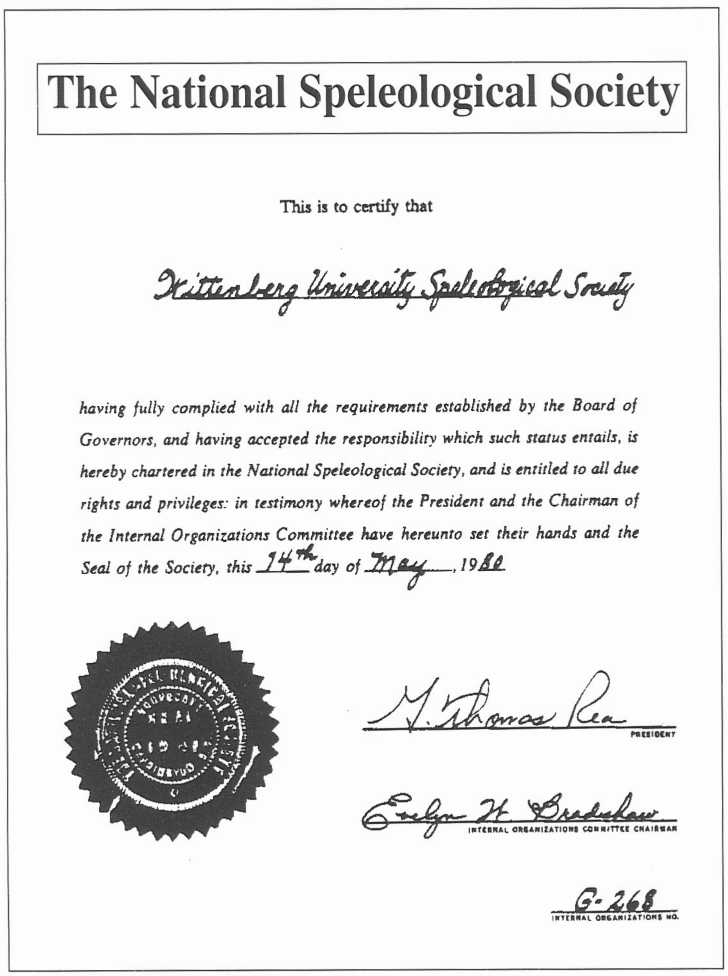
PHOLEOS

Journal Of The Wittenberg University Speleological Society

MAY 1995 VOLUME 15 (2)

The Wittenberg University Speleological Society

The Wittenberg University Speleological Society is a chartered internal organization of the National Speleological Society, Inc. The Grotto received its charter May 1980 and is dedicated to the advancement of speleology, to cave conservation and preservation, and to the safety of all persons entering the spelean domain.



The National Speleological Society

This is to certify that

Wittenberg University Speleological Society

having fully complied with all the requirements established by the Board of Governors, and having accepted the responsibility which such status entails, is hereby chartered in the National Speleological Society, and is entitled to all due rights and privileges: in testimony whereof the President and the Chairman of the Internal Organizations Committee have hereunto set their hands and the Seal of the Society, this 14th *day of* May, 1980

G. Thomas Rea
PRESIDENT

Evelyn H. Bradshaw
INTERNAL ORGANIZATIONS COMMITTEE CHAIRMAN

G-268
INTERNAL ORGANIZATIONS NO.

Cover: Natural Bridge, Carter Caves State Resort Park, Kentucky
Photo By: Scott A. Engel

ISSN: 0733-8864

PHOLEOS

Journal of the Wittenberg University Speleological Society

Volume 15 (II) May, 1995

TABLE OF CONTENTS

GROTTO OFFICERS 1994-1995

President
Annette Summers
1002 N. Fountain Ave.
Springfield, Ohio 45504

Vice President
Toby Dogwiler
740 C N. Fountain Ave.
Springfield, Ohio 45504

Treasurer
Megan Porter
824 1/2 N. Fountain Ave.
Springfield, Ohio 45504

Secretary
Jillian Benjamin
Box 1044
P.O. Box 6100
Springfield, Ohio 45501

Editor
Gregg Savage
33 E. Cassilly St.
Springfield, Ohio 45504

GROTTO ADDRESS: c/o Horton H. Hobbs III, Department of Biology, P.O. Box 720, Wittenberg University, Springfield, Ohio, USA 45501-0720, Tel. (513) 327-6484, FAX: 513-327-6340

SUBSCRIPTION RATE: 1 Volume - (2 issues) - $7.50, Single issues - $5.00. Send to Grotto address.

EXCHANGES: Exchanges with other grottoes and caving groups are encouraged. Please mail to Grotto address.

MEETINGS: Wednesday evenings (when Wittenberg University classes are in session - call to confirm), 7:00 p.m., Room 206, Science Building (corner of Plum and Edwards - parking available in adjacent lot), Wittenberg University, Springfield, Ohio.

Editor's Note

The much anticipated 15th Anniversary edition of *Pholeos* is finally here. It is an issue that exemplifies what the Wittenberg University Speleological Society has been about in the past as well as in the present.

This edition of *Pholeos* begins with several articles that look back on the past fifteen years of WUSS. The first article is a complete, and at times humorous, look at the history of WUSS. Following the history is a listing of the caves surveyed by WUSS members over the years. Believe it or not, WUSS members already have surveyed an incredible 13 miles, much of it in the last five years. Next appears a summary of WUSS student research resulting in publications put together by H. H. Hobbs III. Finally, the stroll down memory lane ends with a listing of all those individuals who have given blood, sweat, and tears to make WUSS what it is today, the officers.

By this time you should have had plenty of time to relive old WUSS memories, and it is time to make a leap from the past to the present. *Pholeos* continues with a fascinating poem by Tom Stitzel on his experience in Canyon Cave. The poem is followed by two student research papers on OZ Spring in Greene County, Ohio. The first is by myself and Tonya Fish, and the second is by Megan Porter, current treasurer of WUSS. Then, WUSS President Annette Summers reviews the current literature on sulfur bacteria in spelean environments. Finally, this issue of *Pholeos* ends with another article by Horton H. Hobbs III, in which he documents the cave articles appearing in the *Ohio Journal of Science*. Can anyone catch Hobbs in the number of times being published in *Pholeos*? I doubt it.

Along with the many great articles, many great photos from the past fifteen years are displayed. Also, the back cover shows a pictorial of most previous *Pholeos* covers. I believe this is one of the best issues to date. I hope you enjoy the 15th Anniversary Edition of *Pholeos* as much as I enjoyed putting it together. Congratulations WUSS and best of luck in the next fifteen years!

Gregg Savage

-Gregg Savage
Editor

The History of the Wittenberg University Speleological Society

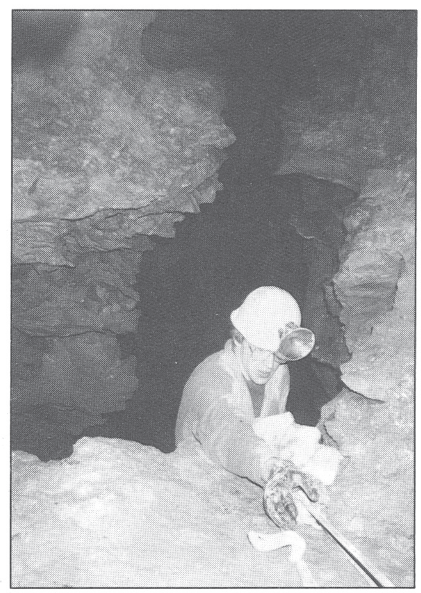
In the spring of 1977, Dr. Horton H. Hobbs III was completing his first year at Wittenberg University and teaching a Limnology course. On a class trip, H. Hobbs decided to expose his students to the science of speleology. Little did he know what he would start! After their introduction to the underground world, the students wanted to learn more. As interest increased, the need for a formal organization became apparent. Soon, officers were elected, and the Wittenberg "Caving Club" became an official university organization, with its first President, Jefferey Marion. The club continued to grow in members, and by the winter of 1979, the group of just under twenty felt it was time to achieve grotto status with the National Speleological Society (NSS). In April of 1980, the Wittenberg University Speleological Society (WUSS) became an internal organization of the NSS. What began was a legacy of hard-hat totting, coverall-wearing, gritty-toothed crawling as sport and science - all in the name of caving! Not one of its members would be able to deny the special bond to the dark worlds, whether they feared it or loved it.

WUSS defined its many goals and purposes to the caving community, as it would abide by the same rules and regulations set forth by the National Speleological Society. Its additional objective was to serve cavers in the southwestern Ohio area. As all speleological organizations set out to do, WUSS also held that it would save and protect those tiny pockets of the region where no footprints or light have ever reached. In addition to the dedication to cave conservation and preservation, and the safety of those who enter the spelean domain, WUSS also wanted to advance speleological research.

One of the early goals of WUSS was the initiation of a systematic survey of the caves and cave fauna in Ohio. Since 1979 to the present, 107 Ohio caves have been mapped and described. Thus far, the largest surveyed cave in Ohio, Freeland's Cave, Adams Co., was surveyed by WUSS in 1984 and 1985; total horizontal cave is 708 meters (2323 feet). Zane Caverns, Logan County, a commercial cave on the Bellfontaine Outlier, was mapped in 1989.

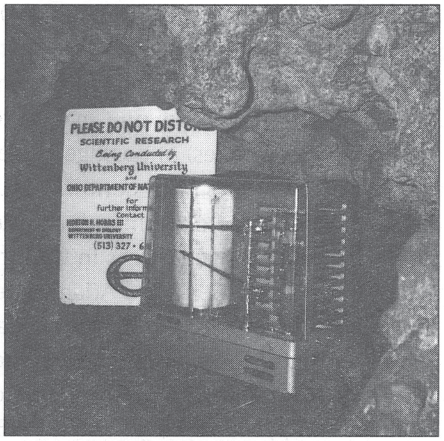
In 1981, the grotto started the survey of caves in and around Carter Caves State Resort Park, Carter County, Kentucky. The first cave map of Laurel Cave was proudly received by park naturalist John Tierney, and others, who immediately "assigned" the Saltpetre-Moon Cave System. The project continued from 1981 to 1982, until publication of the most detailed account of the cave to date. The next big cave surveyed by WUSS was Bat Cave. Began in 1983, it took a little over six years to complete. After over-coming many problems with the contribution and perseverance of twenty-five cavers, a total of 3681 meters (12,074 feet) of passages were unveiled in the longest cave in Carter Caves State Resort Park and the surrounding region. The most recent grotto project has been the Canyon Cave survey, with over 3000 meters (almost 2 miles) of passage surveyed thus far. Thirty-four WUSS members have contributed to the many hours it has taken to complete the map for this difficult cave. Several students initiated cave surveys in Carter County, including Cool James Cave (1990) and Adams Creek Cave (1991), and Cobble Crawl (1994). Other smaller caves within Park boundaries or around the area have been mapped by University students and other WUSS members, including X-Cave (1984) , Rhododendron Pit (1985), the Horn Hollow Cave System (1985), Pillar Cave (1986), Rat Cave (1986), Green Trail Chasm (1986), Peewee Cave (1987), Lake Cave (1987), Loop Cave (1987), Coon-in-the-Crack I and II (1988), Hot Dog Cave (1988), Frasier's Pits (1993), Crevice Cave (1995), Scott Hollow Cave (1995), Harrassment Cave (1995), and Spider Hole (1995). Refer to the detailed list of Caves Surveyed by WUSS (following this review) in the past fifteen years for a better account of cave descriptions and maps.

Additionally, several grotto members have surveyed caves in the Daniel Boone National Forest, Kentucky, in cooperation with the National Park Service. Published maps include such caves as Natural Bridge Cave (Powell Co.; 1990), Ace Bowen Cave (Powell Co.; 1990), Fuzzy Coon Cave (Meniffe Co.; 1990), and Well Cave (Meniffe Co.; 1991). Caves in other states have also been mapped, including Long Rockhouse Cave, Cumberland County, Tennessee (1994).



Final steps up Ladder Pit, Canyon Cave, Carter County, Kentucky Circa 1985.

Since WUSS's charter as a part of the national organization it is an understatement to say the group has accomplished many things. Besides exposing and introducing Wittenberg college students to the delights of caving, the club has also focused on exploration, conservation, education, and research. Members of WUSS have explored caves in Ohio, Indiana, Kentucky, Virginia, West Virginia, Alabama, Georgia, Tennessee, Michigan, Pennsylvania, New York, California, Oregon, New Mexico, South Dakota, Wyoming, Texas, Connecticut, Maryland, North Carolina, Hawaii, Florida, Mississippi, Minnesota, Missouri, Arkansas, Arizona, Colorado, Montana, Washington, Wisconsin, and even as far away as Barbados, Bermuda, Costa Rica, San Salvador and the Andros Islands, The Bahamas, Israel, Romania, Dominica, England, Australia, Switzerland, Mexico, and Kenya.



Hygrothermograph in Freeland's Cave, Adams County, Ohio, doing its thing

WUSS members have initiated and helped assist in biological and geological research (see publication list of Research Conducted by WUSS Members) since 1980. The Ohio Department of Natural Resource (ODNR) Division of Natural Areas and Preserves and Division of Geology have funded on-going work, beginning in 1980, to study Ohio caves. Recently, a grant from the ODNR will provide for research in The Endangered Species Project, which rates six potential candidate species for the endangered species list. In 1992, the United States Department of Agriculture gave WUSS members money to study cave ecology in the Hoosier National Forest. The Department of the Interior and National Park Service funded research for the assessment of the ecological resources of Russell Cave National Monument (Jackson Co., Alabama) and caves at Lookout Mountain, Chickamauga-Chattanooga National Military Park (Dade Co., Georgia and Hamilton Co., Tennessee). The National Speleological Foundation and the government of Barbados financed cave studies in Barbados. Smaller monies have been given by the Wittenberg University Faculty Research Fund Board, other Wittenberg departmental grants, the Scioto River Federation, the Soil Conservation Service, and the National Speleological Society, in order for individual students to study caves and karst areas. Some of the work has included organism drift studies in caves of southern Indiana, Bat Cave and Cobble Crawl, Carter County, KY, as well as geological research that describes the regional stratigraphic and structural characteristics for northeastern Kentucky, and hydrological flow for a karstic drainage in Delaware County, Ohio.

One major WUSS contribution to the whole caving community was the drafting and tooth-pulling presentation of the "Ohio Cave Protection Bill" in the spring of 1987. The bill was introduced to the Ohio Senate in 1987 in an attempt to protect and to preserve the caves of Ohio as Bill 396; at that time the Federal Cave Resources Protection Act was being discussed in the United States. The bill had two or three revamps before the state legislature would accept it. The passage of the bill defined caves, the life in the delicate ecosystems, geological formations, and archeological evidence; through the program of identification and protection, the bill proposed to deliberate public education about the importance of caves and the groundwater associated with them. The bill covered such issues as landowner responsibilities, speleothem destruction and sale, and accidental groundwater pollution by the improper disposal of trash. After being placed aside for some time, the Senate Bill SB#177 finally was passed 31-0 in Senate and 94-5 in the Ohio House of Representatives in November, 1988, after five years of hard work. A copy of the bill is published in this issue of *Pholeos.*

WUSS members sponsored the 1988 National Speleological Society Board of Governors (BOG) and the National Speleological Foundation meetings in February. Several parties were held and all who attended laughed and enjoyed themselves. A respectable number of cavers attended the meeting, as well as the two scheduled trips, one to Freelands's Cave and the other to Ohio Caverns, West Liberty, Ohio.

Organized caving groups often are apprehensive to publicize caving and to open "Pandora's box", but several WUSS members have been seen in the television spot-light. In 1988, *Good Morning America,* hosted by Ronald Reagan Jr., proposed the offer, and WUSS cautiously accepted. The hope was to emphasize the "creed of conservation cavers" and the NSS. Caving was not to be glorified nor sensationalized to the t.v. viewer, but rather demonstrate the implicit importance of safety that, when ignored, undoubtedly keeps accident reports full of macho, ignorant thrill-seekers who are all but prepared. WUSS tried to stress the delicacy of the underground, but the true messages of conservation and respect for caves were abandoned in the final 5-minute television show. Nothing was aired about the sensitivity of caves or the dangers to the inexperienced. Ron Reagan mentioned the cave (Stephen's Gap, Alabama) looked like those he had seen in books and that was exactly what was portrayed -fabulous camera shots for the recruitment of high-adventure lovers and idiots alike. Regardless, the participants can not forget the best (or exceptionally humorous) parts of the adventure - when Ronny wiped cricket droppings from his once pristine, blue ABC coveralls; the Indiana Jones theme echoing in the background; when the floodlights left and the real caving started.

The National Speleological Society awarded WUSS the Conservation Award in 1989 for the grotto's outstanding contributions to cave conservation. The accomplishment is accredited to 1) the work with the Ohio Cave Protection Bill; 2) getting two caves registered as Ohio Natural Landmarks by the Ohio Department of Natural Resources; and 3) the addition of several cavernicoles, restricted to Ohio caves, to be on the Federal register considering them for protective status. Additionally, WUSS also held numerous cave clean-ups in Ohio and Kentucky and placed registers in many caves to monitor visitation impact.

In order to educate the general public, WUSS has been active to instruct safe caving. Local Springfield children have been exposed to cave biology, geology, and conservation in the "Spelunking in Springfield" program through the Wittenberg School of Continuing Education, began in the 1980's. In 1988, WUSS inititated and organized an interperative program at Zane Caverns. WUSS members also have been involved with many Boy Scout troops, local and out-of-state, where the importance of respecting the spelean environment has been implanted in the badge-wearing minds of many titillated boys. Several groups of high school science students have been caving with WUSS members, too.

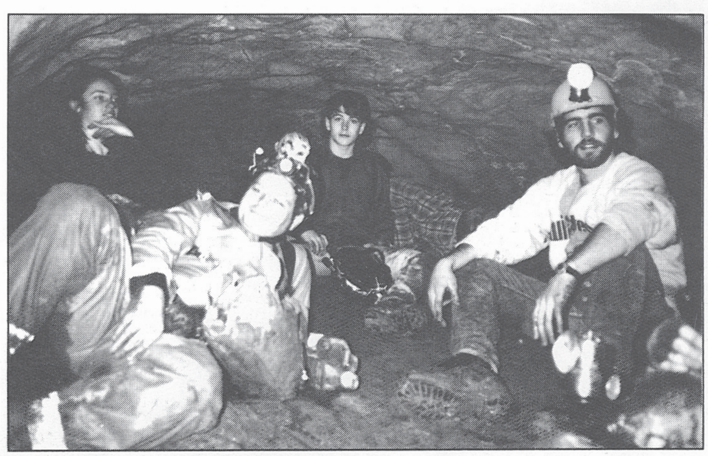
Future WUSS members in Salamander-Crystal Cave, Monroe County, Indiana, 1980.

The grotto publication, *Pholeos*, has been widely received by over 500 individual connoisseurs, state geological and geographical institutions, other NSS grottoes, and 52 different international caving organizations. Over the years, *Pholeos* has changed from the hand-pieced issues to the highly sophisticated, color-cover issues of the last few years. The grotto has utilized the publication facility at the university, and for this issue, has now turned to the operations of a local printing company.

Grotto numbers and leadership have seen a most unusual roller coaster ride in the past fifteen years. Not only have students been active members of WUSS, but Springfield residents and other community people from various surrounding towns have participated in grotto activities. The on-going obstacles that every president (see History of Officers list) had to overcome were the continuous surges and out-pourings of student interest and energy. During some more unfortunate episodes, the caving club consisted of the president (if him/her), one or two officers, and maybe one local member. Then, by some miracle, meetings had over 100 bubbly people, with everyone wanting to go on the next trip. At this point, a total of 365 people (and one dog) have paid WUSS dues. In the past fifteen years, WUSS has seen 7 women presidents, and only 6 men. In all, 53 different officers have served WUSS for at least one year; in most situations, people were elected for more than once.

Relations with Wittenberg University have also changed over the years. Be it between Student Senate, or *The Torch*, WUSS has been over-publicized and under-funded for far too many years than one can count. The first budget received from WUSS by Student Senate in 1980-1981 was $670.10; while for 1995-1996, the proposed budget is for about $12,000.00, but WUSS will probably recieve less than half of that. New technology requires the organization to purchase the newest equipment to insure safety (like getting rid of 7-year-old Gibbs ascenders and trying to buy a GPS unit). In the beginning, the group bought carbide lamps (at $15.95 each); most members now have converted to Wheat lamps and/or Petzel electric lights ($30-$200). For many years, the group has had to find alternative funding due to university budget cuts. Dues have ranged from $2 in the early years, to a current $4 a term for active members. In 1993, a list of different memberships amounts was published in *Pholeos*. Dawn Fuller became WUSS's first life-time member, with Vic Fazzio (a past WUSS president) as the second. Additionally, the grotto has sold T-shirts, patches, pop and candy at movies, maps, old *Pholeos*, and little children as slaves.

All in all, the Wittenberg University Speleological Society has been an extrememly successful grotto of the NSS. Over fifteen years, as the older members began to wrinkle and to sag, the faces of the new members kept getting younger! In addition to all its accomplishments, WUSS has presented approximately 20,750 meters (68,081.34 feet) of cave passages to the world and many times that distance has been explored for fun! In the age of the debated secrecy and caver certification issues, caving gossip at our fingertips on the Internet, high speed cars (and fast women!), and the highly diverse (!) NSS membership of cavers all around the world, WUSS has maintained the down-home, smiling face of southern Ohio as pubescent as the day it was conceived. Hopefully, the next fifteen years (up to 2010) will look as good on WUSS as the past fifteen have. If not, look out for the crouchety attitude of the arthritic, cholesterol-infested, beer-bellied, knobby-knee-ed WUSS cavers of the future!



The future of WUSS? Jill Hitchura, Alan Wallace, Keith Wallace, and Michael Ermarth might disagree

Cave Protection Act

Ohio Revised Code Chapter 1517,

Sections 1517.21 to 1517.26 for the Protection of Cave Resources

SECTION 1
That section 1517.99 be amended and sections 1517.21, 1517.22, 1517.23, 1517.24, 1517.25, and 1517.26 of the Revised Code be enacted to read as follows:

SECTION 1517.21 DEFINITIONS.
As used in sections 1517.21 to 1517.26 of the Revised Code:
(A) "Cave means a naturally occurring void, cavity, recess, or system of interconnecting passages beneath the surface of the earth or within a cliff or ledge, including, without, limitation, a grotto, rock shelter, sinkhole, cavern, pit, natural well, pothole, or subsurface water and drainage system.
(B) "Cave life" means any life form that normally occurs in, uses, visits, or inhabits any cave, except those animals that are included in Chapter 1531. or 1533. of the Revised Code.
(C) "Material" means:
  (1) Any speleothem, whether attached or broken, found in a cave;
  (2) Any clay or mud formation or concretion or sedimentary deposit found in a cave;
  (3) Any scallop, rill, or other corrosional or corrasional feature of a cave;
  (4) Any wall or ceiling of a cave.
(D) "Owner" means any person having title to land in which a cave is located.
(E) "Speleothem" means any stalctite, stalagmite, or other natural mineral formation or deposit occurring in a cave.
(F) "Speleogen" means the surrounding material or bedrock in which a cave is formed, including walls, floors, ceilings, and similar related structural and geological components.
(G) "Sinkhole" means a closed topographic depression or basin generally draining underground, including, without limitation, a blind valley, swallowhole, or sink.
(H) "Gate" means any structure or device that is located in such a manner as to limit, control, or prohibit access to or entry into a cave.

SECTION 1517.22 DECLARATION OF POLICY TO PROTECT CAVES.
The General Assembly hereby finds that caves are uncommon geologic phenomena and that the minerals deposited in them may be rare and occur in unique forms of great beauty that are irreplaceable if destroyed. Also irreplaceable are the archaeological resources in caves, which are of great scientific and historic value. It is further found that the organisms that live in caves are unusual and of limited numbers; that many are rare, threatened, or endangered species; and that caves are a natural conduit for groundwater flow and are highly subject to water pollution, thus having far-reaching effects transcending man's property boundaries. It is therefore declared to be the policy of the General Assembly to protect these unique natural and cultural resources.

SECTION 1517.23 RESPONSIBILITIES OF THE CHIEF OF THE DIVISION OF NATURAL AREAS AND PRESERVES.
With the advice of the Ohio Natural Areas Council created under section 1517.03 of the Revised Code, the chief of the Division of Natural Areas and Preserves shall:
(A) Formulate policies and plans and establish a program incorporating them for the identification and protection of the state's cave resources and adopt, amend, or rescind rules in accordance with Chapter 119. of the Revised Code to implement that program;
(B) Provide technical assistance and management advice to owners upon request.

SECTION 1517.24 PROHIBITIONS.
Without the express written permission of the owner and, if the owner has leased the land, without express written permission of the lessee, no person shall:
(A) Willfully or knowingly break, breakoff, crack, carve on, write on, burn, remove, or in any other manner destroy, deface, mark, or disturb the surfaces of any cave or any natural material that may be found in any cave, whether attached or broken, including, without limitation, speleothems, speleogens, and sedimentary deposits;
(B) Break, force, tamper with, or otherwise disturb any lock, door, gate, or other device designed to control or prevent access to a cave;
(C) Remove, deface, or tamper with any posted sign giving notice against unauthorized access to or presence in a cave or citing any of the provisions of sections 1517.21 to 1517.26 or division (B) of section 1517.99 of the Revised Code;
(D) Place refuse, garbage, dead animals, sewage, or toxic substances harmful to cave life or humans in a cave or sinkhole;
(E) Burn within a cave or sinkhole any substance that produces smoke gas that is harmful to any naturally occurring organism in the her than acetylene gas emission created by carbide lamps;
(F) Use any door, gate, or other device designed to control or prevent access to a cave that does not allow free and unimpeded passage of air, water, and naturally occurring cave life;
(G) Excavate or remove historic or prehistoric ruins, burial grounds, or archaeological or paleontological sites found in a cave, including, without limitation, saltpeter workings, relics, inscription, fossilized footprints, and bones;
(H) Destroy, injure, or deface historic or prehistoric ruins, burial grounds, or archaeological or paleontological sites found in a cave, including, without limitation, saltpeter workings, relics, inscriptions, fossilized footprints, and bones. Violations of the division is desecration under section 2927.11 of the Revised Code.
(I) Remove, kill, harm, or disturb any cave life found within a cave.

SECTION 1517.25 UNLAWFUL SALE OF SPELEOTHEMS.
No person shall sell or offer for sale speleothems collected from caves in this state.

SECTION 1517.26 LIMITS OF LIABILITY OF CAVE OWNERS.
Owners of land and, if the owner has leased that land, the lessee, are not liable for injuries, mental harm, or death sustained by persons using their land, including but not limited to cave resources, for recreational, educational, or scientific purposed if no charge has been made. By granting permission for entry or use, the owner or lessee does not:
(A) Extend any assurance that the premises are safe for such purposes;
(B) Constitute to the permittee and legal status of an invitee or licensee to whom a duty of care is owed;
(C) Assume responsibility for or incur liability for any injury to person or personal property caused by an act or omission of a permittee except as provided in this section.
(D) This section does not limit the liability which otherwise exists for:
  (1) Willful or malicious failure to guard or warn against a dangerous condition, use, or natural structure;
  (2) Failure to guard or warn against a dangerous man-made structure, fixture, or activity.

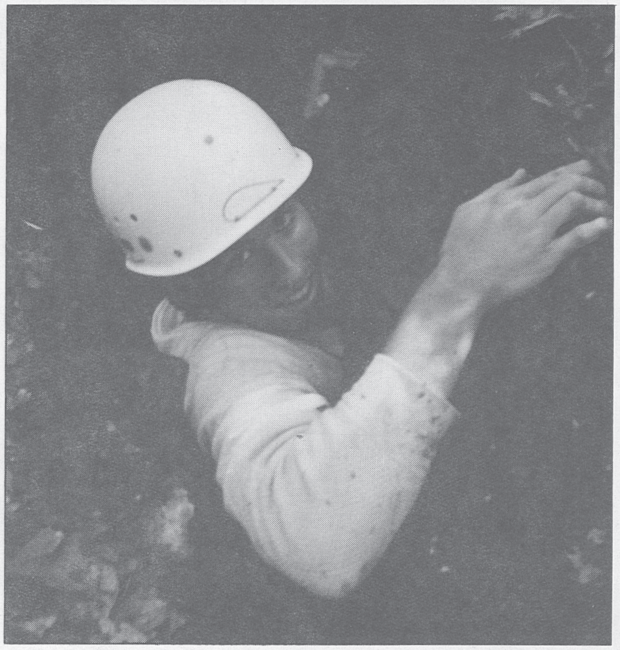
SECTION 1517.99 PENALTIES.
(A) Whoever violates section 1517.021 or 1517.051 of the Revised Code shall be fined not less than twenty-five nor more than five hundred dollars for a first offense; for each subsequent offense the person shall be fined not less than two hundred nor more than one thousand dollars.
(B) Whoever violated section 1517.24 or 1517.25 of the Revised Code is guilty of a misdemeanor of the third degree.

SECTION 2
The existing section 1517.99 of the Revised Code is hereby repealed.

PHOLEOS

the Wittenberg University Speleological Society 15th Anniversary Edition

The first crew - the future of the Wittemberg University Speleological Society, 1978, in Shiloh Cave Lawrence County, Indiana



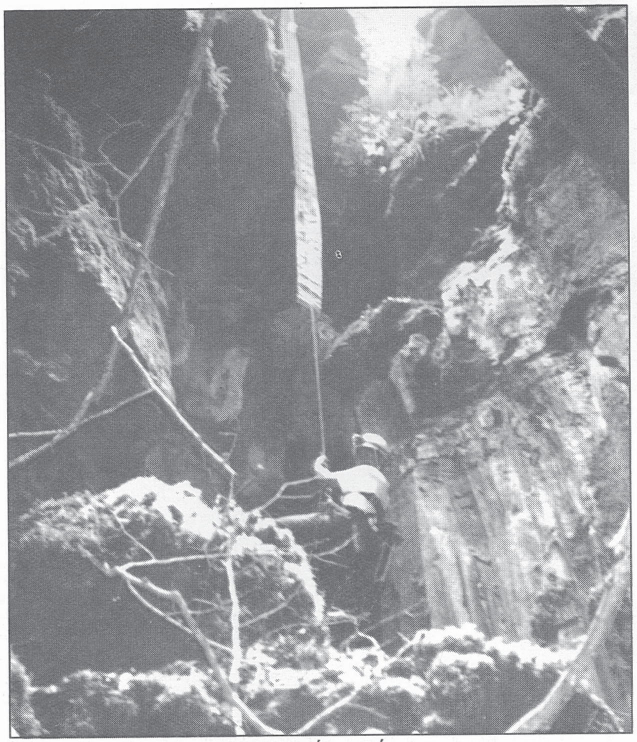
Seth Bridger getting out of Coon-in-the-Crack II, Carter Caves, Kentucky, 1994.

Toby Dogwiler in Freeland's Cave, Adams County, Ohio, 1995.

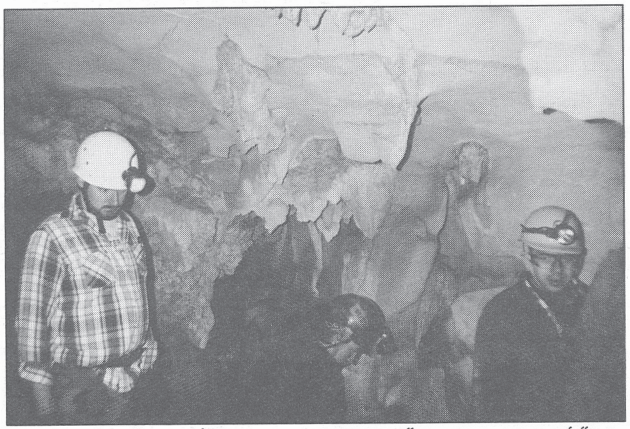
WUSS cavers after good trip, Kentucky, Circa 1988-1989.

Scott Engel in Bat Room, Canyon Cave, Carter County, Kentucky, 1995.

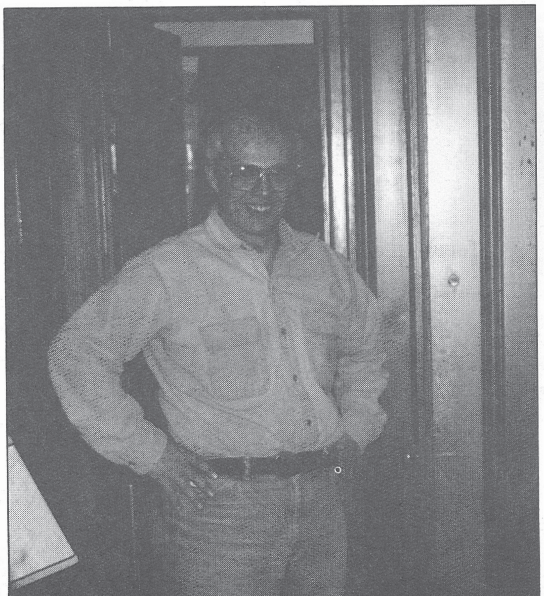
Annette Summers, Anne Huddle, and Howard Kronk after a great trip to the New Section of Marenge Cave, Crawford County, Indiana



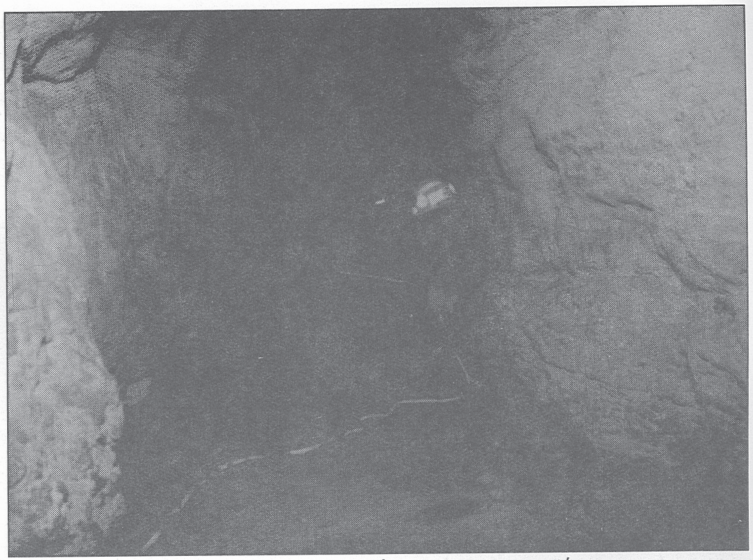
Kevin Simon on rope, Great Saltpeter Chasm, Tennessee, 1994.



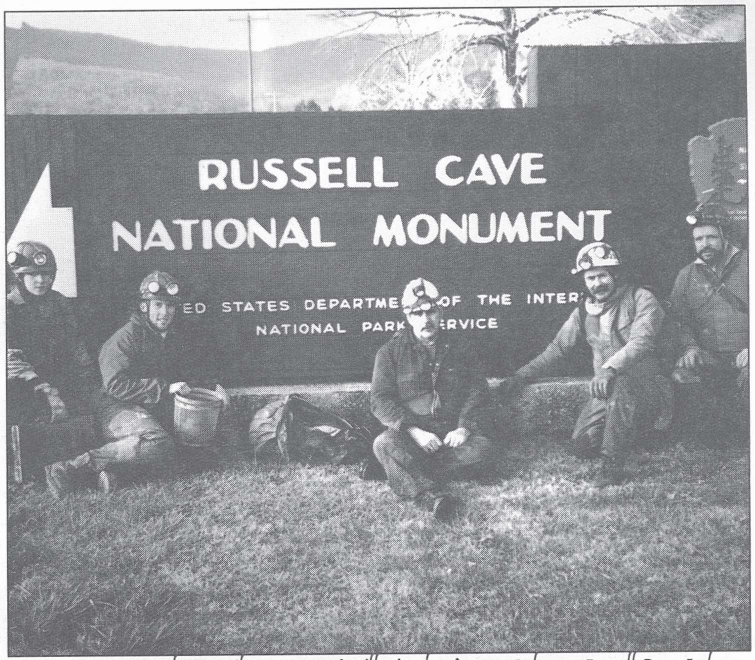
Part of an Alabama research crew, Stewart McGregor, Jeff Rayman, and Nate Pfeffer, in Labyrinth Cave (AL935).



Paul Unger standing tall at Crawlathon, 1993, Carter Caves, Kentucky.

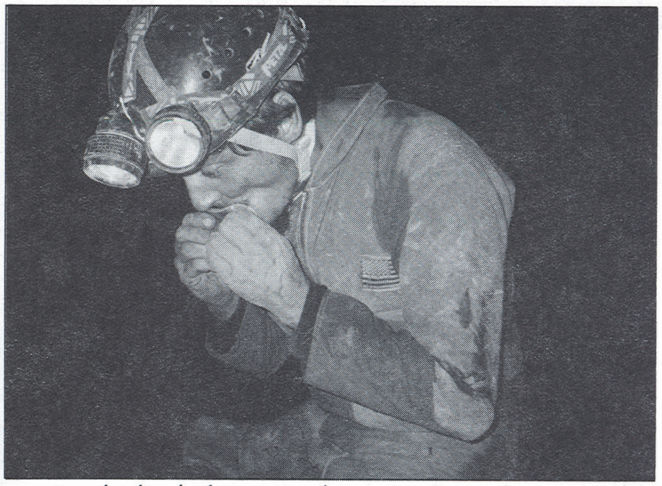


Tom Keller surveying in Cedar Fork Cave, Adams County, Ohio, 1984.

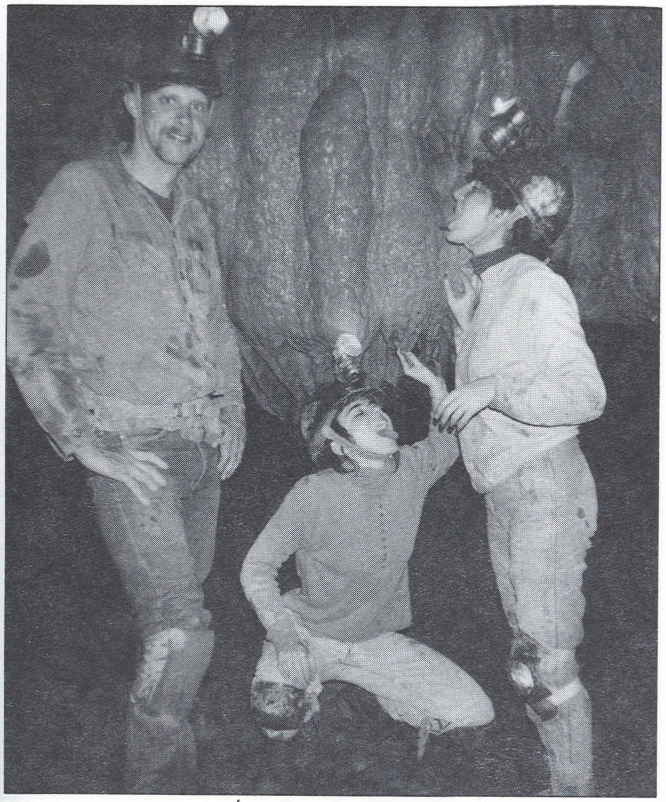


Annette Summers, Toby Dogwiler, Larry Bond, Bill Stitzel, and Dave Culver at Russell Cave, Jackson County, Alabama, 1992.

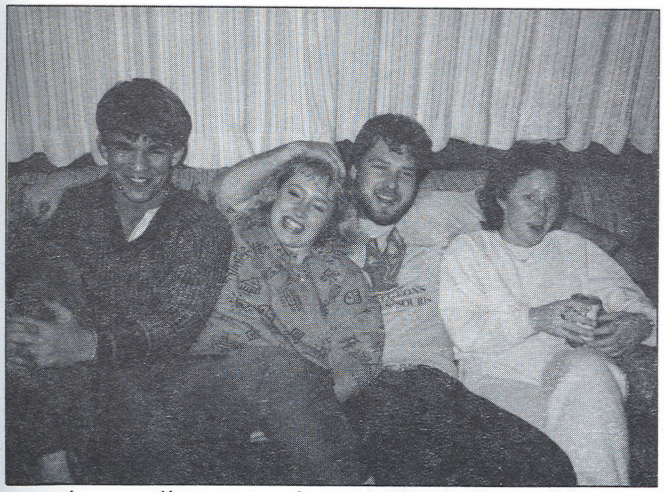
WUSS cavers and ABC television crew, poised against the Alabama courtry-side, 1988.



Howard Kronk sucking chocolate pudding in the New Sectio of Marengo Cave, Indiana, 1993.



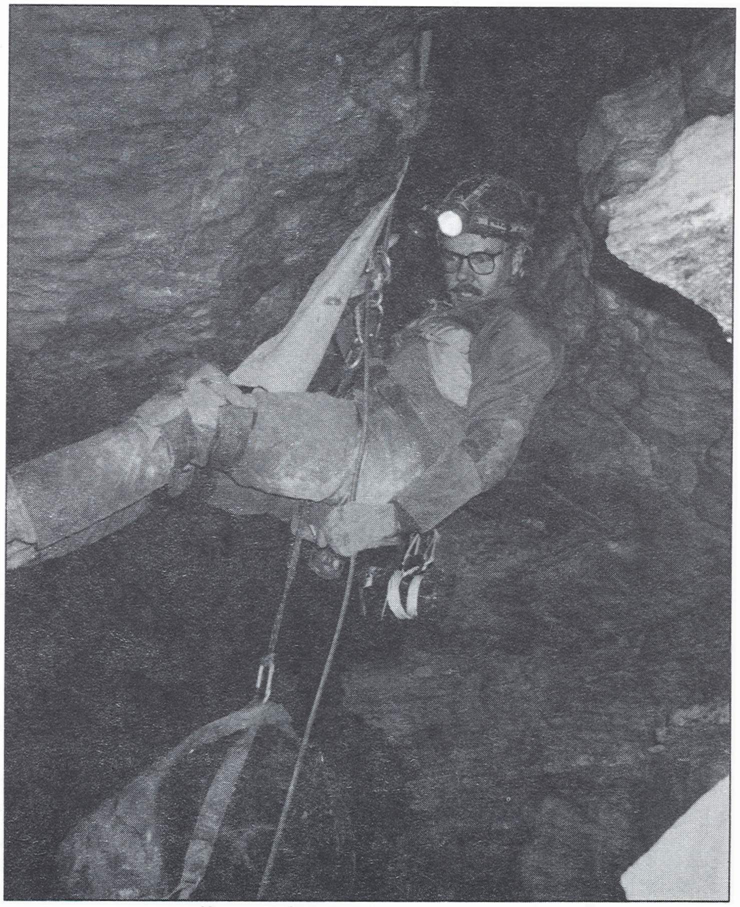
Sean Crossman, Lynel Dennison, and Heidi Durig in Rimstone Cave, Carter County, Kentucky, 1989.



Tim Hopkin, Lori Brockhuid (Pender), Mark Pender, and Heidi Murry at Crawlathon, Carter Caves, Kentucky, 1985-1986

Steve Campbell gazing into Snow Cave, Ohio, in 1979.

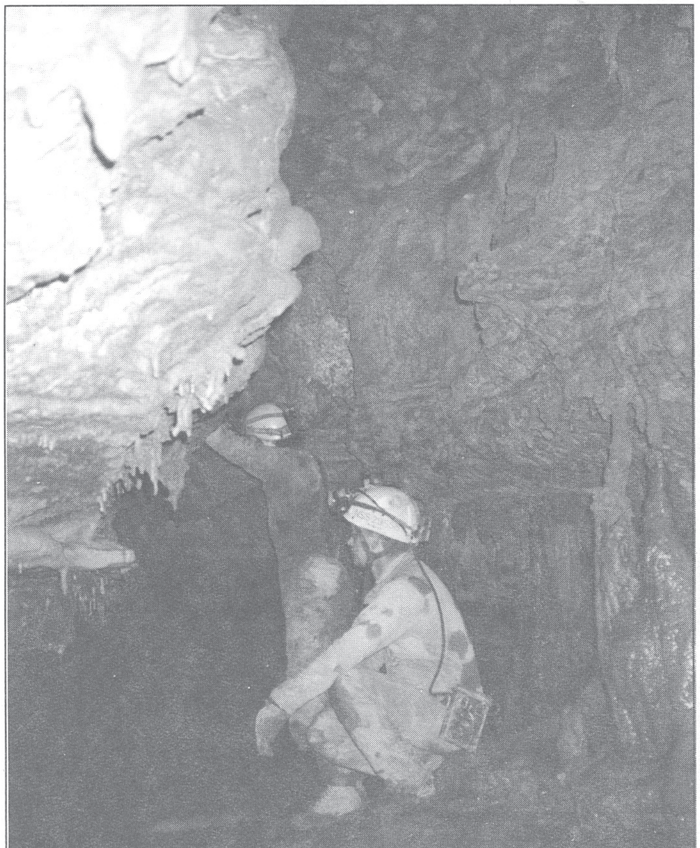
Bill Stitzel keeping dry in a Jackson County, Alabama cave, 1993.



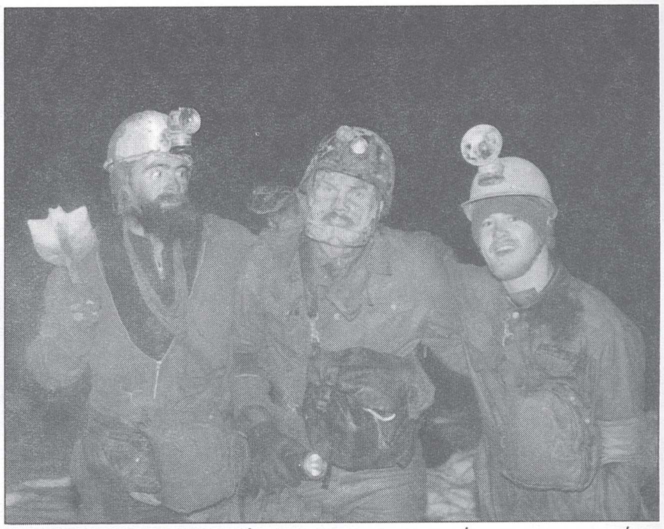
Horton Hobbs on rappel in Canyon Cave, Carter County, Kentucky.

Terry Madigan at the entrance of Hog Waller Cave, Pike County, Ohio, 1982.

A tired Bat Cave Survey crew, 1987, Carter Caves State Park, Kentucky.

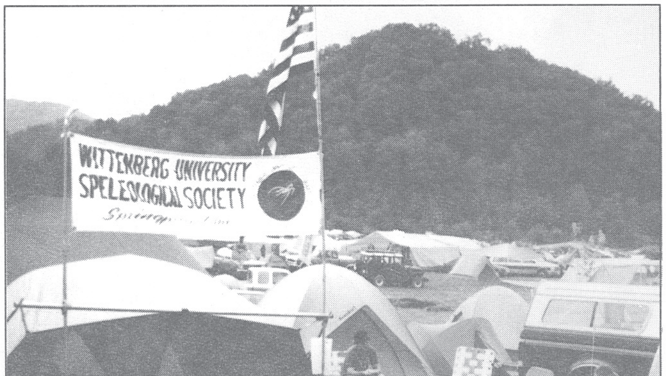


Steven and Charles Kronk looking for critters in Beck's Mill Cave, Indiana, 1993.



Penultimate survey trip to Freeland's Cave, Adams County, Ohio, 1985. Pictured are the grungy Bill Simpson, Horton Hobbs, and Chip Freund.

Vertical practice at "The Wall", Springfield, Ohio. Pictured are Horton Hobbs on belay, Scott Engel on rope, and Alan Wallace and Phil Mumford looking-on.



WUSS represented in force at Old Timers' Reunion, West Virginia, 1994.

Caves Surveyed by WUSS 1978-1995

(THC: Total horizontal cave TVC: Total vertical cave)

Vol. 1(1&2)

Black Run Cave, Adams Co., Oh, 3 July 1980, THC:120m
Fern Cave, Adams Co., Oh, 6 June 1980, THC:18m
Morrison's Cave, Adams Co., Oh., 2 July 1980, THC:110m
Keith's Fracture Cave, Clark Co., Oh., 10 Dec. 1979, THC:12m
Dry Cave, Highland Co., Oh, 1 April 1978, THC:70m
Kessler's Cave, Highland Co., Oh., 1 July 1980, THC:128m
Thompson Cave, Miami Co., Oh., 16 April 1978, THC:15m
Kindt's I Cave, Ottawa Co., Oh, 14 July 1980, THC:164
Frost Cave, Pike Co., Oh., 24 June 1980, THC:180m
Buckskin Cave I, Ross Co., Oh, 26 June 1980, THC:83m
Reif's Cave, Ross Co., Oh, 27 June 1980, THC:145m
Skull Cave, Ross Co., Oh, 21 July 1980, THC:54m
Miami River Cave, Shelby Co., Oh., 10 Jan. 1981, THC:54m
Fredritz Pit, Wyandot Co., Oh., 10 July 1980, THC:10m, TVC:10m
Underground River Cave, Wyandot Co., Oh., 10 July 1980, THC:31m, TVC:19m

Vol. 2(1)

Trimmer's Cave, Ross Co., Oh., 21 July 1980, THC:38m
Preston Cave I, Adams Co., Oh., 11 June 1980, THC: 14m
Preston Cave II, Adams Co., Oh., 11 June 1980, THC: 15m
Preston Cave III, Adams Co., Oh., 11 June 1980, THC: 43m
Devil's Den Cave, Adams Co., Oh., 10 June 1980, THC: 130m
Laurel Cave, Carter Co., Ky, 23 Jan. 1981, THC:1091m

Vol. 2(2)

Indian Trail Caverns, Wyandot Co., Oh., 11 July 1980, THC:182m
Simpson's Cave, Clark Co., Oh., 14 Feb. 1981, THC:16.5m
Via Cave, Miami Co., Oh., 7 April 1978, THC:25m
Buckskin Cave II, Ross Co., Oh., 26 June 1980, THC:45m

Vol. 3(1)

McKimie Cave, Highland Co., Oh., 27 Feb. 1982, THC:70.8m
Witches Cave, Highland Co., Oh., 10 Dec. 19 THC:55.5m
Cave of the Springs, Highland Co., Oh., 30 Dec. 1981, THC:246m
Phantom Cave, Highland Co., Oh., 10 Dec. 1981, THC:74m
Dancing Cave, Highland Co., Oh., 27 Feb. 1982, THC:66m
Bear Cave, Highland Co., Oh., 27 April 1982, THC:61m
Marble Cave, Highland Co., Oh., 10 April 1982, THC:33m
Fairy Grotto, Highland Co., Oh., 27 Jan. 1982, THC:9m
Cliff Cave, Highland Co., Oh., 10 April 1982, THC:11m
Tepee Grotto, Highland Co., Oh., 10 April 1982, THC:10m
Racoon Cave, Highland Co., Oh., 10 April 1982, THC:9m
Gator Cave, Highland Co., Oh., 10 April 1982, THC:14m
Alpha Cave, Highland Co., Oh., 10 April 1982, THC:10m
Pseudo Cave, Highland Co., Oh., 10 April 1982, THC:13m
Devil's Ice Box, Highland Co., Oh., 10 May 1982, THC:9m
Hidden Cave, Highland Co., Oh., 10 April 1982, THC:4m
One-Shot Cave, Highland Co., Oh., 9 May 1982, THC:6m
Funnel Cave, Highland Co., Oh., 9 May 1982, THC:31m
Ellison's Cave, Highland Co., Oh., 9 May 1982, THC:9m
Dare Cave, Highland Co., Oh., 4 May 1982, THC:18m
Tunnel Cave, Highland Co., Oh., 4 May 1982, THC:6m

Vol. 3(2)

Hannah Cave, Pike Co., Oh., 8 May 1982, THC:33.2m
Bartlett's Cave, Adams Co., Oh., 1 March 1981, THC:25m
Ferncliff Cave, Clark Co., Oh., 6 June 1980, THC:11m
Lost Pack Cave, Adams Co., Oh., 12 June 1980, THC:10m
Spider Cave, Greene Co., Oh., 3 Feb. 1979, THC:9.9m
Charelston Falls Cave, Miami Co., Oh., 10 Jan 1981, THC:25m
Crevice Cave, Clark Co., Oh., 21 Feb. 1981, THC:9.2m
Buck Creek Blowing Cave I, Clark Co., Oh., 21 Feb. 1981, THC:7.5m
Buck Creek Blowing Cave II, Clark Co., Oh., 21 Feb. 1981, THC:6m
Hawk Cave, Adams Co., Oh., 13 Feb. 1982, THC:15m
Hole-In-The-Wall Cave, Highland Co., Oh., 24 April 1983, THC:2.27m
Fool's Rappell Cave, Highland Co., Oh., 24 April 1983, THC:6.95m

South Gorge Cave, Geauga Co., Oh., 1982, THC:8.75m
Leaning Cave, Geauga Co., Oh., 1982, THC:9.3m
Chesterland Cave, Geauga Co., Oh., 1982, THC:28m
Extension Cave, Geauga Co., Oh., 1982, THC:29m

Vol. 4(1)
Dry Bone Cave, Pike Co., Oh., 14 May 1982, THC:42m
Saltpetre-Moon Cave System, Carter Co., Ky., Jan 1983, THC:3005m
Hackleshin Cave, Pike Co., Oh., 15 May 1982, THC:83m
Hogwaller Cave, Pike Co., Oh., 16 May 1982, THC:82.7m

Vol. 4(2)
Cedar Fork Cave, Adams Co., Oh., 15 Jan. 1984, THC:210m
X Cave, Carter Co., Ky., 10 Feb. 1984, THC:343.4m
Lost Comb Cave, Adams Co., Oh., 8 Jan. 1984, THC:41m

Vol. 5(1)
Carcass Pit, Adams Co., Oh., 5 Aug. 1984, TVC:5m
Rhododendron Pit, Carter Co., Ky., 5 Feb. 1984, THC:15m
Thirty-Foot Pit, Adams Co., Oh., 4 Aug. 1984, TVC:15m
Alpha Pit, Adams Co., Oh., 5 Aug. 1984, TVC:6.5m
Merrit Hollow Cave, Adams Co., Oh., 4 Aug. 1984, THC:10m
Underground River Cave, Wyandot Co.,Oh., 10 July 1980, THC:31m, TVC:19m
Frost Cave, Pike Co., Oh., 24 June 1980 (reprint)
Reif's Cave, Ross Co., Oh., 27 June 1980 (reprint)
Kindt's I Cave, Ottawa Co., Oh., 14 July 1980 (reprint)
Morrison's Cave (reprint)
Indian Trail Caverns, Wyandot Co., Oh., 11 July 1980 (reprint)

Vol. 5(2)
Horn Hollow Cave System, Carter Co., Ky., Jan. 1985, THC:601m

Vol. 6(1)
Tinker's Cave, Hocking Co., Oh., 1986, THC:20m
Freeland's Cave, Adams Co., Oh., Nov. 1985, THC:708m
Pillar Cave, Carter Co., Ky., 1986, THC:23m

Vol. 6(2)
Rat Cave, Carter Co., Ky., 1986, THC:126.7m
Green Trail Chasm, Carter Co., Ky., 4 Oct. 1985, THC:10m
Mcousta Cave, Preble Co., Oh., 26 Aug. 1985, THC:8.5m
Chicken Cave, Hamilton Co., Oh., 9 Feb. 1986, THC:13.2m

Vol. 7(1)
Liverwurst Cave, Adams Co., Oh., 5 Aug. 1986, THC:6.5m
Charlie-Charlie Cave, Brown Co., Oh., 23 July 1986, THC:5m
Tanglewood Cave, Brown Co., Oh., 23 July 1986, THC:34m
Black Crystal Cave, Erie Co., Oh., 14 Aug. 1986, THC:10m
Crystal Rock Cave, Erie Co., Oh., 14 Aug. 1986, THC:94m
Dead Cat Cave, Erie Co., Oh., 14 Aug. 1986, THC:5m
Fox Den, Erie Co., Oh., 14 Aug. 1986, THC:7m
Giant Cricket Cavern, Highland Co., Oh., 6 Aug. 1986, THC:9.5m
Spider Caver, Highland Co., Oh., 6 Aug. 1986, THC;7m
Lion's Den, Pike Co., Oh., 7 Aug. 1986, THC:5.7m
Bell Cave, Seneca Co., Oh., 12 Aug. 1986, THC:35m

Vol. 7(2)
Peewee Cave, Carter Co., Ky., 1986, THC:6.07m
Lake Cave, Carter Co., Ky., 1986, THC:180m
Loop Cave, Carter Co., Ky., 1986, THC:12.62m

Vol. 8(1)
Robinson's Cave, Perry Co., Oh., 9 July 1987, THC:18.3m
Hendricks Cave, Wyandot Co., Oh., 11 April 1987, TVC: 6.3m, THC:56.6m

Vol. 8(2)
Coon-in-the-Crack Cave I, Carter Co., Ky., Aug. 1987, THC:212.01m
Coon-in-the-Crack Cave II, Carter Co., Ky., Aug. 1987, THC:127.42m

Vol. 9(1)
Hot Dog Cave, Carter Co., Ky., 16 July 1988, THC:45.26m
Doan Brook Cave, Cuyahoga Co., Oh., ND, THC:15.2m
Panther Cave, Medina Co., Oh., 1955, THC:58m
Ice Box Cave, Summit Co., Oh., ND, THC:22.9m
Card's Cave, Geauga Co., Oh., 1954, THC:42.7m
Robber's Cave, Geauga Co., Oh. , 1956, THC:30.5m
The Devil's Den Fracture System, Portage Co., Oh., ND, THC:352m
Great Cheddar Cave, Portage Co., Oh., 1956, THC:30m

Vol. 9(2)
Bat Cave, Carter Co., Ky., 1983-1989, THC:3681m
Fuzzy Coon Cave, Menifee Co., Ky., 5 Nov. 1988, THC:118m

Vol. 10(1)
- Zane Caverns, Logan Co., Oh., Dec. 1989, THC:466m
- Natural Bridge Cave, Powell Co., Ky., THC (sketch map, no scale)

Vol. 10(2)
- Cool James Cave, Carter Co., Ky., June 1990, THC:743m
- Ace Bowen Cave, Powell Co., Ky., 21 Oct. 1989, THC:300.7m

Vol. 11(2)
- Well Cave, Menifee Co., Ky., 19 Aug. 1990, THC:894m

Vol. 12(1)
- Adams Creek Cave, Carter Co., Ky., 1991, THC:513m

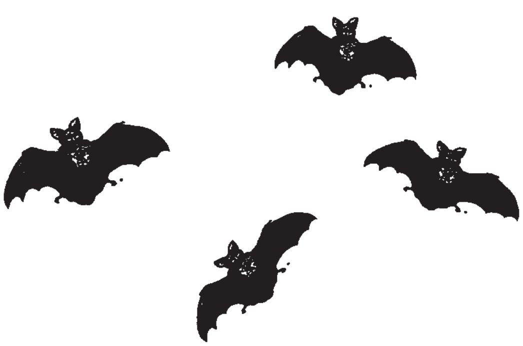
Vol. 14(1&2)
- Long Rockhouse Cave, Cumberland Co., TN, 26 March 1992, THC:55m

Vol. 15(1)
- Loop Cave, Adams Co., Oh., 8 Aug. 1994, THC:15.88m
- Sullivant's Cave, Adams Co., Oh., 8 Aug. 1994, THC:6.75m
- Roadside Cave, Adams Co., Oh., 8 Aug. 1994, THC:10.67m
- Oscar Hole, Ross Co., Oh., 8 August 1994, THC:16.1m
- Crevice Cave, Carter Co., Ky., 22 Feb. 1994, THC:22.12m
- Spider Hole, Carter Co., Ky., 22 Feb. 1994, THC:18.56m
- Harassment Cave, Carter Co., Ky., 19 Feb. 1994, THC:32.25m
- Scott Hollow Cave, Carter Co., Ky., 19 Feb. 1994, THC:77m

Total Cave Passage Surveyed *: 17,593.18m

*This number does not reflect Canyon Cave, Carter Co., KY, which has 3157m of surveyed passage to date. Hopefully, this map will appear in a future issue of *Pholeos*.

Grand Total: 20,750.18m (68,081.34 ft or 12.97mi)



Mad About Bats

The American Bat Conservation Society (ABCS) has opened its new National Bat Center to the public. This center is claimed to be the first living museum dedicated to the conservational of North American Bats. Located at ABC's new headquarters in Rockville, Maryland, the bat center features live bats, educational programs on the flying mammals, and a retail store full of backyard wildlife supplies, such as bat detectors.

Visitors to the center get to meet its mascot "Sweet Pea" (a brown bat). They can also attend demonstration on the usefulness of the "nocturnal heroes." A recent demonstration featured night-fragrance bat gardens. The bats attracted help rid backyards of moths and beetles. For more information about the National Bat Center, call 301/984-2227.

A Summary of Wittenberg University Speleological Society Student Research Resulting in Publications

by

Horton H. Hobbs III
NSS 12386F

Since the early efforts of student members of the Wittenberg University Speleological Society to conduct research on caves and karst features, 43 manuscripts have been published. The first article appeared in 1980 and these efforts have continued to the present with 32 students having been involved in various projects. For those who are interested in statistics, this averages to 2.7 publications each year by student members of WUSS. These "2.7 publications" are not merely trip reports or "my first cave trip," but represent either literature review articles or long term studies in which data were gathered, analyzed, and presented concerning various topics in speleology.

Many students have written grant proposals and have been funded from various sources to conduct the studies and these efforts continue into the 1995 academic year. Students have been supported by grants from the Department of the Interior, the Department of Agriculture, U. S. Fish and Wildlife, the Ohio Department of Natural Resources, the National Speleological Society, and the Biology and Geology departments as well as the Faculty Research Fund Board, Wittenberg University. To all of these sources we extend a gracious "thank you," for without their financial assistance, many of these research projects could not have been conducted.

Presented below is an alphabetical list of the citations for all research published by students since 1980.

[**indicates research paper presented by student(s) at scientific meeting]

** Butler IV, Mark J. 1980. A study of the chemical and physical parameters of a temperate hardwater spring in John Bryan State Park, Greene County, Ohio. Ohio J. Sci., 80:93.

Butler IV, Mark J. and H. H. Hobbs III. 1982. Drift and upstream movement of invertebrates in a springbrook community ecosystem. Hydrobiologia, 89:153-159.

Campbell, Steven. 1981. Geology of Ohio with reference to caves. Pholeos, 1(1,2):3-6.

**Cotner, James B. and Mark J. Butler IV. 1981. Community structure, drift, and upstream migration of the crustaceans Synurella dentata Hubricht and Lirceus fontinalis Raf. in a temperate spring. Ohio J. Sci., 81:97.

D'Angelo, Donna. 1984. The origin and mining of saltpetre. Pholeos, 4(1):12-13.

D'Angelo, Donna. 1984. X Cave. Pholeos, 4(2):5-7.

Davenport, Robert. 1986. Rat Cave. Pholeos, 6(2):7-8.

Engel, Scott. 1991. Adams Creek Cave and the Cool James System. Pholeos, 12(1):8-15.

Fazio, Victor and Donna D'Angelo. 1984. The Saltpetre-Moon Cave system. Pholeos, 4(1):7-12.

**Hobbs III, H. H. and Mark J. Butler IV. 1980. Community dynamics of a cold hardwater spring. Limnol. Oceanogr., Prog. Abstr., 1980:28.

Hobbs III, H. H. and Mark J. Butler IV. 1981. A sampler for simultaneously measuring drift and upstream movements of aquatic macroinvertebrates. J. Crust. Biol., 1(1):63-69.

**Hobbs III, H. H. and Michael F. Flynn. 1981. The cavernicolous fauna of Ohio. Part II: Invertebrates. Ohio J. Sci., 81:109.

Hobbs III, H. H. and Michael F. Flynn. 1981. The cave fauna of Ohio. Pholeos, 1(1,2):7-14.

Hobbs III, H. H. and Michael F. Flynn. 1981. Selected Ohio caves. Pholeos, 1(1,2):15-24.

Hobbs III, H. H. and Michael F. Flynn. 1982. Five Ohio caves. Pholeos, 2(1):4-7.

Hobbs III, H. H., Naomi Mitchell, and Todd Zimmerman. 1986. A description of additional Lilliputian caves formed in Ohio dolomites and limestones. Pholeos, 7(1):5-13.

Hobbs III, H. H. and Marcus M. Pender. 1985. The Horn Hollow Cave system, Carter County, Kentucky. Pholeos, 5(2):17-22.

Hobbs III, H. H. and Marcus M. Pender. 1986. An additional karst feature of Carter County, Kentucky. Pholeos, 6(2):9-10.

Hobbs III, H. H., Nathan Pfeffer, and Terence J. Madigan. 1982. Laurel Cave. Pholeos, 2(1):10-13.

Hobbs III, H. H. and Martin R. Trent. 1987. Notes on a Wyandot County, Ohio Cavern. Pholeos, 8(1):5-6.

**Huddle, Anne. 1994. Community dynamics of benthic macroinvertebrates in a contiguous surface and cave stream, Carter County, Kentucky. Second International Conference on Ground Water Ecology, Preliminary Program, 6.

Keenan, Teressa M. 1987. Caves of Smokey Lake Ridge. Pholeos, 7(2):5-8.

Keenan, Teressa M. 1988. Hot Dog Cave. Pholeos, 9(1):4.

Keenan, Teressa M. 1988. Vespertilionidae: An introduction to the bat species of Ohio. Pholeos, 9(1):19-30.

Keller, Tom. 1984. Cedar Fork Cave. Pholeos, 4(2):3-4.

Kieser, Mark S. 1982. The karst of San Salvador Island, Bahamas. Pholeos, 2(2):6-8.

Kieser, Mark S., Anne Davies, and George S. Smith. 1982. The Blue Holes of San Salvador, Island, Bahamas Pholeos, 2(2):3-5.

Lapp, Jeff. 1993. A study of the drift of the amphipod, *Gammarus minus*, in Bat Cave, Carter County, Kentucky. Pholeos, 13(2):13-16.

Madigan, Terence J. 1988. Coon-in-the-Crack Caves I and II. Pholeos, 8(2):4, 6-7.

Madigan, Terence J. and Benjamin L. O'Sickey. 1982. Chesterland Caves area survey report. Pholeos, 3(1):3-4.

**Mitchell, Naomi and H. H. Hobbs III. 1987. Biological and physicochemical baseline data for selected Ohio caves. Ohio J. Sci., 87(2):51

Palunas, Monika J. 1989. Life histories of the Amblyopsidae with an emphasis on reproductive cycles. Pholeos, 9(2):15-17.

Pederson, Cathy. 1990. A comparative study of drift in a Kentucky cave and surface stream. Pholeos, 11(1):1-10.

**Pederson, Cathy and H. H. Hobbs III. 1991. A comparative study of cave and surface stream drift. Ohio J. Sci., 91(2):74.

**Pender, Marcus M. 1985. The Horn Hollow Cave system. Prog. 1985 National Speleological Society Conv., Frankfort, Kentucky, p.41.

Pender, Marcus M. 1986. Death of a cave. Pholeos, 6(1):2-3.

Porter, Megan. 1993. The formation and biota of inland and oceanic Blue Holes. Pholeos, 13(2):1-8.

**Porter, Megan L. 1995. Comparative study of amphipod and isopod population densities in two temperate cold-water springs, Greene County, Ohio. Ohio J. Sci., 95(2):46.

Proctor, Jonathan. 1990. Cool James Cave, Carter County, Kentucky. Pholeos, 10(2):5.

**Savage, Gregg E. and Tonya N. Fish. 1994. The estimation of primary production using chlorophyll a and diurnal curves on a shallow, rapid flowing spring and effluent in Greene County, Ohio. Proc. National Conference on Undergraduate Research, 1994.

**Summers, A. and H. H. Hobbs III. 1995. Jointing and bedding plane controls on cave passage development, Canyon Cave, Carter County, Kentucky. Ohio J. Sci., 95(2):52.

Tarulli, Laura. 1982. Ohio Cave Survey. Pholeos, 2(2):7-10.

**Titelman, Josefin and Natalie H. Waddell. 1995. Physicochemical trends of Yellow Springs, Greene County, Ohio. Ohio J. Sci., 95(2):52.

History of Officers 1978-1995

1978-1979

pres	Jefferey L. Marion
vpres	Kurt W. Whitford
sec	Terresa Tuel
treas	Barb Bohn

1980-1981

pres	Michael Flynn
vpres	Steven Campbell
sec	Helen Armstrong
treas	Jane Bush
editor	Steven Campbell

1981-1982

pres	Jane Bush
vpres	Lynn Morrill
sec	Terry Madigan
treas	William Simpson
editor	Lynn Morrill

1982-1983

pres	Laura Tarulli
vpres	Victor W. Fazio
sec	Marilyn L. Matevia/ Kathy Crowley
treas	Terrence J. Madigan
editor	Donna J. D'Angelo

1983-1984

pres	Donna J. D'Angelo
vpres	Terrence J. Madigan
sec	Trish Simon/ Anne Dolphin
treas	William O. H. Fruend III
editor	Victor Fazio/Laura Tarulli
PR	John Carter

1984-1985

pres	William O. H. Freund III
vpres	Thomas F. Keller
sec	Trish Simon
treas	Robert S. Davenport
editor	John G. Fray

1985-1986

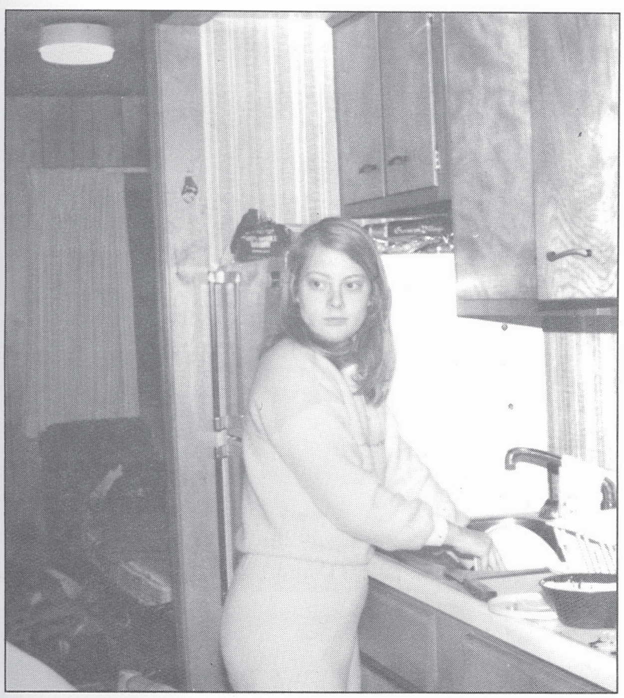
pres	Marc Pender
vpres	Therese Herp
sec	Trish Simon
treas	Robert S. Davenport
editor	William O. H. Freund III

1986-1987

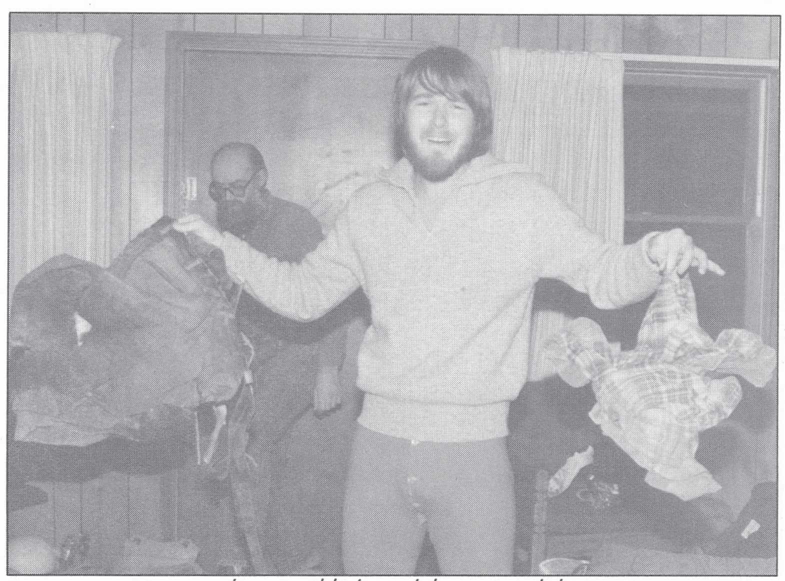
pres	Marc Pender
vpres	Robert Davenport
sec	Teressa Keenan
treas	Therese Herp
editor	Martin R. Trent
ass. ed.	Patrick McCarthy

1987-1988

pres	Martin E. Trent
vpres	Teressa Keenan
sec	Heidi Murry
treas	Monika Palunas
editor	Timothy Hopkin
ass. ed.	Terri Ruben



Someone has to do the dishes! Therese Herp at Crawlathon, 1986.



Mark Pender with his frozen clothes, 1986 Crawlathon.

1988-1989

pres	Teressa Keenan
vpres	Timothy Hopkin
sec	Celise Sternecker
treas	Monika Palunas
editor	Jonathan Proctor
ass. ed.	Sheryl Rowold

1989-1990

pres	Monika Palunas
vpres	Timothy Hopkin
sec	Deborah Keiser
treas	Jeffrey Luoma
editor	Jonathan Proctor

1990-1991

pres	Scott Engel
vpres	Jeff Luoma
sec	Rachel Beverly
treas	Clarie Sandt
editor	Julie Thorp
ass. ed.	Tracy Pollard

1991-1992

pres	Scott Engel
vpres	Chris Frost
sec	Jessica Hoane
treas	Kristin Ferry
editor	Julie Thorp
ass. ed.	Claire Sandt

1992-1993

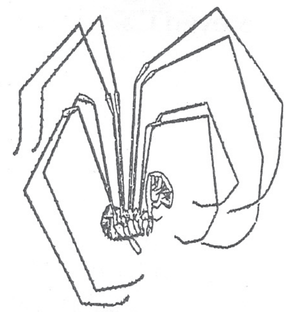
pres	Julie Thorp
vpres	Annette Summers
sec	Anne Huddle
treas	Jessica Hoane
eds.	Jason Bauserman
	Ellen Divoky
	Toby Dogwiler

1993-1994

pres	Annette Summers
vpres	Toby Dogwiler
sec/treas	Anne Huddle
editors	Jason Bauserman
	Gregg Savage

1994-1995

pres	Annette Summers
vpres	Toby Dogwiler
sec	Jullian Benjamin
treas	Megan Porter
editor	Gregg Savage



Chris Frost, Becky Deel, Julie Thorp, Claire Sandt, Tracy Polland, Rachel Beverly at Ohio Caverns, West Liberty, Ohio, 1991.

Yummy! WUSS celebration, 1990.

1988-1989

pres Teressa Keenan
vpres Timothy Hopkin
sec Celise Sternecker
treas Monika Palunas
editor Jonathan Proctor
ass. ed. Sheryl Rowold

1989-1990

pres Monika Palunas
vpres Timothy Hopkin
sec Deborah Keiser
treas Jeffrey Luoma
editor Jonathan Proctor

1990-1991

pres Scott Engel
vpres Jeff Luoma
sec Rachel Beverly
treas Clarie Sandt
editor Julie Thorp
ass. ed. Tracy Pollard

1991-1992

pres Scott Engel
vpres Chris Frost
sec Jessica Hoane
treas Kristin Ferry
editor Julie Thorp
ass. ed. Claire Sandt

1992-1993

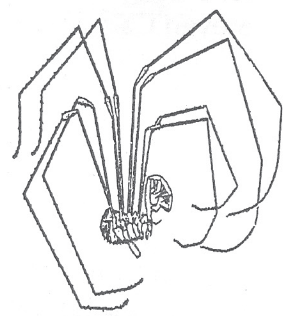
pres Julie Thorp
vpres Annette Summers
sec Anne Huddle
treas Jessica Hoane
eds. Jason Bauserman
Ellen Divoky
Toby Dogwiler

1993-1994

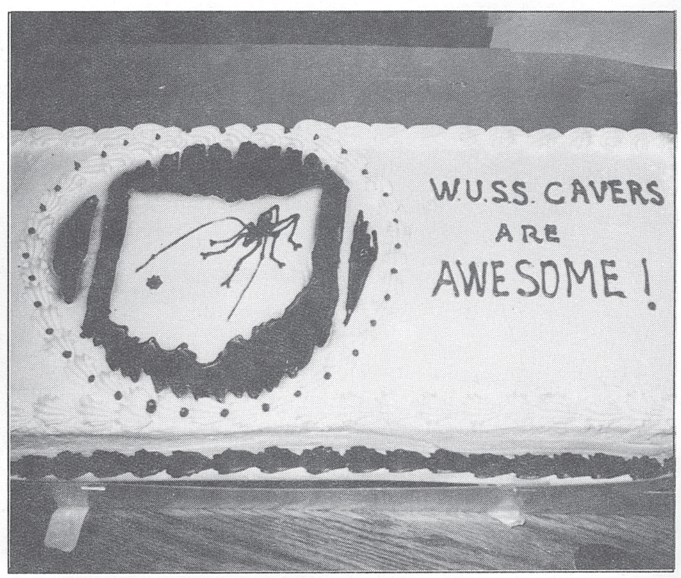
pres Annette Summers
vpres Toby Dogwiler
sec/treas Anne Huddle
editors Jason Bauserman
Gregg Savage

1994-1995

pres Annette Summers
vpres Toby Dogwiler
sec Jullian Benjamin
treas Megan Porter
editor Gregg Savage



Chris Frost, Becky Deel, Julie Thorp, Claire Sandt, Tracy Polland, Rachel Beverly at Ohio Caverns, West Liberty, Ohio, 1991.



Yummy! WUSS celebration, 1990.

Canyon Cave Memoir

by Tom Stitzel

Light slips away slowly.
I'm standing still and it sneaks off behind me
A backward child too shy to share itself with the company of others.
Sometimes light disappears immediately,
Plunging me into a darkness that has never known anything but itself.
The jarring that occurs is almost physical.
I have not moved, the universe has.

Quiet, which is eternal, envelopes me.
I am in awe of its potency.
Out of this peaceful respite from sound
Is born a monstrous nightmare or the sweetest dream come true.
It is matter,
The living, breathing substance of which I am a part.
Swaddled in its dormant power,
I steady myself in anticipation
Of being inhaled into the soundless current of its breath.

Here, there is no dramatic, seasonal upset,
Only climatic perfection.
Here, there is the changeless nature which centers me,
No hot, no cold.
Here, I am safely reassured,
Finally home.

The breath catches.
Disoriented, I cling to a looming face of alien limestone
Suspended over mystic objects,
Muted variations of the same unforgiving shadow.
My god! Are these pitiful screams escaping me, mine?
I am going to fall
Bashing and breaking every bone on the phantom shadows
Before I hit bottom.
Frantically, fragile fingertips dig into microscopic spaces
Begging for support.
Heavily booted feet, desperate to plant themselves in the idea of safety,
Of solidness,
The ideal of which, once found, will not deceive and give way,
Whimper,
No longer proud,
Ashamed,
Worst of all, afraid.

Falling, flapping wildly,
Begging for a savior perch,
Redemption from wreckage,
Faces slams rock, attempting to bore into it.
Manic fingers scramble along unblemished surface,
Seeking home.
Then, a toe catches a thin wedge of thought.
Chest, arms and legs flatten against sheerness of incline,
Daring not to breathe.
The slightest movement can dissolve this fleeting, stationary state of mind;
This momentary pause in its inevitable plunge.

Taking the forbidden leap,
The mind crosses an eternally gray space,
Bloodless air,
Finding the safety it seeks in an even darker haze,
A level plane called earth.
Damned by the memory of my fear,
I am condemned to carry my shame out with me.
I do so burdened with knowledge,
That I have joined with the ranks of history's cowards.

Sunlight greets me with disdain,
Recognizing my darker half.
Pretending I do not know its meaning,
I think of food,
Of water,
Of taking a pee.
Quickly packed away in the recesses of my heart,
Is the defeat,
Where it joins the others.

The Estimation of Primary Production Using Chlorophyll A and Diurnal Curves on a Shallow, Rapid Flowing Spring and Effluent in Greene County, Ohio

by

Gregg E. Savage and Tonya N. Fish

Introduction

A large amount of literature exists on the limnology of streams and the biology of flowing sea waters, but studies on community function rarely have been aimed at obtaining information on primary production. Several researchers, however, have laid the groundwork for estimating production in flowing waters by utilizing changes in dissolved oxygen concentrations (Odum 1956, 1957; Gunnerson and Bailey 1963; McDiffett et al. 1972). Others have chosen more indirect methods, such as measurement of chlorophyll and biomass of the periphyton (McConnell and Sigler 1959; Waters 1961).

The techniques employed to measure production in lotic systems are governed to a large extent by the particular environment (Ryther 1956). Based on the characteristics of OZ Spring, the site utilized in this study, chlorophyll *a* was measured to estimate production. The chlorophyll *a* method was used rather than total chlorophyll because chlorophyll *b* and care accessory pigments that vary among different taxonomic groups and do not play an active role in photosynthesis (Ryther 1956). Odum's (1957) diurnal curve method also was utilized in order to facilitate comparison since it has been suggested that more than one method be used. Odum's method generally is not considered satisfactory for determination of production in shallow, rapid systems as typified by OZ Spring (McConnell and Sigler 1959). It was used in this study, however, to compare the discrepancies between the two methods since neither has been applied extensively on small spring systems. Therefore, the purpose of this study was to examine whether the quantity of chlorophyll *a* and productivity increase along OZ Spring Run from its outflow to its point of convergence with the Little Miami River.

Methods and Materials

The study was conducted in OZ Spring, located in John Bryan State Park, Greene County, Ohio (sec 7 R8 T4 SENWSE-Clifton 7.5 min quadrangle). Five sites were designated as sampling points (Fig. 1). The spring issues from a dolomite bluff above the south bank of the Little Miami River and drains mainly agricultural lands (Butler and Hobbs 1982). OZ Spring emerges within a concrete cistern at an elevation of 290 m and flows through a heavily wooded area down a steep incline for approximately 90 m before entering the river (elev. 270 m). The springbrook's width varies from 0.5 m to 10 m along its length. The substrate is composed primarily of marl deposits, although some dolomite cobbles are present.

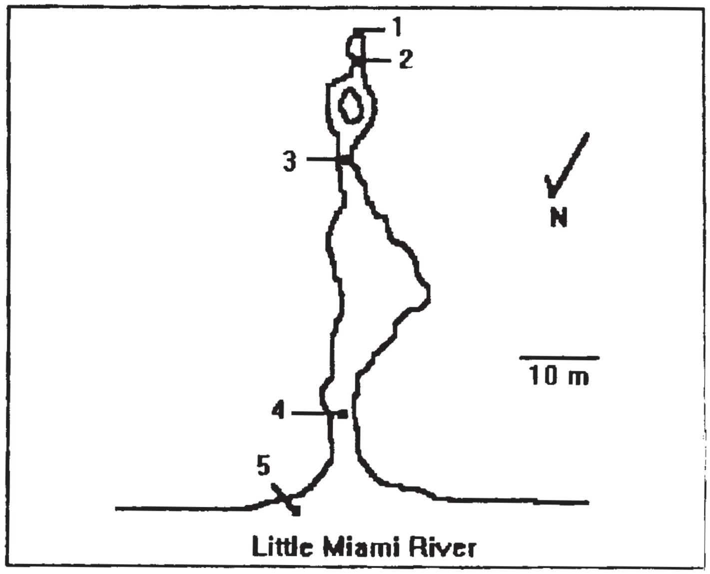
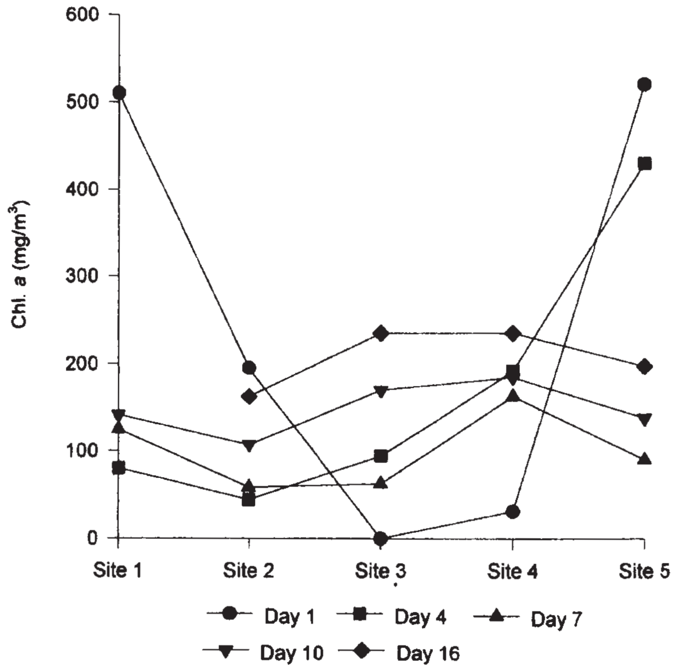


Fig.1. Location of the five sampling sites. Sites 1-4 on OZ Spring Run and site 5 on the Little Miami River (Butler and Hobbs 1992).

Water samples for chemical analyses were taken 2, 19 October 1993 from each of the five sampling stations. The samples were frozen and tested within 24 hours. Nitrate, orthophosphate, sulfate, and total iron levels were measured using the HACH Kit, model DREL/5. Dissolved oxygen and water temperature measurements were taken in the field using the YSI Oxygen Meter Model 54. Also, pH and specific conductance values were taken in the field with the Corning Meter, model M90. The amount of canopy cover was determined by visual estimation.

Two different techniques were used in the measurement of production. The first involved measuring chlorophyll *a* levels from artificial substrata. The methods for this technique were based directly on the procedures described in Clifford et al. (1992). There were, however, several modifications. The substrata utilized were dark-red unglazed clay tiles (7.5 x 7.5 x 0.8 cm). Five colonization periods were established: 1, 4, 7, 10, and 16 days. For each colonization period, a single row of three tiles was retrieved from each study site. Oxygen, pH, temperature, and specific conductance also were measured at each site while collecting tiles. During day four tile analysis, the power switch on the Gilford Spectrophotometer malfunctioned. From that point on, the Bausch and Lomb "Spectronic 20" was used to record absorption values. Absorption was recorded only at wave-



Fir. 2 *Chlorophyll a concentrations at the five sites along Oz Spring.*

lengths of 665 and 750 nm due to time restraints.

The second method involved measuring production by analysis of diurnal curves of dissolved oxygen (Odum 1957). On 2 and 10 October, 24-hour studies were conducted. Every two hours for the 24-hour period, measurements were taken of oxygen, temperature, pH, and specific conductance at each of the five sites. Water samples for chemical analysis also were collected from each site at 4 A.M. and 4 P.M. Samples were frozen immediately in the field and tested within 24 hours. The graphical analysis of a diurnal oxygen curve in order to obtain estimates of gross production from the field data were based on the procedure taken from Eckblad (1978:184).

The two-sample t-test was run to determine the statistical significance of the data. Based on three replicates per sampling period, chlorophyll *a* values were tested between sites at a probability of 5% ($p \leq .05$). Chlorophyll *a* levels also were analyzed within each site to determine if a 16 day colonization period allowed for maximum algal growth. Gross production between sites was examined by the same test based on two replicate samples.

Results

The water temperature at OZ Spring ranged from 11.3^{o}C at site 3 to 12.5^{o}C at site 5. The values for pH fluctuated between 7.7 at site 2 and 8.2 at site 5, while specific conductance varied from 605 umhos/cm at site 2 to 790 umhos/cm at site 1. Dissolved oxygen levels ranged from 4.8 mg/l at site 4 to 8.8 mg/l at site 3. Orthophosphate levels varied from 0.07 to 0.08 mg/l and nitrate values were relatively high, between 2.4 and 6.3 mg/l. Sulfate levels ranged from 43 to 78 mg/l, while total iron levels varied between 0.03 and 0.07 mg/l.

For each colonization period, the quantity of chlorophyll *a* generally increased from site 1 to site 5 (Fig. 2). The major exception was between sites 4 and 5 on days 7, 10, and 16 where levels decreased. Chlorophyll *a* never appeared to reach a maximum quantity during the study. Day 7 and 10 values and day 10 and 16 values were statistically different at every site ($p \leq .05$) except site 4 where day 7 and 10 levels were similar. At all sites except site 5, chlorophyll *a* was found in greater quantities on the tiles after 10 and 16 days than on the tiles with shorter colonization periods of 4 and 7 days. Day 1 levels were overlooked because the Gilford spectrophotometer was used on day 1 rather than the "Spectronic 20", which was used for the remainder of the light absorption measurements. When looking between sites, only sites 3 and 4 and sites 4 and 5 had similar amounts of chlorophyll *a* (Table 1). All other tests between sites indicated that chlorophyll *a* levels were statistically different ($p \leq .05$).

The final gross production values obtained from the diurnal oxygen curves are presented in Table 1. Sites 2, 3, and 4 were found to have statistically similar gross production rates. Rates were also similar between sites 1 and 5. Aside from these, the t-tests indicated statistical difference in gross production at all other sites ($p \leq .05$).

Table 1. *Chlorophyll a and gross production values at the five sampling stations.*

SITE	Chl. *a* (mg/m^3)[a]	Gross Prod. (g/m^2/day)
1	141.56[b]	1.4851
2	162.51	0.0857
3	235.22	0.0894
4	235.45	0.2281
5	197.47	1.5230

a based on day 16 data
b based on day 10 data

Discussion

By monitoring the change in chlorophyll *a* in lotic ecosystems, an accurate estimation of production can be formulated (McConnell and Sigler 1959). In this study, we found that the amount of chlorophyll *a* increased from site 1 to site 4, with a slight decrease at site 5. Therefore, it is assumed that production increased along the system, as hypothesized. Production levels were expected to increase from site 1 to site 5 based on the site environment. Site 1 had silty substrate with very little vegetation and light, which indicates an unproductive habitat. Site 5, however, was a more complex environment in terms of plant and animal growth, and therefore, should be more productive than site 1.

While chlorophyll *a* increased from site 1 and site 4, measurements for sites 3 and 4 only differed by 0.02 mg/m^3. One of two possible explanations for this is that a decrease in nitrate levels by 2,8 mg/l and oxygen levels by 4.0 mg/l between the sites, combined with other chemical variables that were unmeasured, may have limited algal colonization on the tiles, and therefore, chlorophyll *a* content. Secondly, with approximately 80% canopy cover at site 4, as opposed to 65% at site 3, it is possible that canopy cover limited the amount of light reaching the tiles, thereby restricting algal colonization.

Contrary to our expectations, chlorophyll *a* content decreased between sites 4 and 5. A probable explanation is that the tiles, which became covered with silt and allochthonous debris from upstream following day four, did not provide a substrate suitable for algal colonization. According to Clifford et al. (1992), algae need a substrate free of silt and leaves in order to colonize.

Clifford et al. (1992) reported that chlorophyll *a* levels peaked at day 10, and decreased or remained constant through day 16. The data from this study indicate that chlorophyll *a* levels from day 10 were statistically lower ($p \leq .05$) than those from day 16 at every site. Therefore, a 16 day colonization period may not have been an adequate amount of time for chlorophyll *a* values to reach a maximum.

The gross production values obtained from the diurnal curve method indicate that production levels increased from site 2 to site 5. The values of 0.0857 g/m^2/day to 1.5230 g/m^2/day were comparable to values reported by other researchers (Odum 1956; McConnell and Sigler 1959). The gross production rate for site 1, however, was not lower than the rates at sites 2 through 5, but instead it paralleled the rate at site 5. The high rate recorded at site 1 may have been a consequence of Odum's method which is not recommended for shallow, rapid flowing systems. For Odum's method, the diurnal pulse of dissolved oxygen resulted from the accumulation and depletion of photosynthetic oxygen rather than changes in the saturation value associated with diurnal temperature fluctuations, as was observed at site 1 (McConnell and Sigler 1959).

The gross production rate at site 5 was the highest among all sites, and supported the expectation that production would be highest here based on habitat. This rate also indicates that the chlorophyll *a* level reported at this site may have been low for reasons mentioned above. The rate of gross production at site 5 can be attributed to Odum's method, simply because the method is more applicable to larger systems such as the Little Miami River.

Past research suggests that carbon dioxide, nitrogen, phosphorous, and other chemical factors have no impact on primary production, and our data support this (Odum 1957; Whitford 1956). Individual ions such as sulfate, iron, and phosphate were approximately equal at each site, and nitrate levels only fluctuated at site 4. While this nitrate decrease may have influenced chlorophyll *a* levels at site 4, light is considered the primary factor limiting production along the system (Whitford 1965). At site 1, which had the greatest amount of shading due to a rock overhang, chlorophyll *a* concentration was the lowest. The greatest quantity of light reached the system at site 5 where the gross production rate was the highest. Although chlorophyll *a* content was not highest here, this is probably due to the lack of available substrate for algal colonization. Looking at the overall trend, production levels at sites 2, 3, and 4, all of which had moderate canopy cover, fell between those at sites 1 and 5. Therefore, the data support the theory that light is the limiting factor in production.

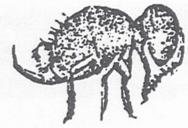
Although the focus of this paper was the trend in production along OZ Spring, a secondary purpose was to examine the applicability of each method as a means of measuring production. The primary method in this study, chlorophyll *a* concentrations, was apropos based on past research in shallow, fast flowing systems (McConnell and Sigler 1959). As hypothesized, the results indicate an increase in chlorophyll *a* along the spring run, and therefore, we consider this method an accurate indicator of production in systems similar to OZ Spring. As previously mentioned, Odum's diurnal curve method is not considered applicable to systems such as OZ Spring. Although gross production rates increased from site 2 to site 5, the surprisingly high rate at site 1 suggested that this trend may have been obtained by chance. Therefore, analysis of chlorophyll *a* content appeared to be better method for measuring production than did the diurnal curves.

As is common in all research, unforeseen obstacles arose throughout this study. Two problems warrant mention. First, a malfunction occurred in the power switch of the Gilford Spectrophotometer, and as a result, we resorted to using the "Spectronic 20" in order to read absorption values for the remainder of the study. The second problem that arose was the disappearance of tiles at site 1 on the seventh day. New tiles were placed at the site, but due to time restraints, we could only collect data through day 10 instead of day 16.

Although small systems such as OZ Spring play a critical role in the aquatic environment, they tend to be neglected by the scientific community. In order to obtain a better understanding of the interrelationships of the stream community, further research on production in shallow, rapid flowing systems is necessary. Also, while a variety of techniques for measuring primary production exist, further investigation of which methods work best in specific environments is essential.

Acknowledgements

We would like to thank Dr. Horton H. Hobbs III for his guidance throughout the study, and his help in editing the manuscript. Also, thank you to Dr. David Mason for his help with the spectrophotometric method, and Dr. Doug Andrews for statistical help. Thanks also to the staff at John Bryan State Park for allowing us to conduct our research on OZ Spring. This project was funded by the Wittenberg University Biology Department.



Refrences

Butler, M. J. IV and H. H. Hobbs III. 1982. Drift and Upstream Movement of Invertebrates in a Springbrook Community Ecosystem, Hydrobiol., Vol. 89, pp. 153-159.

Clifford, Hugh F., Richard J. Casey, and Karen A. Saffran. 1992. Short-term Colonization of Rough and Smooth Tiles by Benthic Macroinvertebrates and Algae (Chlorophyll *a*) in Two Streams, J. N. Am. Benthol. Soc., Vol. 11, No. 3, pp. 304-315.

Eckblad, James W. 1978. Laboratory Manual of Aquatic Biology. Dubuque, Iowa: Wm. C. Brown Co.

Gunnerson, C. G. and T. E. Bailey. 1963. Oxygen Relation ships in the Sacramento River, J. Sanit. Engng. Div., Vol. 89, pp. 95-124.

McConnell, W. J. and W. F. Sigler. 1959. Chlorophyll and Productivity in a Mountain River, Limnol. and Oceanogr., Vol. 4, pp. 335-351.

McDiffett, W. F., A. E. Carr, and D. L. Young. 1972. An Estimate of Primary Productivity in a Pennsylvania Trout Stream Using a Diurnal Oxygen Curve Technique, Amer. Midl. Nat., Vol. 8, pp. 564-570.

Odum, H. T. 1956. Primary Production in Flowing Waters, Limnol. and Oceanogr., Vol. 1, pp. 103-117.

Odum, H. T. 1957. Primary Production Measurements in Eleven Florida Springs and a Marine Turtlegrass Community, Limnol. and Oceanogr., Vol. 2, pp. 85-97.

Ryther, John, H. 1956. The Measurement of Primary Production, Limnol. and Oceanogr., Vol. 1, pp. 72-84.

Waters, T. F. 1961. Notes on the Chlorophyll Method of Estimating the Photosynthetic Capacity of Stream Periphyton, Limnol. and Oceanogr., Vol. 6, pp. 486-488.

Whitford, L. A. 1956. The Communities of Algae in the Springs and Spring Streams of Florida, Ecology, Vol. 37, No. 3, pp. 433-442.

Comparative Study of Amphipod (*Synurella dentata*) and Isopod (*Lirceus fontinalis*) Population Densities in Two Temperate Cold-Water Springs, Greene County, Ohio

by
Megan Porter
NSS 38171

Abstract

The impounded springheads of two temperate cold-water springs located in Greene County, Ohio, are compared in terms of population densities of the amphipod *Synurella dentata* and the isopod *Lirceus fontinalis*. Between the springs, population densities of *L. fontinalis* are significantly different, while densities of *S. dentata* are not. However, within the separate spring communities, the population densities fluctuate significantly. Physicochemical parameters examined indicated that the springheads maintain thermal and chemical stability.

Introduction

A spring can be defined as a natural discharge of water in the form of leakage or overflow from an aquifer through a natural opening in the soil/rock onto land or into a body of water (Hobbs, 1992; Rosenau et al. 1977). The natural flow of a spring is controlled by hydrologic and geologic factors, such as the amount and frequency of rainfall and the porosity and permeability of the aquifer (Hobbs, 1992; Rosenau et al. 1977). Springs also usually have nearly constant physical and chemical environments, making them unique freshwater habitats (Glazier, 1991). Compared with higher order streams, most springs have greater physical and chemical stability, smaller and more isolated habitat areas, and fewer large predators. Sloan (1956) has suggested that with respect to insect populations, these factors play a role in maintaining springheads as areas of biological as well as chemical constancy.

Springs can be classified based on many things, including type of aquifer (artesian or water table), type of opening through which the water surfaces (seepage or tubular), temperature of the water (thermal or non-thermal), and chemical characteristics of the spring water (Hobbs, 1992). Both of the springs examined in this study, Spring #1 and Oz spring, are classified as water table (free flow), seepage, non-thermal (temperate cold-water), hard water springs.

Temperate cold-water springs, such as #1 and Oz, are distinguished by a predominance of amphipods and/or isopods, gastropods, and triclads. It is not uncommon to find a community within a cold hard-water spring to contain over 10,000 individuals per m^2 (Glazier, 1991). In the springs selected for this study, the communities found at the springheads have been influenced by the presence of concrete basins, impounding the effluents as they emerge from beneath dolomite bluffs. These basins form pools that support macroinvertebrate communities consisting largely of amphipods (*Synurella dentata* Hubricht) and isopods (*Lirceus fontinalis* Rafinesque) (Butler and Hobbs, 1982).

The purpose of this study is to compare the population densities of the amphipods and isopods found in these two springs. Differences in community size and structure will be examined in relation to the physicochemical factors found in the temperate cold-water spring environment.

Methods and Materials

Study Site

The study was conducted in the headwaters of two temperate cold-water springs found on the southern side of Clifton Gorge in John Bryan State Park, Greene County, Ohio (Fig. 1). The stratigraphy of the gorge has a massive, porous unit known as the Cedarville Dolomite at the top of the column (Fig. 2). The Cedarville formation (Silurian age) is the dolomite from which the springs examined during the study emerged. Underneath the Cedarville is a less resistant, highly fractured formation known as the Springfield Dolomite (Silurian age). Beneath the Springfield is a more resistant formation named the Euphemia Dolomite (Silurian age). This arrangement causes water-tables perched on a less permeable layer (the Euphemia unit) to surface as springs at the level of the less resistant layers (the Springfield and Cedarville units) (Sweeting, 1973). Rain percolates through the permeable sediments and then moves down gradient along the top of the impermeable unit until it emerges at an outcrop (Hobbs, 1992). Characteristic of this type of aquifer system are intermittent springs, such as are found in many areas in Clifton Gorge; however, the springs in this study maintained constant flow.

The springs studied originate at an elevation of approximately 280 m and flow north to the Little Miami River (Butler, 1980). Although the springs surface in a heavily wooded area, they drain primarily agricultural lands (Butler and Hobbs, 1982). Oz Spring has a velocity of 1.9 cm/s and a discharge of 0.014 m^3/s (Hobbs and Butler, 1980; Butler and Hobbs, 1982). According to Meinzer's (1927) classification of springs based on magnitude of discharge, Oz Spring is a fourth order spring. No information on the discharge of Spring #1 is available at this time.

Both springs surface and are immediately impounded by concrete basins that collect the spring water as it flows from beneath a dolomite bluff. These basins fill to form pools of relatively low velocity. At Spring #1, the basin is 2.4 x 3.85 m and has a mean depth of 0.46 m. The riparian vegetation surrounding the site consists of a dense reed forest of Impatiens and a moderately wooded area of maple, oak, and sycamore trees. The trees shade the basin as well as provide a source of allochthonous input. The basin substrate consists of approximately 0.25 m of leaves, woody debris, and fine organic mud resting on top of a concrete base. Amphipoda (*S. dentata*), Isopoda (*L. fontinalis*), Megaloptera (*Sialis*), Trichoptera (Limnephilidae), Gerridae, Plecoptera (Perlidae), Odonata (*Aeshna*), *Physa*, *Sphaerium*, and salamanders have been observed in Spring #1.

The concrete basin impounding Oz spring measures 1.0 x 2.2 m with a mean depth of 0.12 m. At this site, the basin is situated under an overhang of the dolomite bluff from under which the spring effluent surfaces. The area this spring is located in is much more open, with less riparian vegetation present close to or overlying the basin. Therefore, allochthonous input is minimal. The substrate consists of a layer of marl deposits intermixed with gravel and cobble sized rocks, on top of which sits a layer of fine, silty mud. Amphipoda (*S. dentata*), Isopoda (*L. fontinalis*), *Physa*, and salamanders have been observed at this spring.

Experimental Design

In order to gain a rough estimate of population density, twelve 2.05 x 10^{-3} m^3 cages constructed of 1.27 cm^2 wire mesh were placed in each spring. The cages were filled with substrate and then buried. In Spring #1, the cages were filled with leaves and initially buried completely in the organic mud. Following the collection of the 23 October sample, however, the remaining cages were pulled and repositioned to sit on top of the organic mud layer in the leaf and woody debris zone. The reason for the repositioning of the cages was that greatly elevated numbers of organisms found in the 23 October sample indicated that an accurate estimation of population density was not being obtained from the buried cages. In Oz spring, the cages were filled with the gravel-marl substrate and then buried until the tops of the cages were submerged just below the surface of the water. No samples were taken for the first ten days to allow the spring communities to recover at least partially from the disturbance caused by the setting of the cages. Every three to five days after the initial recovery period, two cages were collected from each spring and the organisms present were counted. To gain a rough estimate of population densities before the cages were set and the basin habitat disturbed, a Hess sampler was used. The sampler was placed into the substrate, and the substrate was stirred while water was pushed through the net. The organisms found were identified and counted. The numbers of organisms observed were used to calculate population density in organisms/meter^2.

Water samples for chemical analyses were collected from the springheads on ten days throughout September, October, and November. The collected samples were frozen and tested within a week. Nitrate (NO_3-N), orthophosphate (PO_4-P), sulfate (SO_4-S), total iron (Fe), silica (SiO_2), and turbidity were measured using the HACH kit, model DREL/5. Dissolved oxygen was determined using the Azide modification of the Winkler Method. Oxygen saturation was calculated using an oxygen saturation nomogram (Wetzel and Likens, 1979). The methyl orange alkalinity method was used to determine alkalinity. Specific conductance was measured in the field using a YSI model 33 S-C-T meter and corrected using a conductivity conversion table (Golterman et al. 1978). Light readings were taken four times at each site during the sampling periods with a Whatman 840006 photosensor light meter. The values were then used to calculate the mean light value of that sample time. Because a working pH meter was not available to take into the field, pH values were measured from the collected water samples using a Hanna instruments 9224 microprocessor printing pH meter.

To determine if physicochemical parameters or population densities differed significantly between Spring #1 and Oz Spring the Mann-Whitney test was performed. Chi-square analysis was used to determine significant differences between physicochemical values and populations within each spring individually.

Results

Statistically, temperature in both springs remained stable. Temperature in Spring #1 varied 2.5^{o} with a low of 10.4^{o}C and a high of 12.9^{o}C. Oz Spring varied 2.1^{o} with a low of 10.8^{o}C and a high of 12.9^{o}C. In comparison, air temperature fluctuated 59^{o}C over the seven weeks of the study. pH in both springs did not change significantly. Spring #1 had a pH range of 7.74 to 8.01, while Oz Spring ranged from 7.73 to 8.17. Specific conductance did not remain constant in either spring. In Spring #1, specific conductance ranged from 530 to 783 umhos/cm. In Oz Spring the range was smaller, from 650 to 754 umhos/cm. Oxygen saturation was constant in Oz Spring but changed significantly in Spring #1. Saturation ranged from 59% to 135% in Spring #1 and from 69% to 100% in Oz Spring. Except for the first sample time at Spring #1, alkalinity did not change significantly in either spring with a range of 247 to 256 mg/l $CaCO_3$ in #1 and a range of 248.6 to 257.2 mg/l $CaCO_3$ in Oz. Light readings were lower at Oz Spring under the dolomite overhang than at Spring #1 under the canopy of trees.

Turbidity ranges were similar in both springs, from 0 to 6 FTU in #1 and 0 to 7 FTU in Oz; however, statistically, turbidity was constant in #1 and showed significant change in Oz. Overall, nitrate-nitrogen values were stable in both springs, varying 2.6 mg/l (3.3-5.9 mg/l) in Spring #1 and 3.6 mg/l (4.4-8 mg/l) in Oz Spring. Silica showed no significant change in either spring. Spring #1 ranged from 7.3 to 12.2 mg/l, while Oz Spring fluctuated between 7.7 and 12 mg/l. Orthophosphate did not fluctuate significantly in either spring. In Spring #1 orthophosphate varied 0.54 mg/l (0.02-0.56 mg/l). In Oz Spring, it varied 0.52 mg/l (0.08-0.6 mg/l). Iron in

Spring #1 showed a slightly decreasing trend, while in Oz Spring the trend increased slightly, however, neither trend is significant. Iron changed 0.05 mg/l in Spring #1, while in Oz Spring it varied 0.13 mg/l. Generally, sulfate levels in both springs increased, although not significantly. Sulfate ranged from 49 to 51 mg/l in Spring #1 and from 37 to 58 mg/l in Oz Spring.

The population density of *S. dentata* increased over time in Spring #1 (Fig. 3). One sample collected on day 13 in Spring #1 had significantly higher numbers of *S. dentata* than any other sample counted during the study. In Oz Spring, *S. dentata* density demonstrated a decreasing trend (Fig. 3). *L. fontinalis* population density showed a significantly increasing trend in Spring #1. In Oz Spring *L. fontinalis* population density had a decreasing trend (Fig. 4). Other organisms collected in the springheads include *Sialis*, *Aeshna*, *Physa*, *Sphaerium*, Limnephilidae, Gerridae, Perlidae, and Oligochaetes.

Statistically, the amphipod and isopod populations found in Spring #1 are significantly different than those found in Oz Spring. However, if the 23 October sample 2 is omitted, the amphipod populations between the two springs are not significantly different. The physicochemical parameters are not statistically different between the two springs.

The population densities of individual species considered separately do not remain stable. During the time research was conducted, all of the populations examined had significantly fluctuating densities.

Discussion

Butler and Hobbs (1982) found Oz Spring to have a mean temperature ranging between 9.5 and 10°C, an oxygen saturation level that remained above 80%, and orthophosphate (0.04-0.07 mg/l), nitrate (4.5-6.7 mg/l), pH (7.0-7.6), conductivity (550-600 umhos/cm), and alkalinity (280-315 mg/l $CaCO_3$) to remain relatively constant. The data from this study support these findings except for the significant fluctuations seen in the conductivity measurements of both springs and the % oxygen saturation of Spring #1. The high nitrate concentrations result from the drainage of agricultural lands. One possibility for the high sulfate concentrations may be the leaching of superphosphate or ammonium fertilizers. Sulfate in ground water can also originate from the oxidation of ferrous disulfides found in carbonate rocks (Langmuir, 1971). The high silica concentrations recorded in these springs have not been previously observed in this area. The silica concentrations found are approaching saturated conditions in the spring water. One possible source of silica may be the loess silt found in this area, which is composed mostly of quartz (Ritter, pers. comm.). Rain water may solution out silica from this quartz loess, carrying it into the groundwater. Storm events may also cause pulses of high nutrient concentrations. In both springs, the highest orthophosphate concentrations recorded occur the day after a storm event.

Both springs examined maintained thermal and chemical stability. Because of this stability, the only variable important to these impounded springhead habitats is allochthonous input. Therefore, the difference in population densities between Spring #1 and Oz Spring can be attributed to the difference in the amount of allochthonous input that the springhead receives (Figs. 3, 4). Spring #1 had higher densities of both populations as well as a large allochthonous input from riparian vegetation. Oz Spring had lower densities of both populations and receives little input from the surrounding vegetation.

One factor that did affect the observed population densities was sampling technique. Before 23 October, all of the samples collected in Spring #1 were taken from the organic mud found below the leaf and woody debris zone. When the cages were pulled for sampling, a slight odor of anaerobic decomposition was noticed. In general, amphipods and isopods cannot survive in and anaerobic environment. According to Pennak (1953), amphipods prefer to hide in vegetation or between debris and stones. Therefore, not many organisms are found in these early samples. Sample 2 from Spring #1, 23 October, was sitting above the organic mud when it was collected. This may account for the elevated numbers of amphipods and isopods found in this sample. Another possibility is that the leaf-filled cage created a more suitable habitat for the aquatic macroinvertebrates found in the basin than the natural habitat. Although none of the other replicates counted contained as many amphipods as this sample did, cages collected after being moved above the layer of mud contained more amphipods than earlier samples.

There are many sources of error in this study. Attempting to sample in a small basin without destroying the habitat or the population is difficult. The technique of using cages to sample was chosen to reduce the destructive effect of the study. However, because the placement of the cages was changed half way through the study, the population was disturbed twice instead of just once at the beginning of the study. Therefore, the community had to recover from a disturbance twice, possibly affecting the observed population densities. The aspect of disturbance plays an unknown role in this study.

Because the basin does not support a uniform habitat in every area, two samples were taken from each site on each sample date and treated as replicates. The basins were not large enough to hold more cages, or more replicates would have been collected.

There were large sources of error in the method used for chemical analysis of the water samples. The HACH kit is unreliable at times. Also, some of the samples analyzed using the Hach kit were not tested until several days after collection. This may have affected the concentrations of some of the chemical parameters measured. Due to lack of the proper chemicals and a malfunctioning digital titrator, water hardness was not tested. A significant error may be present in pH values because the readings were not taken in the field. Also, data taken early in the study had to be disregarded due to the unreliability of one meter and the destruction of another.

Conclusions

Although many aspects of springs have been studied, the difficulty in sampling these ecosystems has left many unanswered questions. Research should be continued on the effects of disturbances on spring communities, agricultural impacts, and with relation to this study, the effect of building basins at the headwaters of streams. Studies such as these need to be continued to further our understanding of spring ecosystems.

Acknowledgments

I would like to thank Lea Greenwood and Steve Kronk for acting as my unofficial research partners, R. J. Groeber for providing me with weather data, Dr. Ritter for his information, Dr. H. H. Hobbs III for all of his support and help, and Josefin Titelman for helping complete this project.

Literature Cited

Carman, J. E. 1946. The geologic interpretation of scenic features in Ohio. The Ohio Journal of Science, 5:241-283.

Butler IV, M. J. 1980. A study of the chemical and physical parameters of a temperate hardwater spring in John Bryan State Park, Greene County, Ohio. The Ohio Journal of Science 80.

Butler IV, M. J. and H. H. Hobbs III. 1982. Drift and upstream movement of invertebrates in a springbrook community ecosystem. Hydrobiologia 89:153-159.

Glazier, D. S. 1991. The fauna of North American temperate cold springs: patterns and hypotheses. Freshwater Biology 26:527-542.

Golterman, H. L., R. S. Clymo, and M. A. M. Ohnstad. 1978. Methods for physical and chemical analysis of fresh waters. Oxford: Blackwell Scientific Publications.

Hobbs III, H. H. 1992. Caves and Springs. In C. T. Hackney, S. M. Adams, and W. H. Martin (eds.), Biodiversity of the Southeastern United States, Aquatic Communities. New York: John Wiley & Sons, Inc., pp. 59-131.

Hobbs III, H. H. and M. J. Butler IV. 1980. Community dynamics of a cold hardwater spring. American Society of Limnology and Oceanography, abstracts, 28.

Langmuir, D. 1971. The geochemistry of some carbonate ground waters in central Pennsylvania. Geochimica et Cosmochimica Acta 35:1023-1045.

Meinzer, O. E. 1927. Large Springs in the United States. United States Geological Survey, Water Supply Papers 557.

Pennak, R. W. 1953. Fresh-water invertebrates of the United States. The Ronald Press Company: New York.

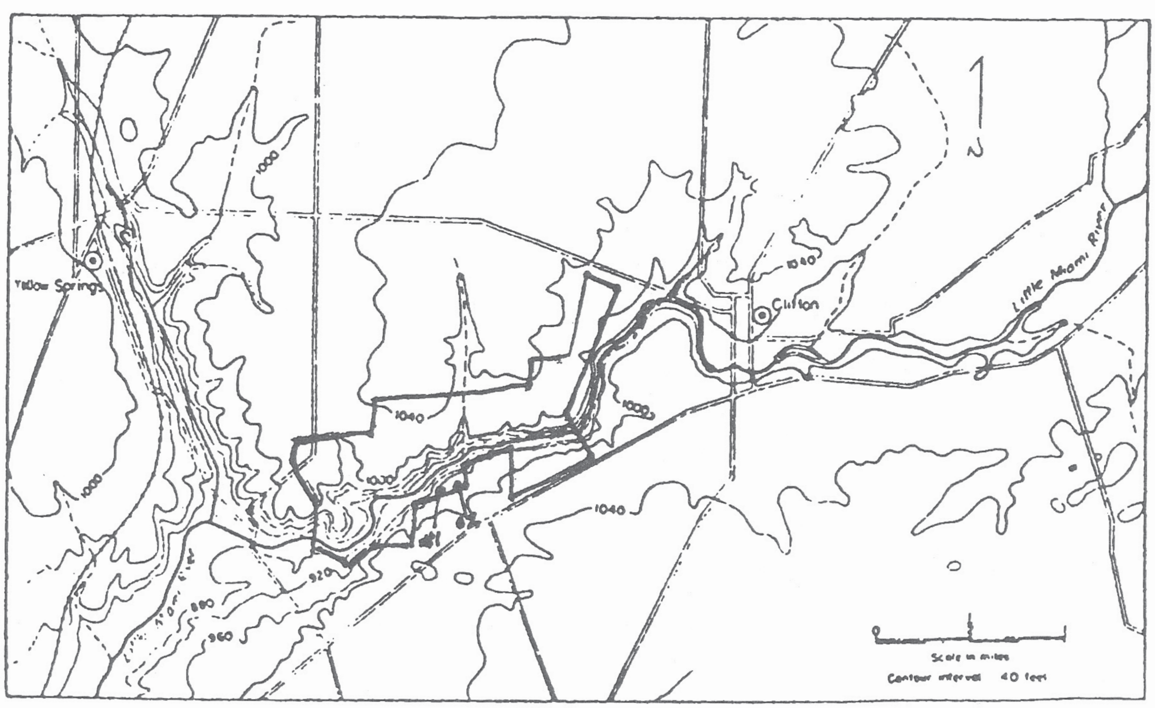
Ritter. J. B. Personal Communication. Wittenberg University, Geology Department.

Rosenau, J. C., G. L. Faulkner, C. W. Hendry, Jr., and R. W. Hull. 1977. Springs of Florida. Florida Bureau of Geology Bulletin 31:1-461.

Sloan, W. C. 1956. The distribution of aquatic insects in two Florida springs. *Ecology* 37(1):81-98.

Sweeting, M. M. 1973. Karst Landforms. Columbia University Press, New York, pp.362.

Wetzel , R. G. and G. E. Likens. 1979. Limnological Analysis. W. B. Saunders Company:Philadelphia.



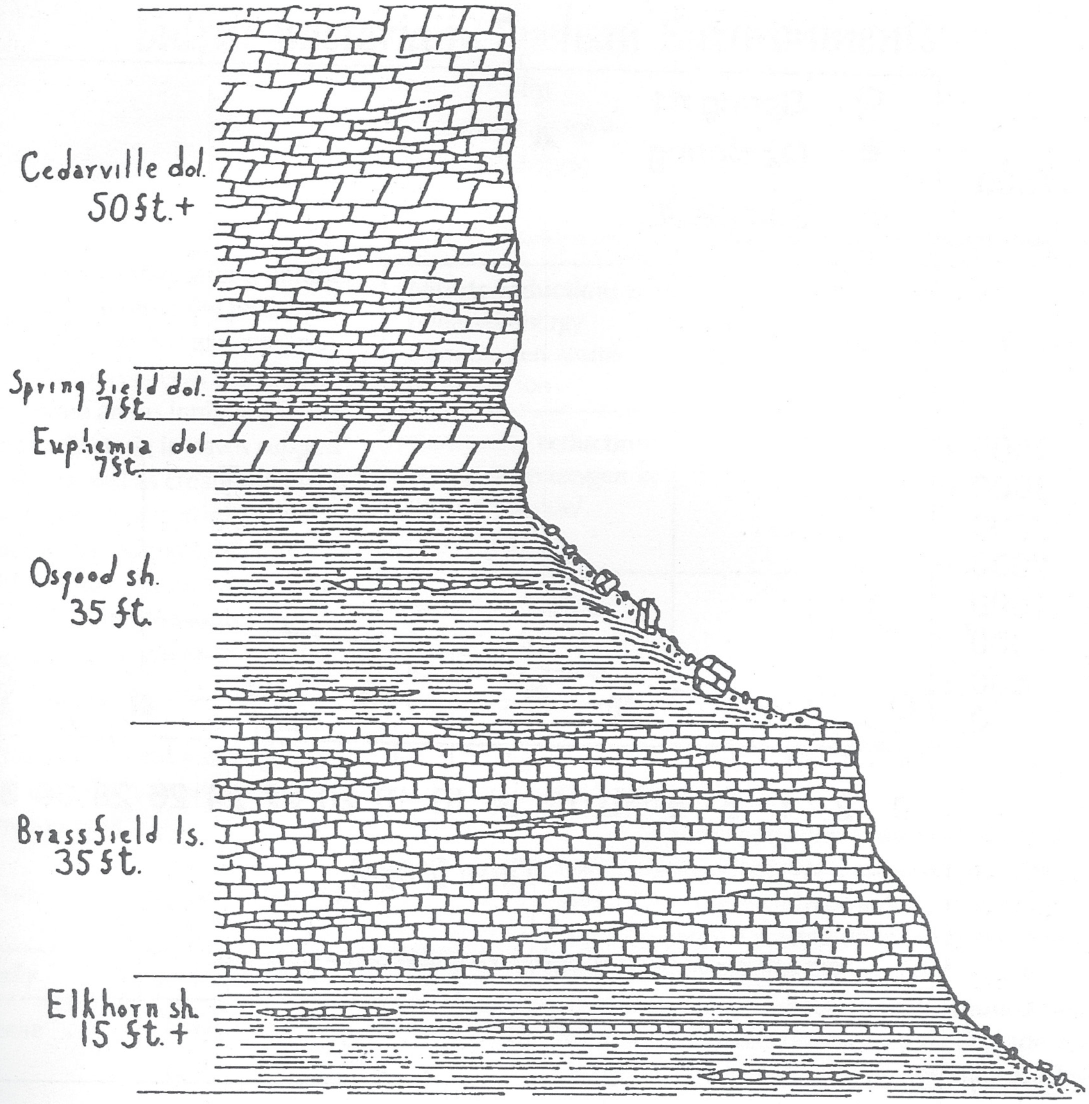
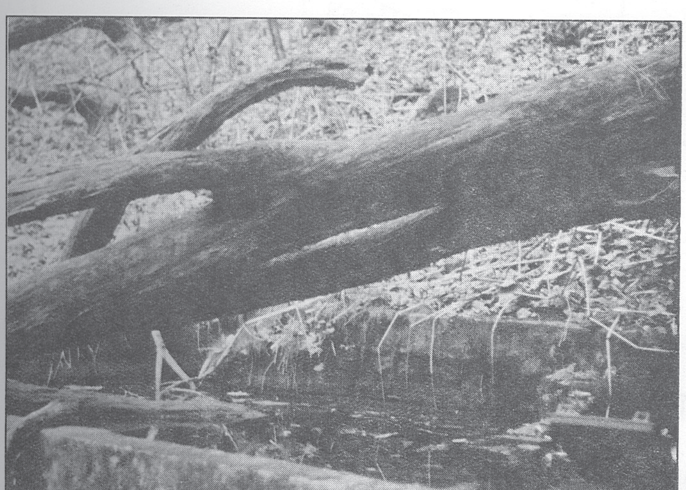
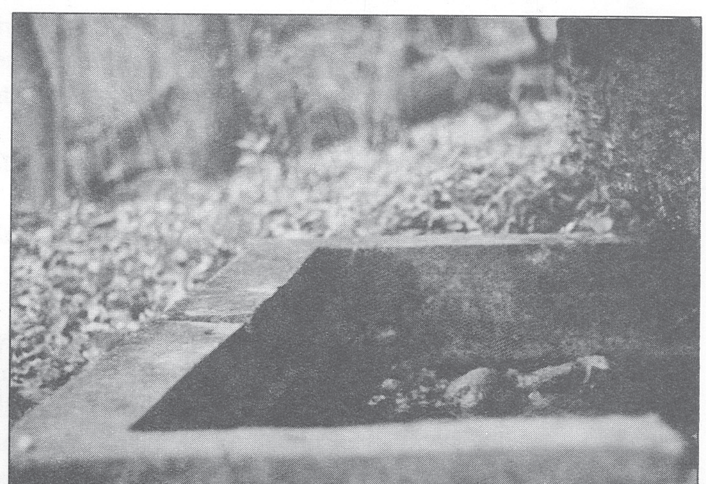


Figure 2. Sratigraphy of Clifton Gorge, John Bryan State Park, Greene County, Ohio (Carman, 1946).



Concrete basin impounding spring #1.



Spring effluent of Oz Spring.

Sulfur Bacteria in Spelean Environments

by
Annette Summers
NSS 31319

ABSTRACT

Sulfurous bacteria thrive within unique ecosystems where they are often the primary producers of food and energy for that community. Of the many environments in which sulfur bacteria are found, none are as intriguing as the spelean environment. Bacteria in caves support higher trophic levels, as well as create their own energy. Chemical reactions occurring within cavern waters induced by microbial activity have been studied recently. Results show that limestone dissolution can be due to the presence of sulfurous bacteria, in which they act as catalysts to speleogenetic processes and might increase the dissolutional power of the water. This review paper is a compilation of literature and research done on sulfur bacteria as they affect the cave environment.

Table 1. Equations for energy from anaerabic respiration. Taken from Postgate (9188).

Nitrate reduction: released energy from oxygen atoms of nitrate ion	$C_5H_2OH + 2NaNO_3O \rightarrow 2NaHCO_3 + H_2O + N_2$
Carbonate reduction: energy from oxygen in carbon dioxide/ carbonate	$4H_2 + CO_2 \rightarrow CH_4 + 2H_2O$
Sulfate reduction: energy obtained from sulfate ion in organic matter	$4H_2 + NaSO_4 \rightarrow 4H_2O + Na_2S$ or $2H_2SO_4 \rightarrow S_2 + 2H_2O + 3O_2$

Table 2. Sulfur Bacteria that Store Elemental Sulfur in the Cell, from Lackey et al. (1965).

Family	Genus
Thiorhodaceae	*Thiosarcina*, *Thiopedia*, *Thiocapsa*, *Thiodictyon*, *Thiothece*, *Lamprocystis*, *Amoebacter*, *Thiopolycoccus*, *Thiospirillum*, *Rhabdomonas*, *Rhodothece*, *Chromatium*
Chlorobacteriaceae	*Chlorobacterium*, *Clathrochloris*
Thiobacteriaceae	*Thiobacterium*, *Thiococcus*, *Macromonas*, *Thiovulum*, *Thiospira*, *Thiobacillus*
Chlamydobacteriaceae	*Sphaerotilus*
Beggiatoceae	*Thiothrix*, *Beggiatoa*, *Thiospirillopsis*, *Thioploca*
Achromatiaceae	*Achromatium*
Incertaesedis	*Thiodendron*

INTRODUCTION

Unusual organisms associated with thermomineral waters create energy for themselves and other life independent of the photosynthetic activity of green plants. Diverse fauna discovered around deep sea hydrothermal vents indicate that the food source of this aphotic environment is created by the chemoautotrophic production of the microbiota (Grassle 1982). Bacteria degrade complex materials and liberate simpler substances that have higher energy levels (Table 1).

Some chemolithoautotrophic bacteria derive energy from the oxidation of inorganic molecules such as nitrogen, sulfur, and iron compounds, or from the oxidation of gaseous hydrogen; this is referred to as bacterial catabolism (1). This reaction is different from anabolism, which requires energy input for the breakdown of a substrate (2). Other bacteria oxidize organic matter for carbohydrate synthesis and generate elemental substances as a result (Cole 1983).

$$\text{Substrate} \rightarrow \text{(catabolism)} \rightarrow \text{breakdown products} + \text{energy} \quad (1)$$

$$\text{Substrate} + \text{energy} \rightarrow \text{(anabolism)} \rightarrow \text{products of synthesis} \quad (2)$$

Anaerobic chemoautotrophs occupy numerous ecological systems where oxygen is absent or present in low concentrations and where substrata are devoid of light (Lackey et al. 1965). Such environments include estuarine and marine sediments, hydrocarbon traps, pond and lake muds, caverns, deep sea hydrothermal vents, polluted soil and water, sewage treatment plants, compost, and dung heaps. For most organisms, the anoxic zone is lethal, but because the anaerobes lack the enzyme catalase (enzyme that decomposes hydrogen peroxide into oxygen and water), they

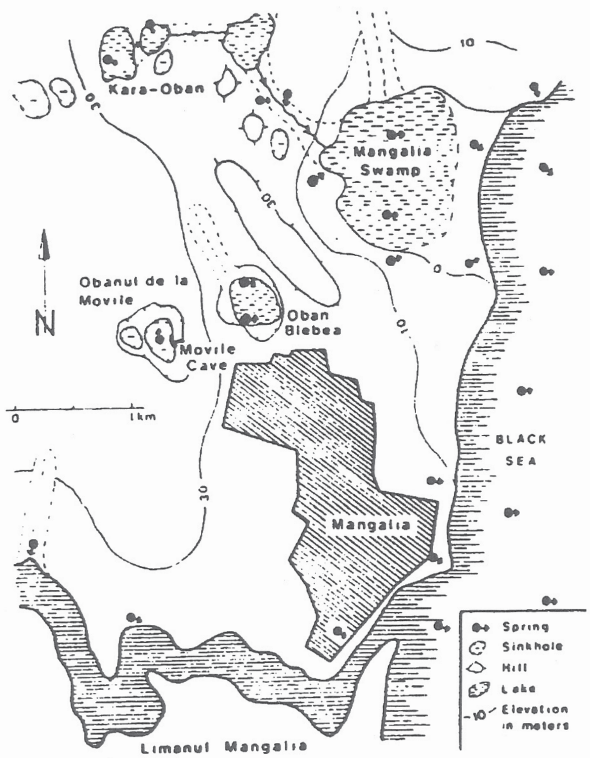


Figure 1a. Location map for Movile Cave, near the city of Mangalia.

can survive (Cole 1983).

This study will focus on the anaerobic utilization of sulfur, in particular elemental sulfur (S_0), sulfide (S_2), and sulfate (SO_4^{2-}), by sulfate-reducing and sulfur-oxidizing bacteria, although microbiota can utilize other substrates for respiration (Table 1; Postgate 1988). Sulfur can be liberated as a constituent of amino acids and various organic or inorganic compounds abundant in soil and water (fresh and saline). This material can be absorbed by the sulfur bacteria (Ellis 1932). Sulfate-reducing bacteria, such as those belonging to the genus *Desulfovibrio*, require oxygen atoms in a sulfate ion, and organic matter or hydrogen oxidation, to obtain energy by transforming sulfate to sulfur and hydrogen sulfide (H_2S) (Table 1; Cole 1983). Other sulfate-reducing bacteria attack organic material, degrading the sulfur-containing protein compounds cysteine, cystine, and methionine (Cole 1983). Sulfur-oxidizers, however, procure energy differently; these bacteria require a hydrogen donor from H_2S for the reduction of carbon dioxide, regenerating elemental sulfur as a byproduct of the converted energy (Cole 1983). *Beggiatoa* spp. are colorless sulfur bacteria and are suitable examples of sulfur-oxidizers, where they occupy the watery anoxic-oxic interface and require an organic carbon source for metabolism.

In general, the term "sulfur bacteria" can be applied to a restricted group of bacteria that 1) contain visible sulfur granules in their cells, aside from all living organisms that possess sulfur as a protoplasmic constituent; 2) produce H_2S in the breakdown of organic matter; and 3) oxidize or reduce sulfur or sulfur compounds, using or storing it as a source of energy (Lackey et al. 1965). Table 2 lists the families and genera of bacteria that are believed to store elemental sulfur within the cell.

There are many examples of sulfur bacteria occupying caves (Høeg 1946, Caumartin 1963, Hobbs 1981, Culver 1982, Sarbu et al. 1991, Hobbs 1992, Sarbu and Popa 1992, Northup et al. 1994, Cunningham et al. 1994, Kane et al. 1994, Mylroie et al. 1994, Sarbu et al. 1994, Vlasceanu and Kinkle 1994). Studies have shown that the presence of chemolithoautotrophic microbiota in spelean habitats (e.g., subterranean pools, streams, corrosive residues, etc.) contribute to peculiar adaptations of higher trophic organisms (Sarbu and Popa 1992, Kane et al. 1994). Sulfur bacteria provide nutrients to the cavern ecosystem by creating H_2S that contains part of the chemical energy utilized by other organisms (Fenchel and Jørgensen 1977). These chemosynthetic autothrophs are primary producers (Hobbs 1981, Culver 1982) in an ecosystem dependent on the presence of sulfur, referred to as a sulfuretum (Postgate 1988).

Cave communities are regarded as simple systems having few species and low productivity (Hobbs 1992). This habitat is a limited ecosystem; life can exist only in narrowly-ranged abiotic conditions where special adaptations of complex organisms have evolved to suit that environment. Most caves lack an autotropic component and organisms must depend on exogenous organic material from the surface. However, an example of an unconventional spelean ecosystem is Movile Cave, located in the limestone plateau of Southern Dobrogea, Romania (Figures 1a, 1b, and 1c). Thick, floating microbial mats composed of chemoautotrophic bacteria cover walls and water surfaces, using H_2S as an energy source. Although other caves have been discovered with populations of bacteria that derive energy from H_2S degradation, Movile Cave is by far the most pristine (Summers 1994). This cave ecosystem is believed to be the first that relies exclusively on autochthonous primary production (Sarbu and Popa 1992).

Recent geological investigations indicate that bacteria contribute to speleogenesis (cave development) (Hill 1990, Hill 1994, James 1994a, Martin and Brigmon 1994). Sulfur-oxidizing bacteria concentrate H_2S; this acid then chemically bonds with water and dissolves limestone. These bacteria may stimulate the accumulation of gypsum ($CaSO_4$) and elemental sulfur. Calcium carbonate ($CaCO_3$) also may be precipitated from the interactions between sulfur bacteria, H_2S-rich waters, and limestone (Sarbu pers. comm. 1995). Hydrocarbon reservoirs (oil and gas) may provide nutrients for bacteria, reinforcing dissolution and secondary mineral deposits. For example, Carlsbad Caverns, Lechuguilla Cave, and other caves in the Guadalupe Mountains have speleogenetic histories initiated by microbiota interacting with oil and brines in the Delaware Basin of New Mexico and Texas (Hill 1987, Hill 1990, Cunningham et al. 1994, Hill 1994).

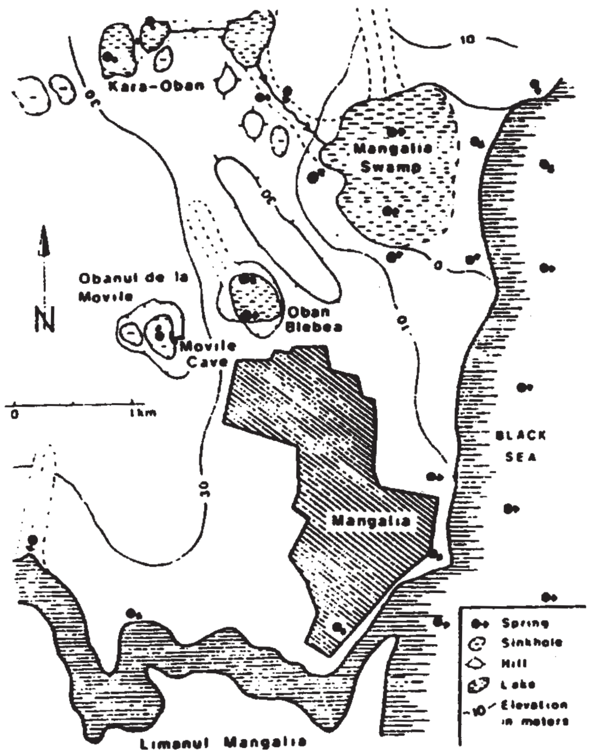


Figure 1a. Location map for Movile Cave, near the city of Mangalia.

can survive (Cole 1983).

This study will focus on the anaerobic utilization of sulfur, in particular elemental sulfur (S_0), sulfide (S_2), and sulfate (SO_4^{2-}), by sulfate-reducing and sulfur-oxidizing bacteria, although microbiota can utilize other substrates for respiration (Table 1; Postgate 1988). Sulfur can be liberated as a constituent of amino acids and various organic or inorganic compounds abundant in soil and water (fresh and saline). This material can be absorbed by the sulfur bacteria (Ellis 1932). Sulfate-reducing bacteria, such as those belonging to the genus *Desulfovibrio,* require oxygen atoms in a sulfate ion, and organic matter or hydrogen oxidation, to obtain energy by transforming sulfate to sulfur and hydrogen sulfide (H_2S) (Table 1; Cole 1983). Other sulfate-reducing bacteria attack organic material, degrading the sulfur-containing protein compounds cysteine, cystine, and methionine (Cole 1983). Sulfur-oxidizers, however, procure energy differently; these bacteria require a hydrogen donor from H_2S for the reduction of carbon dioxide, regenerating elemental sulfur as a byproduct of the converted energy (Cole 1983). *Beggiatoa* spp. are colorless sulfur bacteria and are suitable examples of sulfur-oxidizers, where they occupy the watery anoxic-oxic interface and require an organic carbon source for metabolism.

In general, the term "sulfur bacteria" can be applied to a restricted group of bacteria that 1) contain visible sulfur granules in their cells, aside from all living organisms that possess sulfur as a protoplasmic constituent; 2) produce H_2S in the breakdown of organic matter; and 3) oxidize or reduce sulfur or sulfur compounds, using or storing it as a source of energy (Lackey et al. 1965). Table 2 lists the families and genera of bacteria that are believed to store elemental sulfur within the cell.

There are many examples of sulfur bacteria occupying caves (Høeg 1946, Caumartin 1963, Hobbs 1981, Culver 1982, Sarbu et al. 1991, Hobbs 1992, Sarbu and Popa 1992, Northup et al. 1994, Cunningham et al. 1994, Kane et al. 1994, Mylroie et al. 1994, Sarbu et al. 1994, Vlasceanu and Kinkle 1994). Studies have shown that the presence of chemolithoautotrophic microbiota in spelean habitats (e.g., subterranean pools, streams, corrosive residues, etc.) contribute to peculiar adaptations of higher trophic organisms (Sarbu and Popa 1992, Kane et al. 1994). Sulfur bacteria provide nutrients to the cavern ecosystem by creating H_2S that contains part of the chemical energy utilized by other organisms (Fenchel and Jørgensen 1977). These chemosynthetic autothrophs are primary producers (Hobbs 1981, Culver 1982) in an ecosystem dependent on the presence of sulfur, referred to as a sulfuretum (Postgate 1988).

Cave communities are regarded as simple systems having few species and low productivity (Hobbs 1992). This habitat is a limited ecosystem; life can exist only in narrowly-ranged abiotic conditions where special adaptations of complex organisms have evolved to suit that environment. Most caves lack an autotropic component and organisms must depend on exogenous organic material from the surface. However, an example of an unconventional spelean ecosystem is Movile Cave, located in the limestone plateau of Southern Dobrogea, Romania (Figures 1a, 1b, and 1c). Thick, floating microbial mats composed of chemoautotrophic bacteria cover walls and water surfaces, using H_2S as an energy source. Although other caves have been discovered with populations of bacteria that derive energy from H_2S degradation, Movile Cave is by far the most pristine (Summers 1994). This cave ecosystem is believed to be the first that relies exclusively on autochthonous primary production (Sarbu and Popa 1992).

Recent geological investigations indicate that bacteria contribute to speleogenesis (cave development) (Hill 1990, Hill 1994, James 1994a, Martin and Brigmon 1994). Sulfur-oxidizing bacteria concentrate H_2S; this acid then chemically bonds with water and dissolves limestone. These bacteria may stimulate the accumulation of gypsum ($CaSO_4$) and elemental sulfur. Calcium carbonate ($CaCO_3$) also may be precipitated from the interactions between sulfur bacteria, H_2S-rich waters, and limestone (Sarbu pers. comm. 1995). Hydrocarbon reservoirs (oil and gas) may provide nutrients for bacteria, reinforcing dissolution and secondary mineral deposits. For example, Carlsbad Caverns, Lechuguilla Cave, and other caves in the Guadalupe Mountains have speleogenetic histories initiated by microbiota interacting with oil and brines in the Delaware Basin of New Mexico and Texas (Hill 1987, Hill 1990, Cunningham et al. 1994, Hill 1994).

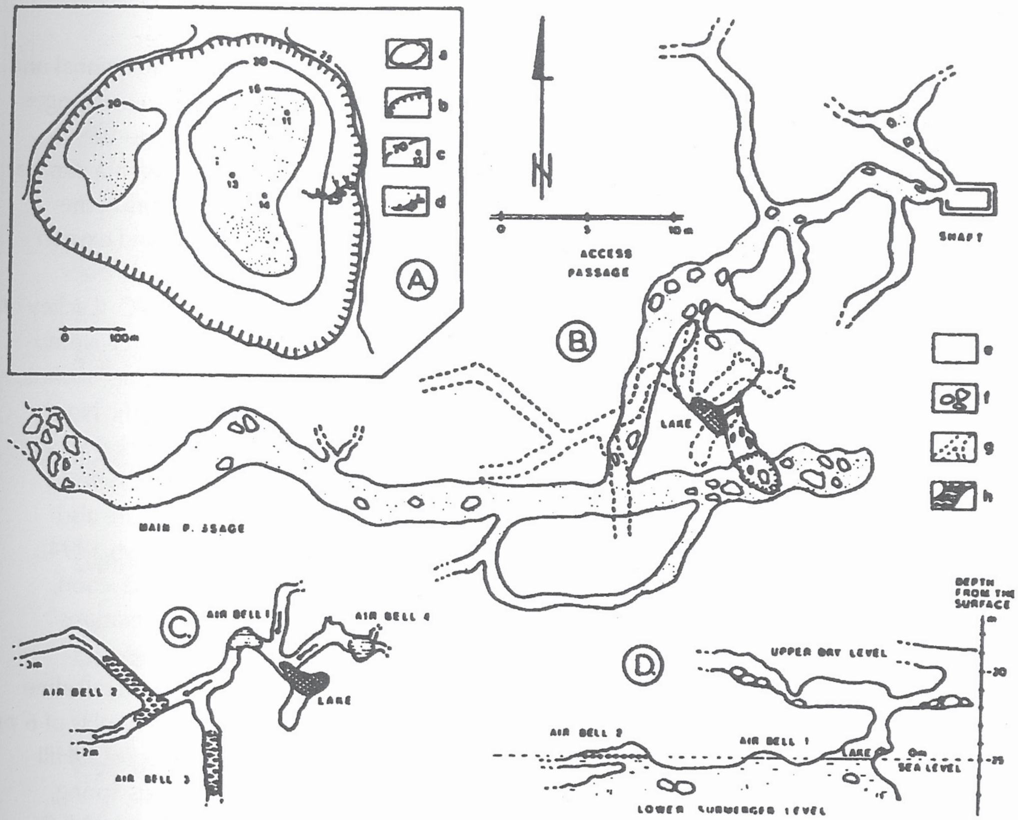


Figure 1 b.The Movile Cave.

A: location of the cave in the "Obanul de la Movile" sinkhole;
a. bottom of the sinkhole;
b. edge of sinkhole;
c. altitude in meters;
d. cave.

B: plan of the upper level of the cave;
e. clay;
f. breakdown;
g. lower level;
h. air bells containing floating mats.

C: plan of submerged level of cave.

D: cross-section of the Lake Room.

This review will focus on the important roles sulfur bacteria play in spelean environments by describing the functions of sulfate reduction and sulfur oxidation in speleogenesis and by detailing parameters that are important to the growth and abundance of microbiota. Specific discussion will address caves like those in the Guadalupe Mountains and Movile Cave.

METHODS AND MATERIALS

The study of sulfur bacteria has been a tenuous discipline because even the official definition of the term "sulfur bacteria" has been debated (Lackey et al. 1965). The main problem for taxonomists has been that most genera historically have not been grown in pure culture successfully, nor had bacteria been isolated and maintained with much mastery (Ellis 1932, Winogradsky 1949, Lackey et al. 1965, Sarbu pers. comm. 1995). Observations were made decades ago from materials in the microbes' natural habitat or from enrichment cultures (Mezzino et al. 1984).

Through time, research methods became more reflective of technology and experiments became more chemically dependent. Most recently, methodology utilizes microscopes and scanning electron instruments, typically utilized in microbiology and cellular disciplines. However, the pure culture is vitally imporant for bacterial analyses. Successful cultures achieved by Lackey et al. (1965), La Riviere (1961), Mezzino et al. (1984), Nelson et al. (1986), and Schmidt et al. (1987) involved growing bacteria in a variety of media.

Current researchers have seen the development of new tools for microbial studies, including the use of nucleic acid sequencing, flourescein-labelled RNA probes, DNA probes, and gene amplification by the polymerase chain reaction (PCR) (Kane et al. 1994). According to Pace (1994), molecular methods for microbial ecosystem analysis based on ribosomal RNA sequences should allow researchers to identify organisms without the requirement of cultivating them. He suggests cloning environmental DNA and nucleotide sequences so that phylogenetic comparative analysis of the sequences can be used to determine evolutionary relationships between the members of the community and cultivated species. Ghiorse (1994) introduced more sensitive direct microscopic imaging of bacterial cells and a computerized laser scanning microscope (LSM) to indicate the bacteria

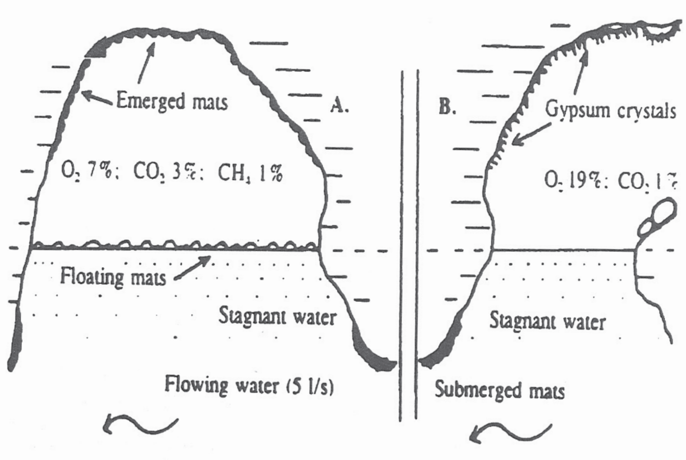


Figure 1c. Cross-section of air bells within Movile Cave. Map and information from Sarbu and Popa (1992).

present in the vadose zone. Microscopes are being used to determine if material in thermomineral waters contain both microorganisms and non-living particulate matter (Kane et al. 1994). One powerful technique for the detection of specific bacteria (because using nucleic acid stains can often stain clay colloids and non-cellular organic matter) *in situ* has been the utilization of immunofluorescence microscopy using strain-specific antibodies with fluorochromes (i.e., fluorescein) (Kane et al. 1994). Kane et al. are also using a relatively new method that distinguishes cell viability, using a DNA gyrase inhibitor and a substrate, resulting in the elongation of viable cells.

In the cave, however, conditions are not as sterile, controlled, nor pure, making observations and sampling extremely crucial for an accurate analysis of a sulfuretum. Although investigators highlight the constancy of caves,

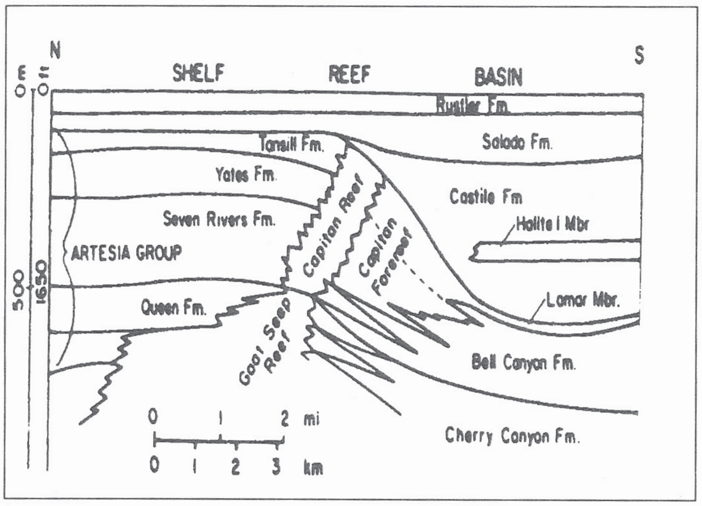


Figure 2a. Upper Permian stratigraphic units of the back-reef-shelf, reef, and basin. From Hill (1990).

physical conditions do vary temporally and spatially (Hobbs 1992). Researchers have devised many alternative approaches for microbial investigations in caves. In most situations, scientists collect samples of the water or of the substrate material (e.g. lithology and sediment for corrosion residues (Northup et al. 1994)) for a more detailed analysis in a laboratory. Sarbu et al. (1991) collected floating microbial mat material with plastic syringes, then the mat particulates were thoroughly homogenized and mixed with a sulfurous broth. Bacterial colonies were collected by Brigmon et al. (1994) from suspended chunks of filamentous material in gradient zones where upwelling, hypo-oxic, sulfide-containing water contacted aerated water.

Sulfur isotope data are important to understand the speleogenic processes (Hill 1990). Gypsum and native sulfur deposits were collected from caves in the Guadalupe Mountains, New Mexico and Texas. In general, sulfides and sulfur are ground and heated to produce SO_2 in excellent yield (Jäger and Hunziker 1979). Whole rock samples can be examined by this same technique.

RESULTS

Abiotic Conditions

Although it is difficult to set limits on habitational and environmental factors for all sulfur bacteria, definitive ranges of temperature, pH, salinity, photic exposure, pressure, substrate, and chemical conditions for specific genera can be summarized. However, the extremely vital factors in the environment are the available sources of sulfur and oxygen (Lackey et al. 1965, Nelson et al. 1986).

Most bacteria live between 20^{o} and 30^{o}C (Lackey et al. 1965). In contrast, *Beggiatoa* spp. have been recovered from waters at 4^{o} to 31^{o}C in Warm Mineral Springs, Florida. Sulfurous bacteria found in hot springs in the Pacific Northwest grow in temperatures from 40^{o} to 55^{o}C (Lackey et al. 1965, Stoner 1994). Within cave systems where bacteria have been detected, air and water temperatures are also within 20^{o} to 30^{o}C (Korshunov and Semikolennyh 1994). However, Hill (1994) suggests bacterial sulfate reduction, involving the production of H_2S, occurs at temperatures >30^{o} C.

Sulfur bacteria are much more common to alkaline waters, rather than acidic (Lackey et al. 1965). At pHs of 6 or 7, chemical breakdown of H_2S is most likely to occur (Hill 1994, Marcella et al. 1994). Hot spring (Octopus Spring, Wyoming) microbial mats form in slightly alkaline (pH 8-9) waters, where anaerobic transformation of organosulfur compounds has occurred (Stoner 1994). To contrast, a pH of 2.1 was measured from Telford Spring Cave, having a large population of sulfur bacteria (Martin and Brigmon 1994). The pH of waters in Movile Cave range from 7.5 to 8 where they flow through limestone (Sarbu et al. 1994); however, sulfuric acid in the cave as a byproduct of sulfide oxidation is responsible for pH values as low at 3.7 to 4.2 (measured on the walls).

In general, other abiotic factors are specific for one or more genera of sulfur bacteria but are not as extensively researched and/or documented. Light is required by some bacteria, albeit light is not necessary for life; caves do not have a photic zone where bacteria usually live. There is little information for any of the sulfur bacteria regarding hydrostatic, barometric, and osmotic pressure (Lackey et al. 1965).

Oxygen and Sulfur

Schmidt et al. (1987) discovered that *Beggiatoa alba* assimilates sulfide in the presence of oxygen; in the absence of oxygen, there was not measurable uptake of sulfide. When bacteria contained numerous sulfur inclusions in their filaments, endogenous respiration by *B. alba* was not significant; whereas for *Thiothrix nivea* it was 20 to 25-fold greater in organisms with inclusions (Schmidt et al. 1987). Bacteria that contain sulfur inclusions use them as a reserve source of sulfur. If the supply of H_2S is low, the inclusions disappear (Schmidt et al. 1987).

Nelson et al. (1986) determined that several strains of *Beggiatoa* spp. occupy a narrow region between the

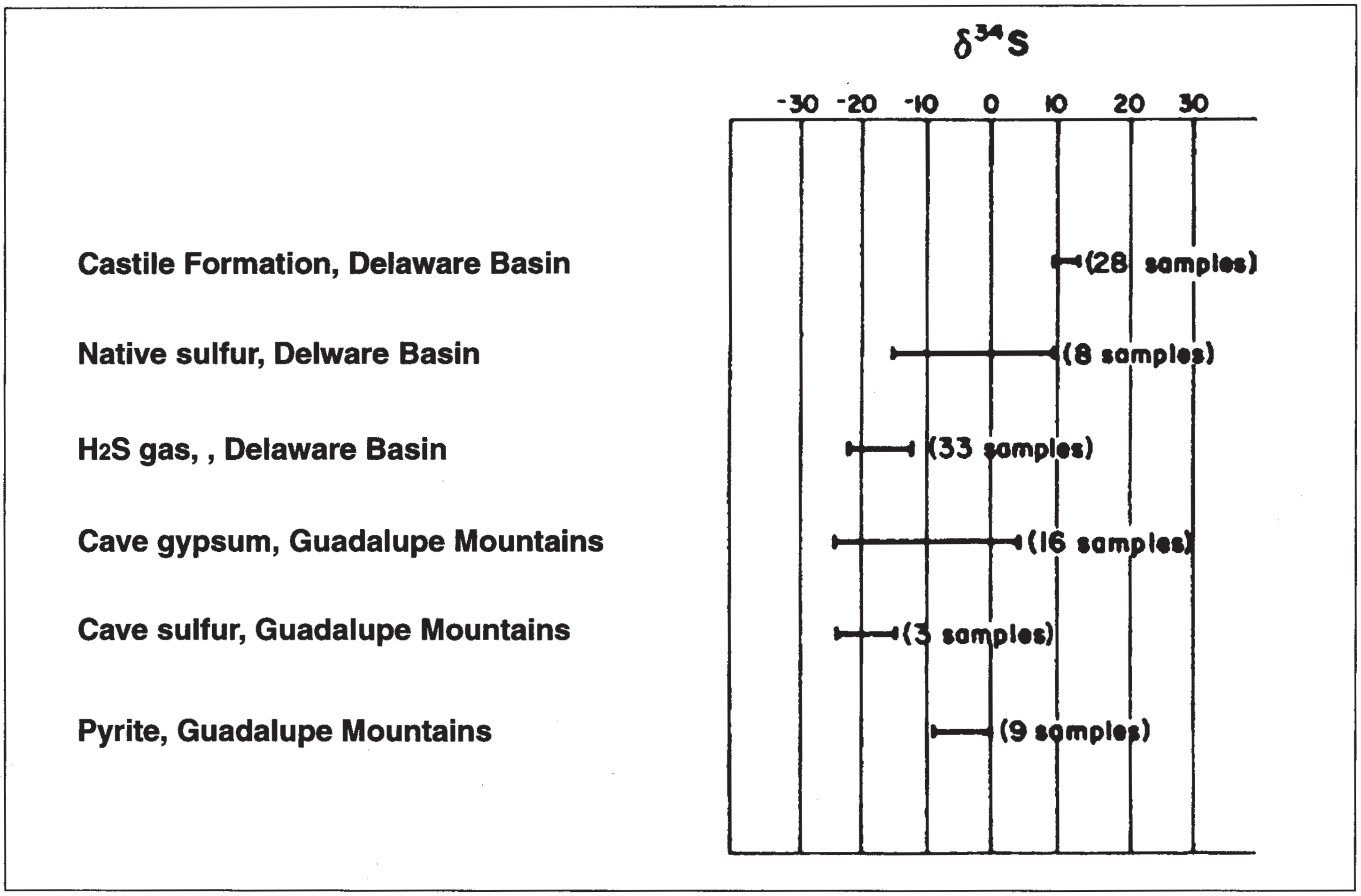


Figure 2b. δ^{34} S values (CDT) of various deposits in the Delaware Basin and Guadalupe Mountains. Values from various sources cited by Hill (1990).

oxic-anoxic interface. In microbial tufts of *Beggiatoa alba*, the endogenous metabolism lowered the concentration of dissolved oxygen to an undetectable level at the surface of the tuft (Schmidt et al. 1987). At the point where oxygen neared zero, sulfide was detected and it reached a concentration of 10 µM well inside the tuft. The values for sulfide increased when *B. alba* contained sulfur inclusions.

Evidence provided by sulfur isotope data demonstrates that cave gypsum in Guadalupe caves could not have been derived from anhydrite beds, particularly the Castile Formation gypsum (Figure 2a; Hill 1990). Gypsum and native sulfur deposits were significantly enriched in ^{32}S (Figure 2b). The S isotope fractionation depends on the difference between the two reaction rates (3) and (4).

$$^{34}SO_4^{2-} \rightarrow k_1 \rightarrow H_2{}^{34}S \quad (3)$$

$$^{32}SO_4^{2-} \rightarrow k_2 \rightarrow H_2{}^{32}S \quad (4)$$

The ratio between k_1/k_2 depends on the energy level changes of sulfur bonding (Jäger and Hunziker 1979). Under pure circumstances, equation (4) should control fractionation; however, extremely low sulfate concentrations or abnormally high food supplies make equation (3) the rate-controller and bring the net fractionation to zero.

The rate-controlling oxidation step will produce light sulfate and heavy sulfide. Hill (1981) reported $\delta^{34}S$ values as low as -21.1‰ for cave gypsum and -20.0‰ for cave sulfur. Hill (1989) compiled all of the $\delta^{34}S$ data on the Guadalupe cave gypsum and sulfur and found depletions as great as -25.6‰ for gypsum and -25.8‰ for sulfur. As a result, Hill (1990) observed that the Guadalupe caves are significantly enriched in ^{32}S (Figure 2b). Furthermore, for the cave mineral deposits to be derived from basin-ward beds (Figure 2a), isotope ratios should be similar. The "castile" sulfur has $\delta^{34}S$ values of -15.1‰ to +9.2‰ (Hill 1990). The cave sulfur and gypsum are even more enriched in ^{32}S than the "castile" buttes, implying that hydrocarbons and sulfur bacteria were also involved in the genesis of the cave deposits. Only these biologically induced reactions could produce the large isotopic fractionations (Figure 2b; Hill 1990).

Quantitatively, the sulfur cycle is more dominant in marine environments than in freshwater (Figure 3; Fenchel and Jørgensen 1977). In freshwater, sulfate occurs similar to oxygen concentrations, whereas sulfate amounts in seawater are 100-fold higher. In marine sediments, sulfate is usually found down to 1 m or more depth (Goldhaber and Kaplan 1974, as cited by Fenchel and Jørgensen 1977). In lakes, sulfate is often not detectable right below the sediment surface, thus sulfate diffusion into the sediment becomes a limiting factor in the rate of reduction (Cappenberg 1974, as cited by Fenchel and Jørgensen 1977).

Sulfur Bacteria in Caves

Bacteria in cave systems strongly correlate to bacteria studied from surface freshwater and marine environments. Similarly, energy availability greatly affects the numbers and biomass that can be supported in an ecosystem (Hobbs 1992). Even though Movile Cave receives no surface input, the chemolitho-autotrophic bacteria cycle the nutrients and energy for the system, supporting a large population of organisms. Bacteria and fungi occupy mats that cover cavern walls or float on water surfaces, particularly in air bells (Figure 1c). Microbiota at 4.3 x 10^5 cells per liter occupy the water column of the submerged passages (Sarbu and Popa 1992).

Colonies of heterotrophic bacteria isolated and identified from the mats also include *Beggiatoa* sp., *Thiobacillus thiooxidans, T. thioparus, T. ferrooxidans,* and *Desulfovibrio* sp., as well as other microorganisms involved in the sulfur cycle (Sarbu and Popa 1992). Preliminary results showed that the type of bacteria varied with depth. The main focus for the research was to find how the microbial activity was characterized by the chemolithoautotrophic carbon fixation in the organisms of the sulfurous waters. Bacteria in the mats and water oxidize H_2S and use the resulting energy for carbon fixation, as suggested by deposits of elemental sulfur within the floating mats (Sarbu and Popa 1992).

In most caves, food and energy input are limited by stream flow and water seepage through fissures in the surrounding rock (excluding input from trogloxenic organisms such as bats). Preliminary results from bacterial studies in Lechuguilla Cave, New Mexico (Figure 4), indicate that the oligotrophic (low nutrient) chemoheterotrophs found in pools also live in soils and freshwater environments (Northup et al. 1994). Because they are found within the cave they were probably introduced to the pool by filtration through overlying rocks. Other genera might be anthropogenic-influenced. Consequently, Northup et al. (1994) believe that the oligotrophic chemoheterotrophic bacteria are probably indigenous to the cave, due to their relative abundance at all of the tested pools (e.g., Lake of the White Roses, Sulfur Shores, Pink Dot Pool, Hudson Bay, etc.; Figure 4). *Seliberia* spp. and *Caulobacter*-like bacteria occupy pool samples (Cunningham et al. 1994, Northup et al. 1994). Additional bacteria could not be identified. The number of bacteria observed in samples was low, at 2-6 cells per 0.5ml, but consistent with an extremely oligotrophic environment (Northup et al. 1994). Preliminary results suggest the bacteria recently found in Lechuguilla are not sulfurous, indicating speleogenesis of Lechuguilla was dependent on ancient microbial activities.

Bacterial Association with Other Organisms

Little information is known about microbial interactions with aquatic and terrestrial life. However, bacteria constitute an important food source for free-living protozoa (Fenchel and Jørgensen 1977). Protozoa are the most significant consumers of bacteria and create a link in "food chains" between microbes and higher-trophic level organisms. The rates of bacterial consumption have been studied, indicating that some ciliates can consume 500-600 bacteria/individual/hour (Fenchel and Jørgensen 1977); larger or more efficient ciliates may eat several thousand bacteria per hour. Several small groups of ciliates (*Plagiophyldea* trichostomatids, several genera within *Heterotrichida,* and other forms) are mainly found within or near anaerobic, sulfide-containing habitats. These organisms feed predominately or exclusively on sulfur bacteria (Fenchel and Jørgensen 1977).

The restrictive influence of H_2S in natural waters is exemplified by some of the organisms that do not occur with sulfur bacteria. The relative resistance of an organism to abiotic factors is a complex subject that might not depend on toxicity alone (Lackey et al. 1965). Microorganisms, such as green algae, are extremely rare; other organisms like *Monas socialis* (zooflagellata), *Paramecium trichium* (ciliata), and *Euplotes vannus* (ciliata) cohabit some Florida springs with sulfur bacteria because they might find satisfactory food species in the sulfurous microbiota (Lackey et al. 1965).

The bacteria within Lechuguilla's ceiling-bound residue deposits act as primary producers and are food for fungi (Cunningham et al. 1994, Northup et al. 1994). Additionally, fungi and bacteria do co-exist in corrosion residues, but a precise relationship is unknown (Northup et al. 1994).

The cave community in Movile Cave, Romania (Figure 5), is rich in chemolithoautotrophic microbiota that support higher trophic terrestrial and aquatic organisms (Sarbu and Popa 1992). Precursory investigation suggests that sulfide-oxidizing bacteria occupying mats and the water provide enough food to sustain the entire troglobitic community (Popa and Sarbu 1991). Fungi and heterotrophic bacteria have been observed feeding or grazing upon the autotrophic bacteria, as well as flagellates, nematodes, oligochaetes, copepods, amphipods, collembola, and terrestrial isopods (Sarbu and Popa 1992). However, unlike surface food webs, ciliates did not feed on the sulfurous bacteria (Figure 5).

DISCUSSION

The removal of chemically dissolved bed rock (such as limestone) and saturated water are only possible by the utilization of pre-existing openings like bedding planes, fractures, or prominent jointing (Palmer 1991). In most areas, rock is dissolved by the action of carbonic acid-rich waters (HCO_3^-), as described by equation (5). Additionally, the life processes of microorganisms result in either the net production of carbon dioxide or net use of carbon dioxide, affecting the series of equilibria in the following equation (5) (James 1994a).

$$CaCO_3 (s) + CO_2 (aq) + H_2O \rightarrow Ca^{2+} (aq) + 2HCO_3^- (aq) \quad (5)$$

However, hydrogen sulfide-bearing solutions derived from the mixing of hydrocarbons and oxygen-rich waters create sulfuric acid (H_2SO_4). Hill (1990) has developed a model of

$$H_2S (aq) + 2 O_2 (aq) \rightarrow 2H^+ (aq) + SO_4^{2-} (aq) \quad (6)$$

$$H_2S(aq) + O_2(aq) + CO_2(g) + H_2O \rightarrow \text{aerobic bacteria} \rightarrow 2[CH_2O] + 2H^+(aq) + SO_4(aq) \quad (7)$$

hydrogen sulfide reaction with dissolved oxygen near the water table (Figure 6). Hill believes H_2S gas remained in a reduced state while ascending from basin to reef (Figure 2a) in the Capitan Reef aquifer. When the H_2S was oxidized it was converted to sulfuric acid (6). The sulfuric acid immediately attacked the limestone and dissolved out voids (8). The greatest removal of limestone took place at the water table at the mixing zone.

$$HSO_4^- + H^+ + CaCO_3 + 2H_2O \rightarrow Ca^{2+} + SO_4^{2-} + 3H_2O + CO_2 \quad (8)$$

Horizontal levels were created by acidic waters; massive gypsum derived from the calcium and sulfate ions in equation (8) were precipitated. Once the water table lowered, the gypsum hardened and was significantly enriched in ^{32}S. High carbon dioxide levels in the cave air, produced from equation (8), caused pronounced condensation-corrosion in the vadose zone of the cave (Figure 6). Once sulfate is produced it can be reduced in anoxic conditions, whether waters are alkaline or acidic. In acidic environments, the end products are H_2S, CO_2, and H_2O; whereas for basic or near neutral waters, the products are H_2S and HCO^{3-}. Therefore, sulfide oxidation decreases the pH, favoring the solution of limestone. Sulfate reduction increases the pH and favors calcite precipitation (James 1994a).

In general, subterranean waters become more aggressive when they reach the water table and become colonized by sulfur bacteria (Sarbu and Popa 1992). The creation of sulfuric acid from microbially-driven chemical reactions also aids in limestone dissolution and cavern development (Kane et al. 1994). Furthermore, one conclusion derived from studies in Bungonia Caves, New South Wales, Australia, suggests that carbon dioxide produced by microbes dissolves the limestone in both vadose and phreatic regions (James 1994b). Evidence for possible bacterial activity includes high concentrations of hydrocarbons in limestone, sulfur deposits in the cave, a few sulfide deposits in the limestone and in ore veins, high concentrations of iron, siderite, and iron sulfides, and high temperature caves (thermomineral waters and thermally heated) (Korshunov and Semikolennyh 1994).

In order to assess the influence of sulfur bacteria in

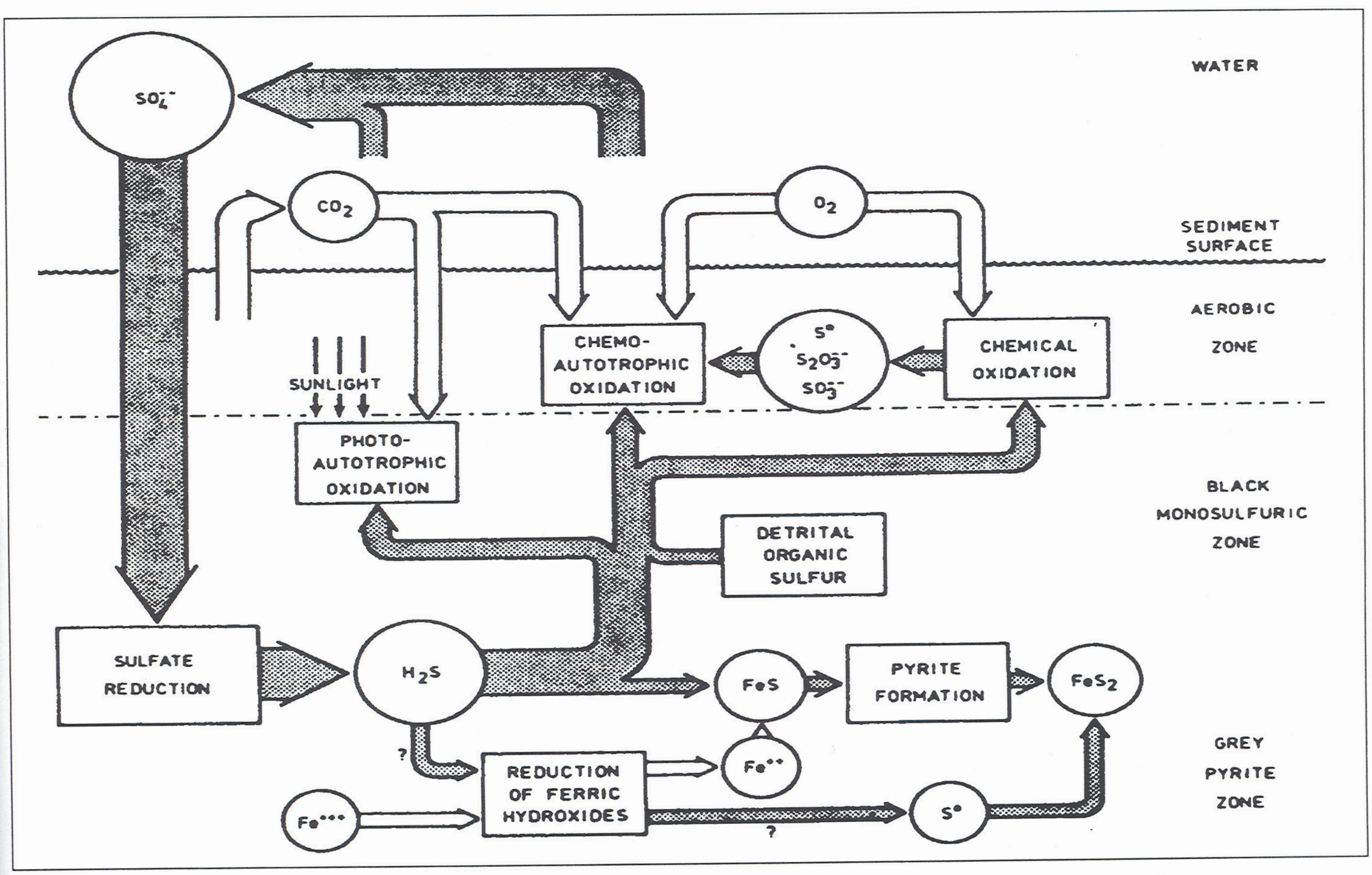


Figure 3. The sulfur cycle of aquatic sediments, taken from Fenchel and Jørgensen, 1977, complete with the chemical processes that give off free energy naturally (Fenchel and Jørgensen 1977).

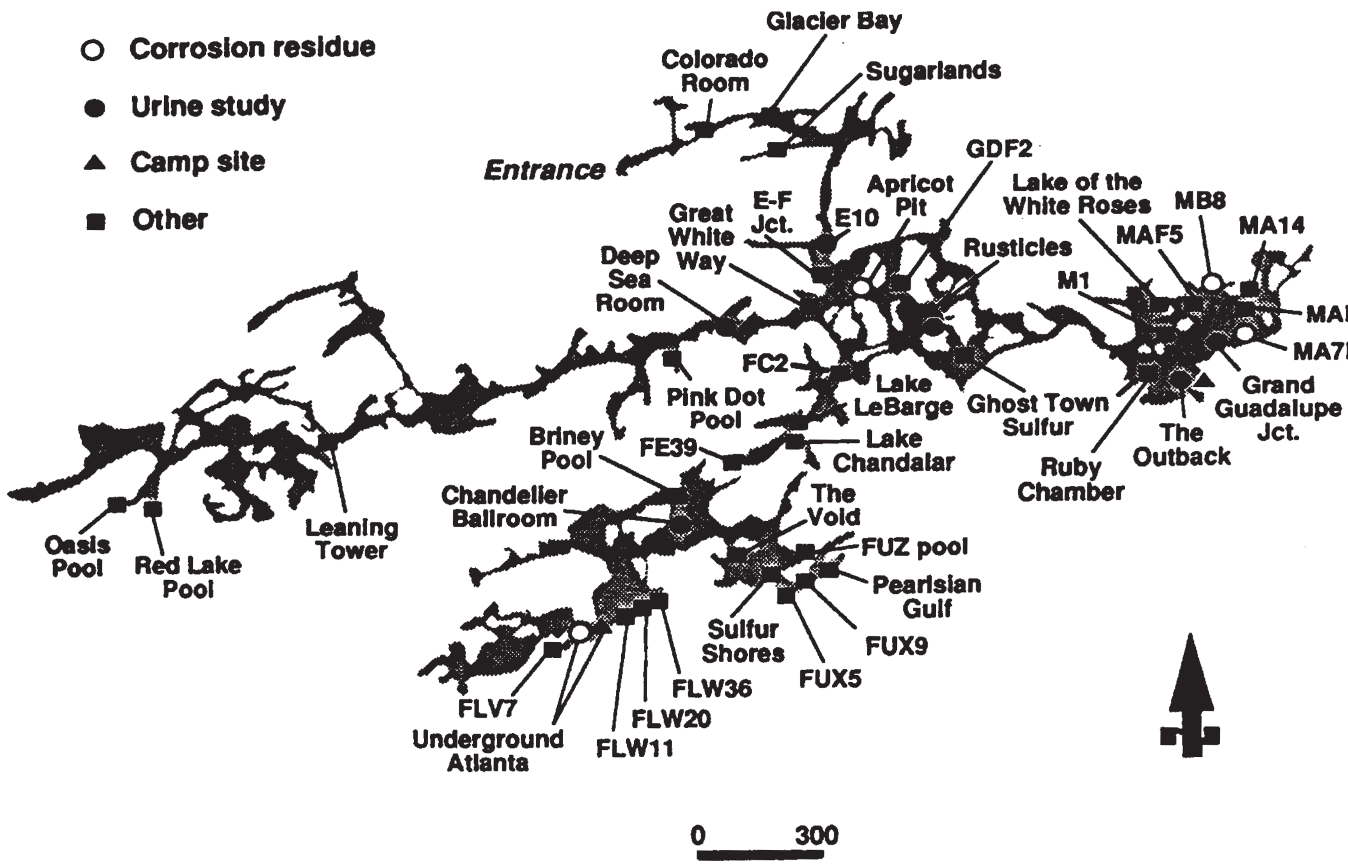


Figure 4. General Map of Lechuguilla Cave, New Mexico, taken from Northup et al., 1994.

speleogenesis, known chemical reaction products were evaluated from Odyssey Cave, Australia, on the acid-base system (James 1994a). Values for pH were approximately 7 with the major inorganic carbon being HCO_3^-. A sulfuretum existed at the bottom of the cave, where recycling of sulfur was possible though microbial reactions of sulfide, sulfur-oxidizing, and sulfur-reducing bacteria. In this cave, bacteria (chemolithotrophic *Thiobacilli* genera) were opportunistic, taking advantage of enhanced carbon dioxide levels and sulfur compounds (James 1994a).

The metabolic flexibility offered by the coupling of sulfur reduction to anaerobic oxidation of endogenous carbon reserves or hydrogen may be essential to an organism that exists in a changing environment (Schmidt et al. 1987). Bacterial catabolism relates to the slow breakdown of compounds, usually in the absence of an external food supply. The degree of breakdown of substances depends on the genetic constitution of the bacteria. In aerobic conditions, sulfur is oxidized with the reduction of oxygen to water and the amount of sulfur and oxygen in the ecosystem. When inorganic substances are reduced for energy at the expense of carbon dioxide, the bacteria are autotrophic.

Reduced sulfur compounds at various stages of reduction, generally yield sulfate as in the reactions (9) and (10); but if H_2S is a substrate, it is oxidized to elemental sulfur, as seen in reaction (11).

$$2S + 3O_2 + 2H_2O \rightarrow 2H_2SO_4 + \text{energy} \qquad (9)$$

$$Na_2S_2O_3 + 2O_2 + H_2O \rightarrow Na_2SO_4 + H_2SO_4 + \text{energy} \qquad (10)$$

$$2H_2S + O_2 \rightarrow 2S + 2H_2O + \text{energy} \qquad (11)$$

Anaerobic oxidation occurs by utilizing inorganic oxidants as alternatives to oxygen or organic substances for a hydrogen acceptor (Schmidt et al. 1987). Sulfate becomes reduced to H_2S during oxidation. This anaerobic respiration may be the means by which bacteria produce energy to glide in and out of the oxic-anoxic interface, particularly for *Beggiatoa* spp.

The energy yield of sulfate respiration in the sulfur cycle is small in comparison to oxygen and nitrate respiration; however, the end-product (H_2S) contains a significant portion of the chemical energy that is exploited by bacteria discussed in this paper (Figure 3). Although the schematic shows oxidation is dependent on light and oxygen, it has been suggested through this research that in environments such as caves, this is not always true. The narrow gradient between H_2S and O_2 is where colorless sulfur bacteria live and compete with the chemical processes that give off free energy naturally (Fenchel and Jørgensen 1977).

Sulfide-oxidizing bacteria, living in the water column and forming mats on the water surface such as those in Movile Cave, Romaina, are present-day examples of what caves in the Guadalupe Mountains might have been like. Although there is only evidence of sulfurous bacteria invasion, there are no sulfur bacteria that contribute to speleogenesis of the Guadalupe caves (Northup et al., 1994); formations grow due to surface water percolation. Sulfur bacteria would have produced enough food to sustain the entire cavernicolous community, as well as aid in speleogensis.

ACKNOWLEDGEMENTS

The author would like to thank all those who aided in the research of this paper, including those who offered suggestions and those who assisted in searching the literature: T. Algeo, S. Engel, L. Judy, H. Hobbs III, H. Hobbs IV, M. Porter, and S. Sarbu. Special gratitude goes to M. Porter, T. Dogwiler, H. Hobbs III, and G. Savage for revising drafts.

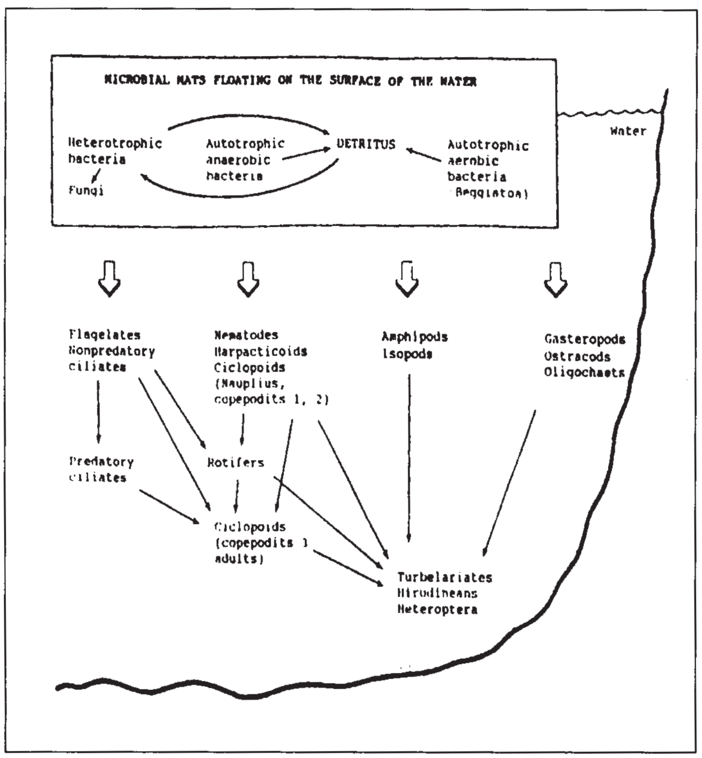


Figure 5. *Scheme of the trophic relations in the aquatic community of Movile Cave (Sarbu and Popa 1992.)*

REFERENCES CITED

Brigmon, R.L., H.W. Martin, T.L. Morris, G Bitton, and S.G. Zam. 1994. Biogeochemical ecology of *Thiothrix* spp. in underwater limestone caves: Geomicrobiology Journal, 12: 141-159.

Cappenberg, T.E. 1974. Interrelations between sulfate-reducing and methane-producing bacteria in bottom deposits of a fresh-water lake. I. Field observations, Antonie van Leeuwenhoek J. Microbiol. Serol. 40, 285.

Caumartin, V. 1963. Review of the microbiology of underground environments: Nat. Spel. Soc. Bull., 25: 1-14.

Cole, G.A. 1983. Textbook of Limnology. 3rd ed. London:The C.V. Mosby Company, 401p.

Culver, D.C. 1982. Cave Life. Cambridge:Harvard University Press, 189 p.

Cunningham, K.I., H.R. DuChene, C.S. Spirakis, and J.S. McLean. 1994. Elemental sulfur in caves of the Guadalupe Mountains, New Mexico, *in* Breakthroughs in Karst Geomicrobiology and Redox Geochemistry. Sasowsky, I.D. and M.V. Palmer (eds.) Karst Waters Institute: Abstracts and Field-Trip Guide, Colorado Springs, Colorado, 11-12.

Ellis, D. 1932. Sulphur Bacteria. London: Longmans, Green and Co., 261 p.

Fenchel, T.M. and B.B. Jørgensen. 1977. Detritus food chains of aquatic ecosystems: the roles of bacteria, *in* Advances in Microbial Ecology, vol. 1. Alexander, M., ed. New York: Plenum Press, 1-58.

Ghiorse, W.C. 1994. Viable, but unculturable bacteria in deep vadose sediments: development of methods for detecting microbial life in terrestrial environments at low population density, *in* Breakthroughs in Karst Geomicrobiology and Redox Geochemistry. Sasowsky, I.D. and M.V. Palmer (eds.). Karst Waters Institute: Abstracts and Field-Trip Guide, Colorado Springs, Colorado, 24-25.

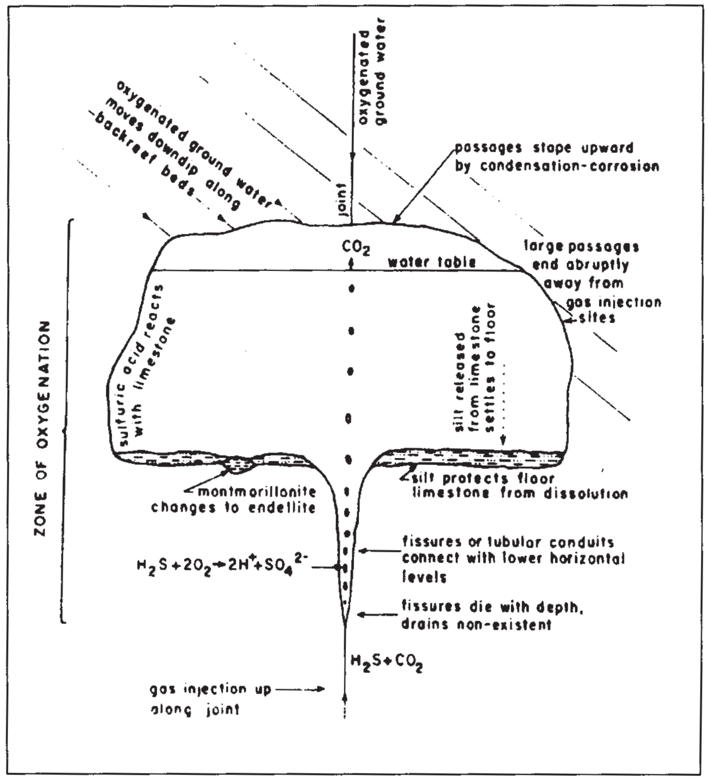
Goldhaber, M.B. and I.R. Kaplan. 1974. The sulfur cycle, *in* The Sea. E.D. Goldberg, ed. New York: John Wiley and Sons, 569-655.

Grassle, J.P. 1982. The biology of hydrothermal vents, a short summary of recent findings: Marine Technol. Soc. J., 16: 38.

Hill, C.A. 1981. Speleogenesis of Carlsbad Cavern and other caves in the Guadalupe Mountains: Eigth International Congress of Speleology Proceedings, Bowling Green, Kentucky, 143-144.

—. 1987. Geology of Carlsbad Cavern and other caves in the Guadalupe Mountains, New Mexico and Texas: New Mexico Bureau of Mines and Mineral Resources, Bulletin 117, 150p.

—. 1989. The evolution of the Delaware Basin - preliminary results, *in* Subsurface and outcrop examination of the Capitan shelf margin, northern Delaware Basin P.M. Harris and G.A. Grover, eds.: SEPM Core Workshop no. 13, 467-473.
—. 1990. Sulfuric acid speleogenesis of Carlsbad Cavern and its relationship to hydrocarbons, Delaware Basin, New Mexico and Texas: Amer. Assoc. of Petroleum Geol. Bull., 74: 1685-1694.
—. 1994. Sulfur redox reactions: hydrocarbons, native sulfur, Mississippi Valley-type deposits, and sulfuric acid karst, Delaware Basin, New Mexico and Texas, *in* Breakthroughs in Karst Geomicrobiology and Redox Geochemistry. Sasowsky, I.D. and M.V. Palmer (eds.). Karst Waters Institute: Abstracts and Field-Trip Guide, Colorado Springs, Colorado, 25-28.
Hobbs, H.H., III. 1981. Ecology of caves, Pholeos 2(1), 14-24.
—. 1992. Caves and Springs, *in* Biodiversity of Southeastern United States/ Aquatic Communities. Hackney, C.T., S.M. Adams, and W.A. Martin. John Wiley and Sons, Inc., 59-131.
Høeg, O.A. 1946. Cyanophycea and bacteria in calcareous sediments in the interior of limestone caves in Nord-Rana, Norway. Nytt Magasin for Naturvidenskapene, 85: 99-104.
Jäger, E. and J.C. Hunziker. 1979. Lectures in Isotope Geology. Berlin:Springer Verlag, 329 p.
James, J.M. 1994a. Microorganisms in Australian caves and their influence on speleogenesis, *in* Break throughs in Karst Geomicrobiology and Redox Geochemistry. Sasowsky, I.D. and M.V. Palmer (eds.). Karst Waters Institute: Abstracts and Field-Trip Guide, Colorado Springs, Colorado, 31-34.
—. 1994b. Microbially produced carbon dioxide and studies on its effects on speleogenesis, *in* Break-throughs in Karst Geomicrobiology and Redox Geochemistry. Sasowsky, I.D. and M.V. Palmer (eds.). Karst Waters Institute: Abstracts and Field-Trip Guide, Colorado Springs, Colorado, 28-30.
Kane, T.C. S. Sarbu, and B.K. Kinkle. 1994. Chemoautotrophy: methodological approaches, geological implications, and a case study from Southern Roma nia, *in* Breakthroughs in Karst Geomicrobiology and Redox Geochemistry. Sasowsky, I.D. and M.V. Palmer (eds.)Karst Waters Institute: Abstracts and Field-Trip Guide, Colorado Springs, Colorado, 38-39.
Korshunov, K. and A. Semikolennyh. 1994. A model of speleogenic processes connected with bacterial redox in sulfur cycles in the caves of Kugitangtou Ridge, Turkmenia, *in* Breakthroughs in Karst Geomicrobiology and Redox Geochemistry. Sasowsky, I.D. and M.V. Palmer (eds.). Karst Waters Institute: Abstracts and Field-Trip Guide, Colorado Springs, Colorado, 43-44.



Firgure 6. Model of hydrogen sulfide reaction with dissolved oxygen near the water table. From Hill (1987).

Lackey, J.B., E.W. Lackey, and G.B. Morgan. 1965. Taxonomy and Ecology of the Sulfur Bacteria. University of Florida; Engineering and Industrial Exp. Station, Bull. no. 119, 22p.
La Riviere, J.W.N. 1961. Cultivation and physicological characteristics of *Thiovulum* and other sulfur organisms. Abstracts of Symposium on Marine Microbiology.
Marcella, L., E. Heydari, R.K. Stoessell, and M. Schoonen. 1994. Sulfur geochemistry and limestone dissolution in coastal Yucatan cenotes, *in* Breakthroughs in Karst Geomicrobiology and Redox Geochemistry. Sasowsky, I.D. and M.V. Palmer (eds.). Karst Waters Institute: Abstracts and Field-Trip Guide, Colorado Sprngs, Colorado,48.
Martin, H.W. and R.L. Brigmon. 1994. Biogeochemisrty of sulfide oxidizing bacteria in phreatic karst, *in* Breakthroughs in Karst Geomicrobiology and Redox Geochemistry. Sasowsky, I.D. and M.V. Palmer (eds.). Karst Waters Institute: Abstracts and Field-Trip Guide, Colorado Springs, Colorado, 49-51.
Mezzino, M.J., W.R. Strohl, and J.M. Larkin. 1984. Characterization of *Beggiatoa alba*: Arch. Microbiology, 137: 139-144.
Mylroie, J.E., J.L. Carew, S.H. Bottrell, and W. J.Balcerzak. 1994. Microbial processes and cave development in the freshwater lens of a Quaternary carbonate island, San Salvador, The Bahamas, *in* Breakthroughs in Karst Geomicrobiology and Redox Geochemistry. Sasowsky, I.D. and M.V. Palmer

(eds.). Karst Waters Institute: Abstracts and Field-Trip Guide, Colorado Springs, Colorado, 54-55.

Nelson, D.C., N. P. Revsbech, and B.B. Jørgensen. 1986. Microoxic-anoxic niche of *Beggiatoa* spp.: microelectrode survey of marine and freshwater strains: Applied and Environ. Microbiology, 52(1): 61-168.

Northup, D.E. , D.L. Carr, M.T. Crocker, K.I. Cunningham, L.K. Hawkins, P. Leonard, and W.C. Welborn. 1994. Biological Investigations in Lechuguilla Cave. Nat. Speleo. Society Bull., 56(2): 54-63.

Pace, N.R. 1994. Molecular methods for microbial ecosys tems analysis, *in* Breakthroughs in Karst Geomicrobiology and Redox Geochemistry. Sasowsky, I.D. and M.V. Palmer (eds.). Karst Waters Institute: Abstracts and Field-Trip Guide, Colorado Springs, Colorado, 56.

Palmer, A. 1991. Origin and morphology of limestone caves. Geol. Soc. Amer. Bulletin 103, 1-21.

Popa, R. and S. Sarbu. 1991. Trophic structure in an aquatic troglobitic community based upon chemoautotrophic carbon fixation. Trav. de l'Inst. Speol., Bucharest, 30: 51-58.

Postgate, J. 1988. Bacterial worlds built on sulphur. New Scientist, 119: 58-62.

Pringsheim, E.G. 1964. Heterotrophism and species concepts in Beggiatoa. Am. J. Bot., 51: 898-913.

Sârbu, _.M., R. Popa, and I. Goliat. 1991. Chemoau totrophic production in a thermomineral sulfurous cave. Trav. Inst. Spéol. «Émile Racovitza », t. XXX: 59-61.

—. 1995. Personal Communication. University of Cincinnati, Cincinnati, Ohio.

Sarbu, S.M. and R. Popa. 1992. A unique chemoautotrophically based cave ecosystem, *in* The Natural History of Biospeleology. A. Camacho (ed.). 1Luis Arguero Publ.:Madrid: 637-666.

Sarbu, S.M., L. Vlasceanu, R. Popa, P. Sheridan, B.K. Kinkle, and T.C. Kane. 1994. Microbial mats in a thermomineral sulfurous cave, *in* Microbial Mats.

Stal, J.L. and P. Caumette (eds.). Berlin: Springer-Verlag. NATO ASI Series, G 35: 45-50.

Schmidt, T.M., B. Arieli, Y. Cohen, E. Padan, and W.R. Strohl. 1987. Sulfur metabolism in *Beggiatoa alba*: J. of Bacteriology, 169(12): 5466-5472.

Stoner, D.L. 1994. Transformation of volitile organosulfur compounds in hot springs microbial mats, *in* Breakthroughs in Karst Geomicrobiology and Redox Geochemistry. Sasowsky, I.D. and M.V. Palmer (eds.). Karst Waters Institute: Abstracts and Field-Trip Guide, Colorado Springs, Colorado, 69-70.

Summers, A. 1994. The Movile: put this one your wish list of caves to explore, *in* Speleo Digest 1993, no. 38. Fee, S. (ed.). National Speleological Society, Inc., 434.

Vlasceanu, L. and B.K. Kinkle. 1994. Characterization of microorganisms in a sulfide-rich groundwater system, *in* Breakthroughs in Karst Geomicrobiology and Redox Geochemistry. Sasowsky, I.D. and M.V. Palmer (eds.). Karst Waters Institute: Abstracts and Field-Trip Guide, Colorado Springs, Colorado, 71-72.

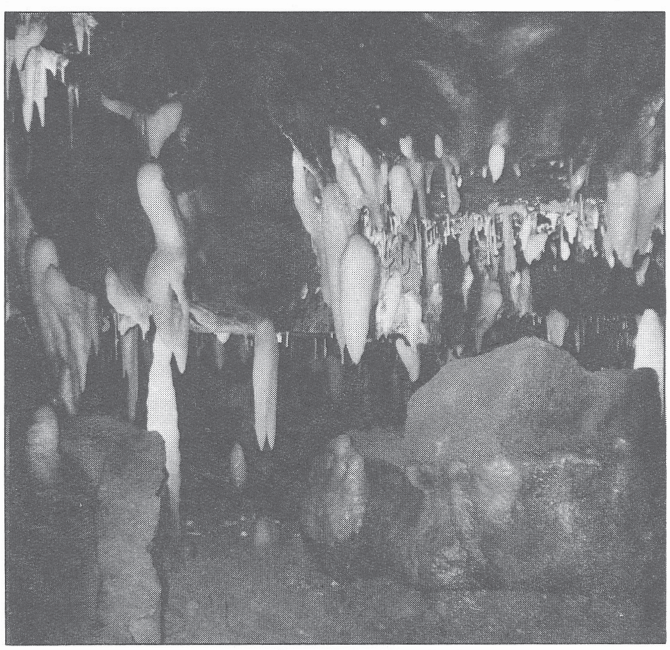
Winogradsky, S. 1949. Microbiologie du Sol. Problemes et Methods. Contribution a la Morphologie et Physiologie des Sulfobacteries. Masson et Cie, Paris: 83-126.

PHOLEOS

A Look Back...

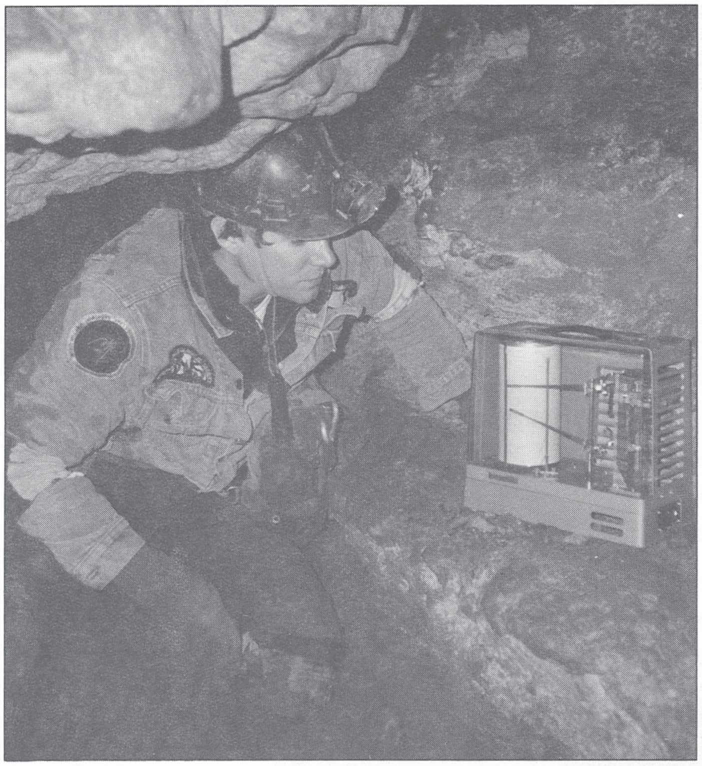
Seven Caves, Ohio

Howard & Charles Kronk looking suave at Cave Capers, Indiana, late 1980's

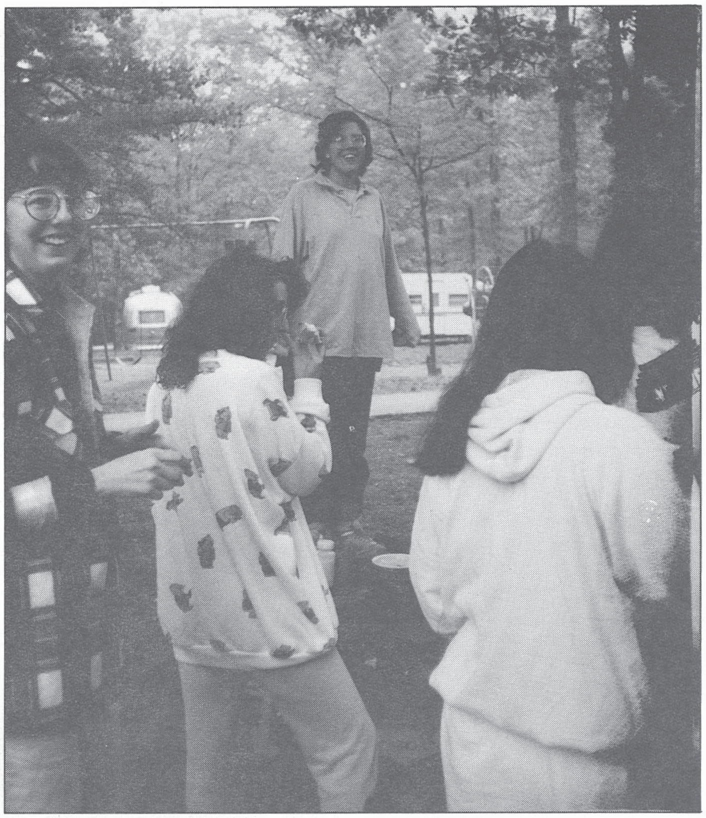


Formations in Ohio Caverns, West Liberty, Ohio

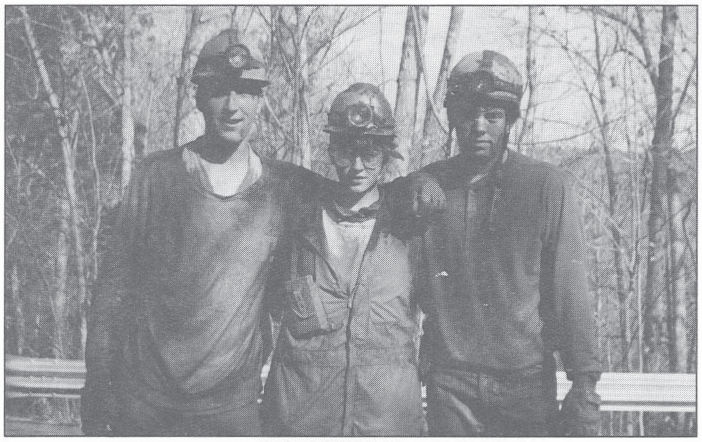
Cobble Crawl, Carter Caves, Kentucky, 1984.



Mike Flynn and Hygrothermograph in Cave of the Springs, Seven Caves, Ohio, 1987.

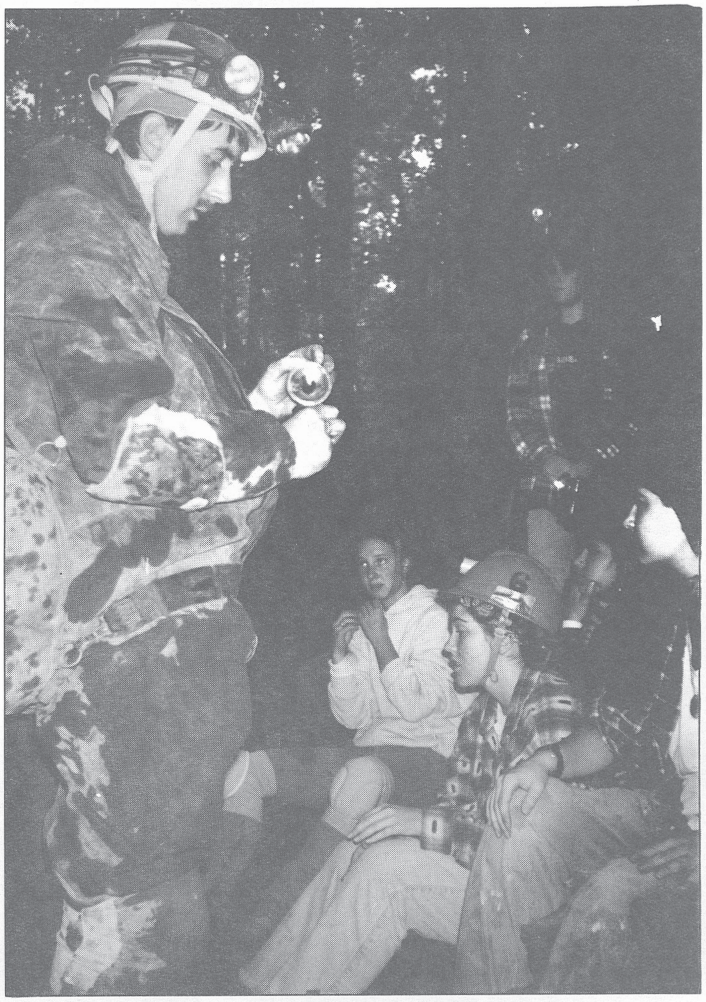


Monika Palunas taking charge on a Carter Caves trip, Kentucky, 1989.



Jeff Lapp, Annette Summers, and Chris Frost after battling Hog Dog Cave,
Carter Caves, Kentucky, 1991.

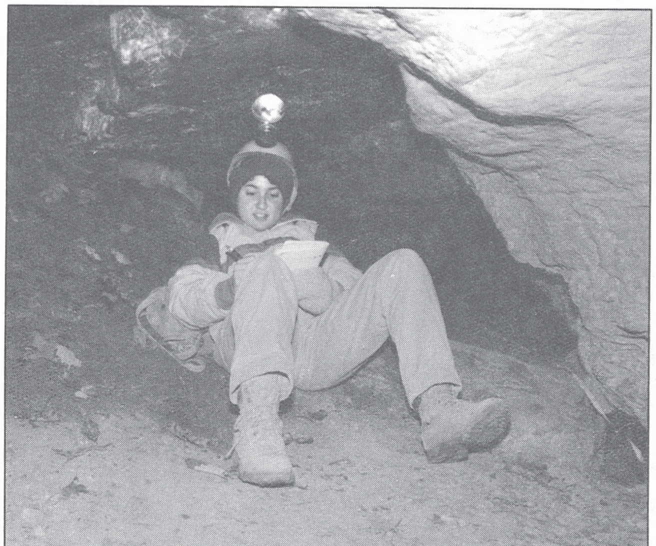
Andy Werner checking out Hackleshin Cave, Pike County, Ohio 1982.



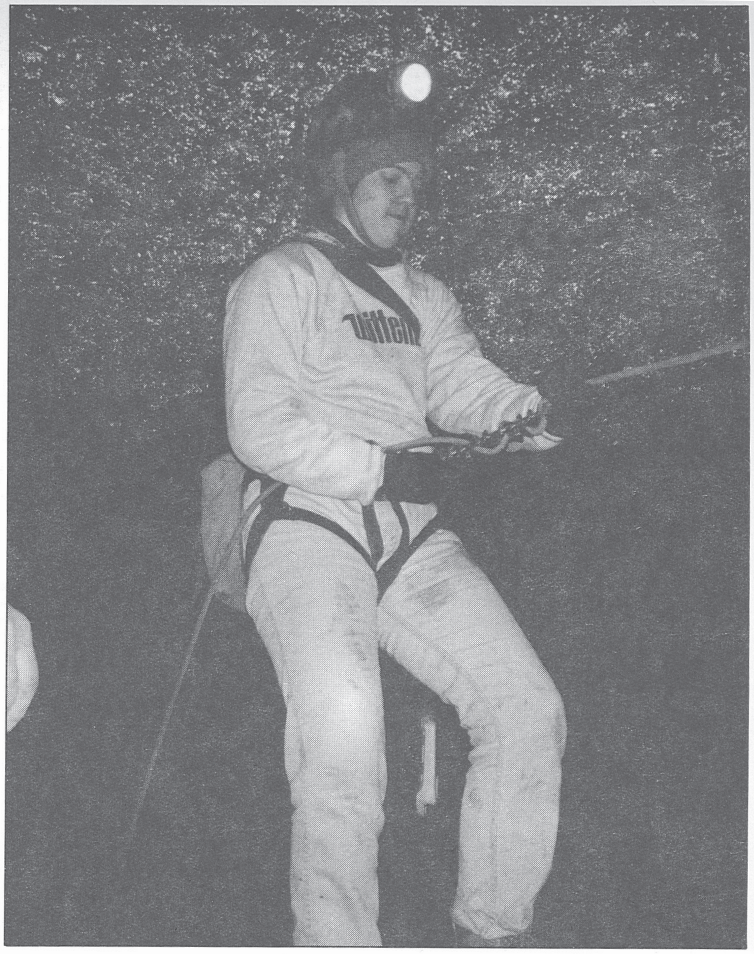
The helpful Steven Johnston showing first time cavers the wonderful carbide light,
Carter Caves, Kentucky 1994.

Warm water! Mark Butler in Lighthouse Cave, San Salvador Island, Bahamas.

Bill Stitzel and Bob Klapthorp at Coon-in-the Crack I entrance, Carter Caves, Kentucky, circa 1987.



Laura Tarulli in Cedar Fork Cave, 1984.



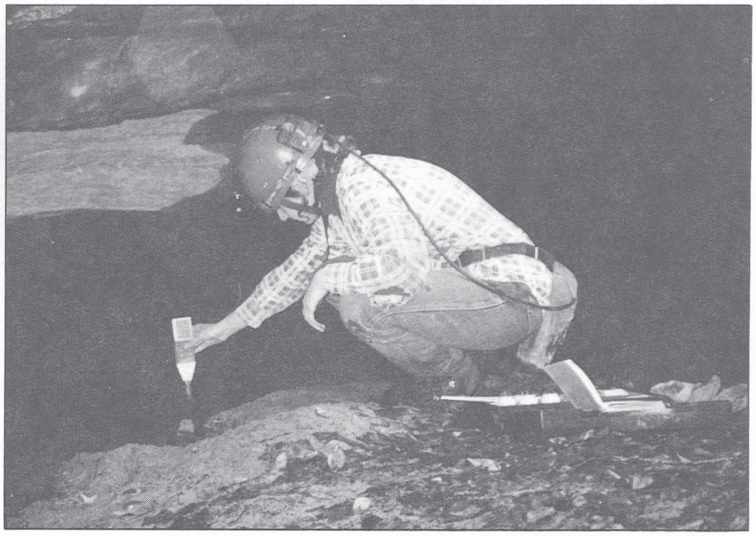
Megan Porter on rope in Canyon Cave, Carter County, Kentucky, 1993.

Nate Pfeffer and Bill Simpson at Crawlathon, 1986.

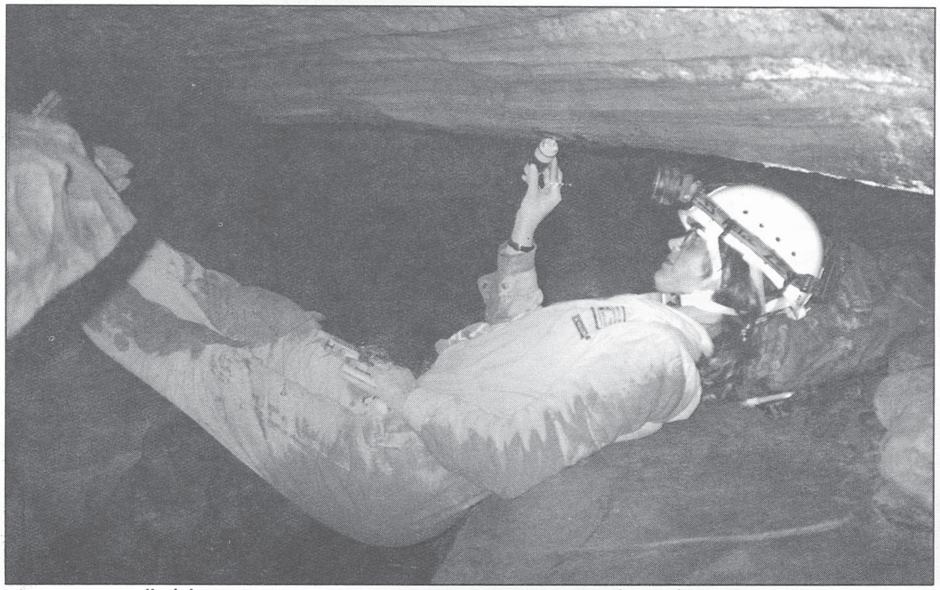
Jessica Hoane and Mike Hood getting to know one another, Doghill-Donahue Cave, Indiana, 1992.

Vertical Clinic gone wild! WUSS members at "The Wall", 1994.

Jeff Lapp? Hot Dog Cave, Carter Caves, Kentucky, 1991.



Annette Summers collecting physico-chemical data at Ridley Cave, Alabama, 1993.



Dawn Fuller holding LED on point in Canyon Cave, Carter County, Kentucky, on a low and wet survey, 1994.

WUSS members Luz Rodriquez, Randy McBride, Mark Butler, Kathy Fulker, Steve Campbell, and Keith Graham at Indian Run Cave, Ohio, 1979.

Documentation of Cave Articles Appearing in the Ohio Journal of Science

by
H. H. Hobbs III
NSS 12386F

After a request from Bill Torode, National Speleological Society Librarian, to fill in some informational "holes" in his list of cave articles that have appeared in the *Ohio Journal of Science*, it seemed likely that this information might be useful to other cavers. What appears below is an alphabetical listing by author of articles that have been published in the journal that in some way treat caves, including "blue holes." Caves are arranged alphabetically by state, county, and cave name. Most of the references are to Ohio caves and some 90 caves are cited in 45 articles. All cave names are presented as they appeared in print and currently accepted nomenclature is shown in parentheses and alternate names in brackets.

Ashley, David C. and Francis C. Rabalais. 1980. Helminth parasites of *Pipistrellus subflavus* from Ohio. Ohio J. Sci., 80(2):64.
** "...caves in Adams County, Ohio."

Barrows, W. M. 1918. A list of Ohio spiders. Ohio J. Sci., 18(8):297-318.
** "...caves of Ohio."

Beckett, David C., Philip A. Lewis, and John R. Holsinger. 1977. Report of an amphipod species new to Ohio: *Gammarus minus* Say (Amphipoda:Gammaridae). Ohio J. Sci.,77(5):242-243.
** Cedar Fork Cave - Adams County, Ohio

Carman, J. Ernest. 1946. The geologic interpretation of scenic features in Ohio. Ohio J. Sci., 46(5):241-283.
** Ohio Caverns - Champaign County, Ohio
** Olentangy Caverns - Delaware County, Ohio
** Blue Hole - Erie County, Ohio
** Rocky Fork Caves - Highland County, Ohio
** Ash Cave - Hocking County, Ohio
** Old Man's Cave - Hocking County, Ohio
** Rock House - Hocking County, Ohio
** Canters Cave - Jackson County, Ohio
** Zane's Cavern - Logan County, Ohio
** Put-In-Bay caves - Ottawa County, Ohio
** Goode's Cave (Seneca Caverns) - Seneca County, Ohio
** Underground River Cave - Wyandot County, Ohio

Chantell, Charles J. 1970. *Crotalus horridus* remains from two caves in Miami Co., Ohio. Ohio J. Sci., 70(2):120-121.
** Painter Creek Cave - Miami County, Ohio
** Thompson's Cave - Miami County, Ohio

Cottingham, Kenneth. 1919. The origin of the caves at Put-in-Bay, Ohio. Ohio J. Sci., 20(2): 38-42.
** "...caves at Greenfield, Ohio." - Ross County, Ohio
** Put-In-Bay caves - Ottawa County, Ohio
** Duff Cave - Ottawa County, Ohio
** Victory Cave - Ottawa County, Ohio

Ford III, Denneth M. and Ron Bowerman. 1995. Educational Opportunities at the paleontological excavation near Carey, Ohio. Ohio J. Sci., 95(2)(April Program Abstracts):51.
**Sheriden Pit - Wyandot County, Ohio

Ford III, Kenneth M., J. Alan Holman, and Andrea Bair. 1995. Paleoecology of the Sheriden Pit site, Indian Trial Caverns, Wyandot County, Ohio. Ohio J. Sci., 95(2)(April Program Abstracts):28.
** Sheriden Pit - Wyandot County, Ohio

Forsyth, Jane L. 1983. The Columbus Cuesta in north-central Ohio. Ohio J. Sci., 83(2):23.
** Blue Holes of Castalia - Erie County, Ohio
** Ohio Caverns - Champaigne County, Ohio
** Zane Caverns - Logan County, Ohio
** Olentangy Caverns - Deleware County, Ohio

Gartman, Donald K. 1974. Some observations made during a one day scuba investigation of the Miller Blue Hole, Sandusky County, Ohio. Ohio J. Sci., 74(5):330-331.
** Miller Blue Hole - Sandusky County, Ohio

Goslin, Robert M. 1955. Animal remains from Ohio rock shelters. Ohio J. Sci., 55(6):358- 362.
** Kettle Hill Cave - Fairfield County, Ohio
** Ash Cave - Hocking County, Ohio
** Boone Cave - Jackson County, Ohio
** Buzzard Cave - Jackson County, Ohio
** Canter Caves (Indian Cave, Echo Cave) - Jackson County, Ohio
** Twinsburg Rock Shelter - Summit County, Ohio

Goslin, Robert M. 1964. The gray bat, *Myotis grisescins* Howell, from Bat Cave, Carter County, Kentucky. Ohio J. Sci., 64(1):63.
** Bat Cave - Carter County, Kentucky

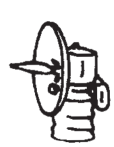
Hills, Thomas M. 1916. Reames Cave. Ohio J. Sci., 16(6):209-215.
** Reames Cave (Ohio Caverns) - Champaign County, Ohio

Hobbs III, H. H. 1979. Preliminary investigations of the caves and cave fauna of Ohio. Ohio J. Sci., 79(2):96.
** Cedar Fork Cave - Adams County, Ohio

Hobbs III, H. H. and Michael F. Flynn. 1981. The cavernicolous fauna of Ohio. Part II:Invertebrates. Ohio J. Sci., 81(April Program Abstracts):109.
** "...caves and rock shelters of Ohio."

Hobbs III, H. H. 1984. A unique karst feature in southern Ohio. Ohio J. Sci., 84(2):14.
** Freeland's Cave - Adams County, Ohio

Hobbs III, H. H. 1985. The Ohio Cave Survey - an update. Ohio J. Sci., 85(2):28 (abstr.).
** Fern Cave - Adams County, Ohio
** Freeland's Cave - Adams County, Ohio
** Ohio Caverns - Champaign County, Ohio
** Perry's Cave - Ottawa County, Ohio
** Frost Cave - Pike County, Ohio
** Buckskin Cave I - Ross County, Ohio



Hobbs III, H. H. 1991. Ecology and fauna of the caves of Costa Rica, Central America. Ohio J. Sci., 91(2):74 (abstr.).
** "...caves in the Neily region of southern Costa Rica."

Hobbs III, H. H. 1993. Protection of karst resources - are we too late? Ohio J. Sci., 93(2):42.
** Federal Cave Resources Protection Act

Hobbs III, H. H. 1994. Status of the federally endangered Alabama Cave Shrimp *Palaemonias alabamae* Smalley (Decapoda:Caridae:Atyidae). Ohio J. Sci., 94(2):38.
** caves - Madison County, Alabama

Hobbs III, H. H. 1994. Cave resource inventory: case studies in the southeastern United States. Ohio. J. Sci., 95(2)(April Program Abstracts):42.
** Russell Cave - Alabama
** Lookout Mountain - Georgia and Tennessee

Hubbard, George D. 1932. The caves of Yarim Burgaz, Turkey. Ohio J. Sci., 32(4):331.
** "Caves about 12 miles west of Istanbul..." - Yarim Burgaz, Turkey

Jones, Wayne and James M. Raab. 1991. Hydrogeology of Seneca Caverns area, Thompson Township, Seneca County, Ohio. Ohio J. Sci., 91(2):31.
** dolines - Seneca County, Ohio

Joseph, John M. 1950. A description of Warner's Hollow. Ohio J. Sci., 50(3):134-135.
** Barometer Cave - Ashtabula County, Ohio

Langlois, Thomas H. 1964. Amphibians and reptiles of the Erie Islands. Ohio J. Sci., 64(1):25.
** Duff's Cave - Ottawa County, Ohio
** Heineman's Cave - Ottawa County, Ohio

Melin, Brian E. and Robert C. Graves. 1971. The water beetles of Miller Blue Hole, Sandusky County, Ohio. (Insecta, Coleoptera). Ohio J. Sci., 71(2):73-77.
** Miller Blue Hole - Sandusky County, Ohio
** Castalia Blue Hole - Erie County, Ohio

Mitchell, Naomi and H. H. Hobbs III. 1987. Biological and physicochemical baseline data for selected Ohio caves. Ohio J. Sci., 87(2):51.
** Freeland's Cave - Adams County, Ohio

Muchmore, William B. 1964. New terrestrial isopods of the genus *Miktoniscus* from eastern United States. (Crustacea: Isopoda: Oniscoidea). Ohio J. Sci., 64(1):51-57.
** Shelta Cave - Madison County, Alabama
** Cedar Sink - Edmonson County, Kentucky
** White Cave - Edmonson County, Kentucky
** Luray Caverns - Page County, Virginia

Pederson, Cathy L. and H. H. Hobbs III. 1991. A comparative study of cave and surface stream drift. Ohio J. Sci., 91(2):74.
** Bat Cave - Carter County, Kentucky

Pettit, Lincoln. 1958. The effects of weathering and other changes at Nelson Ledges State Park Ohio J. Sci., 58(3):182-186.
** Gold Hunters Cave - Portage County, Ohio

Pinkava, D.J. 1963. Vascular flora of the Miller Blue Hole, Sandusky County, Ohio. Ohio J. Sci., 63(3):113-127.
** Castalia Blue Hole - Erie County, Ohio
** Miller Blue Hole - Sandusky County, Ohio

Porter, Megan L. 1995. Comparative study of amphipod and isopod population densities in two temperate cold-water springs, Greene County, Ohio. Ohio J. Sci., 95(2) (April Program Abstracts):46.
** OZ Spring - Greene County, Ohio
** Spring #1 - Greene County, Ohio

Potter, Martha A. and Raymond S. Baby. 1964. Hopewellian dogs. Ohio J. Sci., 64(1):36-40.
** "...three small limestone caverns..." - Franklin County, Ohio
** Cave Number 1 - Franklin County, Ohio
** Scioto Cavern - Franklin County, Ohio

Prufer, Olaf H. and Douglas H. McKenzie. 1966. Peters Cave: Two woodland occupations in Ross County, Ohio. Ohio J. Sci., 66(3):233-253.
** Peters Cave - Ross County, Ohio

Ruedisili, L. C., G. E. Kihn and R. C. Bell. 1990. Geology of Seneca Caverns, Seneca Co., Ohio. Ohio J. Sci., 90(4):106-111.
** Seneca Caverns - Seneca County, Ohio

Schmitt, J.A. and E.S. Beneke. 1962. Aquatic fungi from Outh Bass and neighboring islands in western Lake Erie. II. Additional biflagellate and uniflagellate phycomycetes. Ohio J. Sci., 62(1):11-12.
** Miller's [sic] Blue Hole - Sandusky County, Ohio

Sears, Paul B. 1967. The Castalia Prairie. Ohio J. Sci., 67(2):78-88.
** Castalia Blue Hole - Erie County, Ohio

Seibert, Henri C. and Ronald A. Brandon. 1960. The salamanders of southeastern Ohio. Ohio J. Sci., 60(5):291-303.
** Ash Cave - Hocking County, Ohio
** Old Man's Cave - Hocking County, Ohio
** Rock House - Hocking County, Ohio
** Big Cave - Pike County, Ohio
** cave near Byington - Pike County, Ohio

Smith, Phillip M. 1953. The Ohio Cave Survey. Ohio J. Sci., 53(6):325-326.
** Reames Cave (Ohio Caverns) - Champaign County, Ohio
** South Bass Island caves - Ottawa County, Ohio

Stout, Wilber. 1944. Sandstones and conglomerates in Ohio. Ohio J. Sci., 44(2):75-88.
** Ash Cave - Hocking County, Ohio
** Canter's Cave - Hocking County, Ohio
** Old Man's Cave - Hocking County, Ohio
** Rock House - Hocking County, Ohio

Stout, Wilber. 1958. Rock Mill. Ohio J. Sci., 58(3):171-176.
** Ash Cave - Hocking County, Ohio
** Old Man's Cave - Hocking County, Ohio

Summers, Annette M. and Horton H. Hobbs III. 1995. Jointing and bedding plane controls on cave passage development, Canyon Cave, Carter County, Kentucky. Ohio J. Sci., 95(2)(April Program Abstracts): 52.
** Canyon Cave - Carter County, Kentucky

Tintera, John J. and Jane L. Forsyth. 1980. The karst landscapes of the Bellevue-Castalia region. Ohio J. Sci., 80 (April Prog. Abstr.):30.
** "...Blues of the Castalia area," sinkholes, swallowholes - Erie County, Ohio

Titelman, Josefin and Natalie H. Waddell. 1995. Physicochemical trends of Yellow Spring, Greene County, Ohio. Ohio J. Sci., 95(2)(April Program Abstracts): 52.
** Yellow Spring - Greene County, Ohio

Verber, J. L. and David H. Stansberry. 1953. Caves in the Lake Erie Islands. Ohio J. Sci., 53(6): 358-362.
** Brown's (3) caves - Ottawa County, Ohio
** caves on South Bass Island - Ottawa County, Ohio
** cave on Green Island - Ottawa County, Ohio
** Cedar Forest Cave - Ottawa County, Ohio
** Cedar Forest (3) caves - Ottawa County, Ohio
** Coil's Cave (Green Island) - Ottawa County, Ohio
** Crystal Cave (Heineman's Cave) - Ottawa County, Ohio
** Crystal Rock Cave (mainland) - Erie County, Ohio
** Duff's (2) caves - Ottawa County, Ohio
** Gascoyne Cave - Ottawa County, Ohio
** Hole Cave - Ottawa County, Ohio
** John Brown's Cave - Ottawa County, Ohio
** Kindt's I Cave - Ottawa County, Ohio
** Kindt's (3) caves - Ottawa County, Ohio
** Larcomb's Cave - Ottawa County, Ohio
** Mammoth Cave (Daussa's, Danssa's) - Ottawa County, Ohio
** State Park Cave - Ottawa County, Ohio
** Two Tree Cave - Ottawa County, Ohio
** Paradise Cave - Ottawa County, Ohio
** Perry's Cave - Ottawa County, Ohio
** Victory Cave - Ottawa County, Ohio
** Wulkowicz Cave - Ottawa County, Ohio
** Zura's (3) caves - Ottawa County, Ohio

Ver Steeg, Karl. 1932. Nelson Ledge State Park. Ohio J. Sci., 32(3):177-193.
** Gold Hunter's Cave - Portage County, Ohio
** Hanging Wall Cave - Portage County, Ohio
** Devil's Den - Portage County, Ohio
** Old Maid's Kitchen - Portage County, Ohio
** Devil's Ice Box - Portage County, Ohio

Ver Steeg, Karl. 1933. The State Parks of Hocking County, Ohio. Ohio J. Sci., 33(1):19-36.
** Ash Cave - Hocking County, Ohio
** Old Man's Cave - Hocking County, Ohio
** Rock House - Hocking County, Ohio

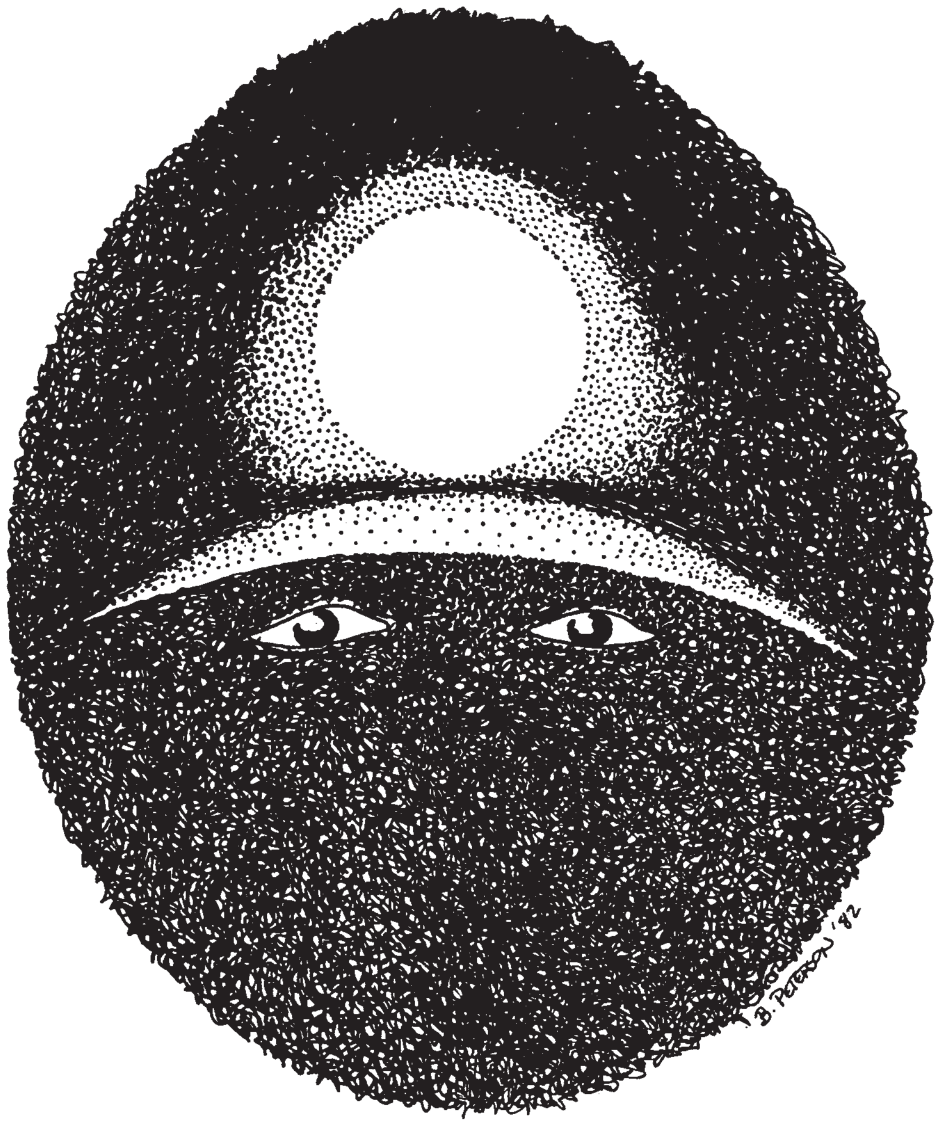
Ver Steeg, Karl and George Yunck. 1932. The Blue Hole of Castalie. Ohio J. Sci., 32(5):425-435.
** Castalia Blue Hole - Erie County, Ohio

Weaver, Thomas R. 1995. Significant small-scale glacial landforms of southwestern Ohio. Ohio J. Sci., 95(2)(April Programs Abstract):41.
** glacial landforms of southwestern Ohio

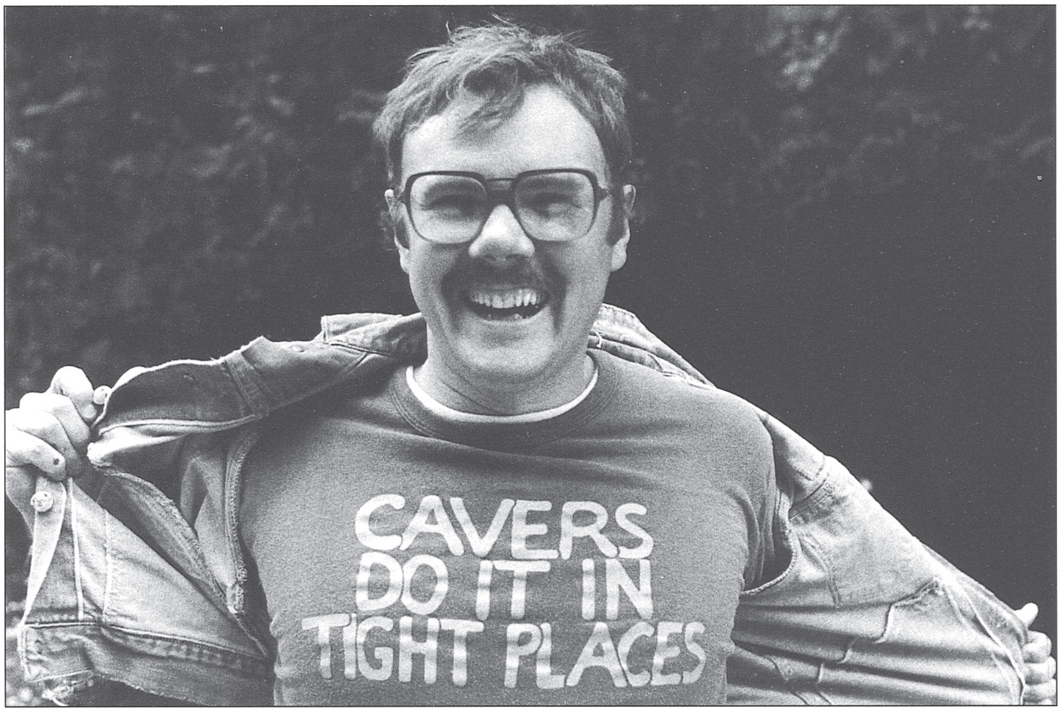
White, George W. 1926. The limestone caves and caverns of Ohio. Ohio J. Sci., 26(2): 73-116.
** Ohio Caverns (historically Reames Cave) - Champaign County, Ohio
** Lawrence Cave (Olentangy Indiana Cave)[Olentangy Cave] - Delaware County, Ohio
** Blue Hole of Castalia - Erie County, Ohio
** Brewery Cave - Erie County, Ohio
** Crystal Rock Cave - Erie County, Ohio
** Crystal Rock Park caves - Erie County, Ohio
** Bear Cave - Highland County, Ohio
** Buzzard's Glory Cave - Highland County, Ohio
** Coon Cave (Raccoon Cave) - Highland County, Ohio
** Crescent Cave (McKimie Cave, Mckimmey's Cave) - Highland County, Ohio
** Dancing Cave - Highland County, Ohio
** Dry Cave - Highland County, Ohio
** Ellison's Cave - Highland County, Ohio
** Fox Cave - Highland County, Ohio
** King's Wardrobe Cave (Witches Cave) - Highland County, Ohio
** Marble Cave - Highland County, Ohio
** Rocky Fork Caves - Highland County, Ohio
** Wet Cave (Cave of the Springs) - Highland County, Ohio
** Zane's Cavern [historically called Unagsts Cave] - Logan County, Ohio
** Miami River Cave - Shelby County, Ohio
** Painter Creek Cave - Miami County, Ohio
** Thompson's Cave - Miami County, Ohio
** Crystal Cave - Ottawa County, Ohio
** Mammoth Cave - Ottawa County, Ohio
** Smith's Cave - Ottawa County, Ohio
** Paradise Cave - Ottawa County, Ohio
** Perry's Cave - Ottawa County, Ohio
** Put-In-Bay caves - Ottawa County, Ohio
** Buckskin Caves - Ross County, Ohio
** Goode's Cave (Seneca Cave) - Seneca County, Ohio
** Underground River Cave - Wyandot County, Ohio

Williams, Stephen R. 1932. An *Eucrangonyx mucronatus* Forbs a subterranean blind shrimp. Ohio J. Sci., 32(4):356-360.
** Wyandot Cave - Crawford County, Indiana
** Mayfield's Cave - Monroe County, Indiana
** Mammoth Cave - Edmonson County, Kentucky

Wood, R. D. 1947. Characeae of the Put-In-Bay region of Lake Erie (Ohio). Ohio J. Sci., 47(6):240-258.
** Blue Hole of Castalia - Erie County, Ohio
** Miller Blue Hole - Sandusky County, Ohio


B. PETERSON '82

Horton H. Hobbs III



The hardest part about writing a piece such as this is figuring out how to keep it from becoming an entire volume of *Pholeos* on its own. There is so much that can be said about Horton H. Hobbs III, as a scientist, as a professor, as WUSS advisor, and most importantly, as a caver.

For the past fifteen years, H. Hobbs has spent much of his time introducing students and community residents to the fascinating world of caving. He has taught us, by example, the importance of safety, of cave conservation, and of respecting the cave environment and all the critters that live in it. Through his research and exploration he has increased the understanding of scientists, as well as non-scientists, of the importance of cave ecosystems around the world. Horton Hobbs is an explorer and a caver in the truest sense of the words.

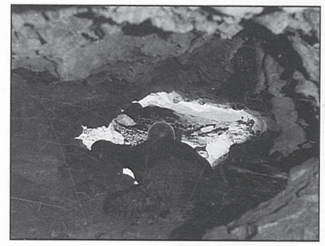
In this same fifteen year period, H. Hobbs has been the silent leader of the Wittenberg University Speleological Society. Although he will forever give the credit to the student leaders, WUSS would not be where it is today without his guidance and hard work. From editing *Pholeos*, to planning weekend trips, to working out the budget, he has played a vital role in all the caving club's activities. As an advisor, Horton Hobbs is the best that students and local residents could ask for.

With the fifteen years that have past, H. Hobbs has been with WUSS through all its ups and downs. As a result the members of WUSS can only begin to say thank you by presenting Horton H. Hobbs III with The Lifetime Achievement Award. To those of us that have been lucky enough to know him, he is a caver, a teacher, a scientist, an advisor, and most importantly, a friend. I would like to say, and I think that I can speak for everyone, thank you for all that you have done and continued success in the next fifteen years with the Wittenberg University Speleological Society.

-Gregg Savage
Editor

Vol. 1 (1 & 2), 1981

Vol. 2 (1), 1981

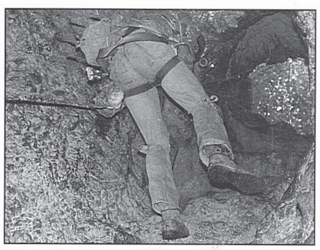


Vol. 2 (2), 1982

Vol. 3 (1), 1982

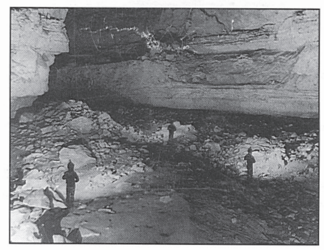
Vol. 3 (2), 1983

Vol. 4 (1), 1984

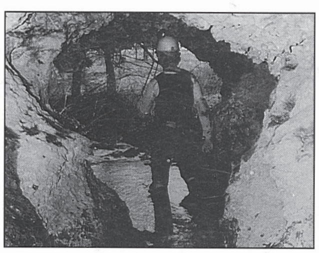


Vol. 5 (1), 1985

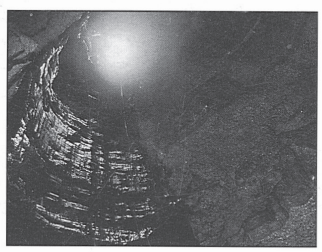
15 YEAR ANNIVERSARY
WITTENBERG UNIVERSITY SPELEOLOGICAL SOCIETY
SPRINGFIELD, OHIO
SCIENCE • EXPLORATION • SURVEYING



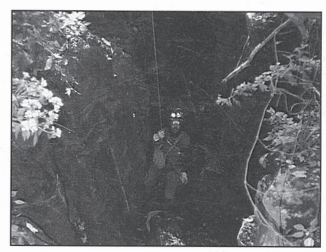
Vol. 5 (2), 1985



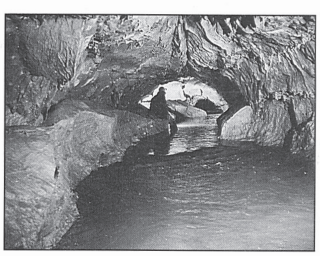
Vol. 6 (1), 1986



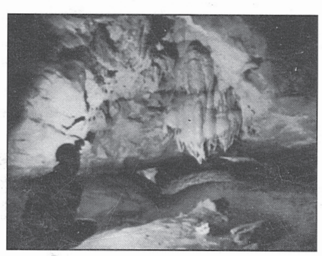
Vol. 6 (2), 1986



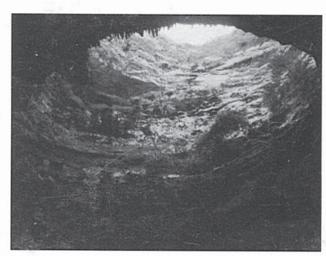
Vol. 7 (1), 1986



Vol. 7 (2), 1987



Vol. 9 (1), 1988



Vol. 14 (1 & 2), 1994