit. In our paper we also speculated that the deposit was of Sangamonian age, despite the fact that we had obtained a radiocarbon age determination of 25,050 ± 660 radiocarbon years BP (ISGS-424) and that the juvenile sabertooth cat tentatively identified (probably erroneously) as *S.* cf. *floridanus* had previously been found only in middle to late Wisconsinan contexts. The identification of an adult sabertooth cat from this deposit as *S. fatalis* suggests that the radiocarbon age determination of 25,050 BP is erroneous and that the deposit is indeed Sangamonian in age.

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