Material to be included in a given number must be received at least 90 days prior to the first of the month in which publication is desired. No submission will be accepted for publication unless and until one of the three options in our printed "Copyright Agreement" form has been selected by the author(s) and the form has been properly dated, signed, and returned to the Editor.

Discussion of papers published in The Bulletin is invited. Discussions should be 2000 words or less in length, with not more than 3 illustrations; they should be forwarded to the appropriate editor within 3 months of publication of the original paper.

A voluntary contribution of $25.00 per page is solicited from authors after their manuscripts have reached page-proof stage.

This represents about one-quarter of the cost of publication.

All issues through Volume 40 (1978) are copyrighted © by The National Speleological Society; the photocopying or reproduction, or recording by any electrical or mechanical process of any issue still in print is a violation of copyright, unless prior permission has been granted. However, abstracts, figures, and tables may be freely copied by anyone so long as proper credit is given.

Beginning with Volume 41 (1979), the complete issues are still copyrighted © by The National Speleological Society. Individual papers, however, may be in the public domain, copyrighted by the NSS, or copyrighted by the authors, personally (but with the right to grant permissions for non-profit use delegated to the NSS). The copyright status of each paper is given on its first page. No copyrighted paper still in print may be photocopied or reproduced, or recorded by any electrical or mechanical process without prior permission; permissions for the commercial use of papers copyrighted by their authors must be obtained from the authors. As previously, abstracts, figures, and tables may be freely copied by anyone so long as proper credit is given.

A catalog of issues still in print and their cost can be obtained from our Business Office at no charge; facsimile copies of out-of-print issues can be supplied for a nominal fee.

The "fair use doctrine" permits free copying for scholarly or educational purposes, the above conditions not withstanding.

Cover: See Grady, page 9.
A sophisticated computer-aided design (CAD) system produces maps from a large cave database (25,000+ survey stations). A unique feature is how the data is moved between the raw processing stage, database stage, and final computer-map drafting stage, all within the internal confines of the computer system.

INTRODUCTION

Central Kentucky contains the largest cave system in the world. Mammoth Cave alone contains well over 300 miles of surveyed passages at present (Cave Research Foundation, 1985). If the surveyed footage from adjacent, yet unconnected systems is added to this amount, almost 500 miles of cave is obtained.

Exploration and survey of the extensive caves within this area was formally organized in the mid 1950's (Brucker and Watson, 1976). Since then, survey continues on a variety of fronts. The Mammoth Cave survey is under the auspices of the Cave Research Foundation (CRF). Survey projects outside the Mammoth Cave Park are managed by a number of separate groups, all affiliated with the National Speleological Society.

In 1981 a small hole was dug open near the top of a ridge on the Fisher Farm in central Kentucky. Subsequent exploration and survey revealed a fully integrated cave system of considerable length (Fig. 1). The exploration continues today with almost 50 miles of survey and nearly 10,000 total survey stations, ranking the Fisher Ridge Cave System in the top ten longest caves in the world (Gulden, 1982). This project is being managed by members of the Detroit Urban Grotto, of which the author is a member.

Cave survey and exploration depends heavily on knowing precisely where the cave passages lie with respect to the surface and with respect to each other. If a cave passage terminates in mud fill at the edge of a sinkhole, then the prospects of digging through to additional discoveries are minimal. If a passage heads into an adjacent ridge then exploration efforts can be directed towards that passage in an attempt to make new major discoveries. Similarly, if two passages are heading towards each other on the same level, efforts can be made to connect the passages in order to provide a short-cut around existing obstacles.

Like most projects of this type, the Fisher Ridge Cave Project turned towards computer applications in order to interpret the mass of survey data produced. The original survey data processing program was written by C. Hopper in 1981. Additional modifications and improvements were implemented by both C. Hopper and the author over the next few years. The CAD interface and data base approach to be discussed here were implemented entirely by the author.

One of the unique advantages of the integrated data processing system to be discussed here is its fast turnaround time. On some weekends of active exploration and survey, over 10,000 feet of new survey with several hundred stations is developed. This data can be processed within hours to

**Figure 1.** Line map of Fisher Ridge Cave System.

*Department of Chemical Engineering, Wayne State University, Detroit, MI 48202.
provide an updated line map that can be overlaid with the corresponding topographic section. This fast turnaround is important to maintain momentum of the project and to make timely decisions on upcoming trips.

Of long term interest to the project is the production of a final publication style map. An interface between the database and an existing computer-aided design (CAD) package has been developed so that most of the tedious manual drafting problems can be eliminated. Since the cave systems under consideration are very extensive, the cave must be broken down into section maps. The CAD interface produces highly accurate section maps identifying the locations of all survey stations in the section. An option exists to connect the stations by single lines, or for the computer to draw straight cave passage walls. Each section takes about 15 minutes of interactive effort on a terminal.

Unfortunately, the computer is not capable at present of drawing a complete final map. Some things that humans can draw cannot be easily drawn by computers. The converse is true as well. The computer is excellent at accurately placing the survey stations and lettering, tasks that are performed poorly by humans. Conversely, the computer is ill-adept at drawing the irregular lines that constitute the cave passage walls, providing proper passage intersections, floor detail and cross sections. Many of these features cannot be drawn even interactively using a graphics terminal. The final system to be considered here is a hybrid system, using the most capable components of both the computer and the human world.

The information to be presented here will be valuable to others attempting to implement similar systems at their own facilities. The result represents many years of development effort and, in the author's opinion, is the best that can be achieved using presently available hardware and software.

THE CAVE SURVEY PROCESS

The cave survey is a low accuracy survey using hand-held instruments. The measurements are taken in spherical coordinates using a compass, clinometer and measuring tape. A schematic diagram of the process is shown in Figure 2.

To begin a survey, a station is marked at an appropriate location on the wall or floor of the cave passage. A measuring tape is stretched from this initial station to an appropriately marked next station and the distance is recorded. A compass is used to measure the azimuth and a clinometer reading is taken to measure the inclination of the tape. Backsight readings on both compass and clinometer are generally taken to ensure that no blunders have been made. Finally, the distance from the station to the left, right, top and bottom cave walls is measured. All data items are recorded in a notebook, along with a rough sketch of the passage, as shown in Figure 3.

Note that the station names have an alphabetic and numeric component (although this convention is not universal). The alphabetic component identifies the survey while the number identifies the station. For instance, a typical survey sequence would be "A1" to "A2" to "A3," and so forth. A side passage or new survey would receive a new letter designation. Each station name must be unique in the entire cave system.

The accuracy afforded by this type of survey is typically a few percent (Ganter, 1986). This is usually adequate for exploratory purposes. However, a problem can arise in loop closure due to accumulated error. The problem is demonstrated in Figure 4. Suppose a survey is performed in a passage that represents a loop, connecting back to an existing survey station as shown. Due to accumulating errors in the survey process, the final plotted data will demonstrate an offset between the initial location of station A2 and the new location at the end of the loop. The distance indicated represents a loop closure error.

Loop closure errors represent an annoyance in the final map plotting stages and must be removed. The procedure is simply to distribute the error around the stations that constitute the loop, weighted by the inverse length of each survey shot. The problem is complicated considerably when multiple loops occur and when adjacent loops have common survey legs. A least-squares method is available to solve this problem (Schmidt and Schelleng, 1970) and a computer program has been written (Thrun, 1982).

GENERAL OVERVIEW OF COMPLETE SYSTEM

A schematic of the complete processing system is provided in Figure 5.

Raw survey data is entered into a microcomputer system via an interactive data entry program written in BASIC. This program is written specifically for the application and understands the raw data structure and formatting. The raw data is stored temporarily on floppy disk. The data is then transmitted to the minicomputer where it is stored as a file on hard disk. The raw data processing program is invoked

Figure 2. The Cave Survey Process. (Reproduced by permission from Ganter, 1986.)
Figure 3. A sample page from a survey notebook. (Original design by Keith Ortiz.)

Figure 4. Loop Closure Problem.

and the new survey data is reduced and incorporated into the cave file database.

Correction and editing of the raw data is performed either on the microcomputer or on the minicomputer using commonly available line editing programs.

Two directions are possible from the database. In the first direction to the right on Figure 5, the data is processed through a non-interactive program to produce a linemap of the complete cave system on the plotter. This is the fastest path and is usually taken to see immediate results.

The second direction goes to the interactive CAD system. First, however, the information must be extracted from the database and converted to a format compatible with the CAD system. This is accomplished by an interactive program. The program asks the user to designate a cave section to be drawn and any applicable options, and then produces the necessary CAD system macro containing the required drawing commands.

Finally, the MEDUSA CAD system is invoked. Con-
tained within MEDUSA is a predrawn library of drawing sheets, title and information blocks, and section identifiers. The user simply calls up the sheet and executes the macro containing the data. The MEDUSA system draws the cave related information on the sheet using the information contained in the macro. To complete the map the user interactively places the title block and section identifier at a convenient place on the map. The user can perform other optional drawing operations at this time, if required.

All minicomputer programs are written in Fortran IV.

**RAW SURVEY DATA REDUCTION**

The first step is to reduce the raw survey data and incorporate it into the database.

The functions of the raw data processing program are as follows: First, it must read the raw data and the existing database and any user specified options. Second, it must determine that the new survey stations are logically connected to existing survey. Third, it computes the Cartesian coordinates of the new stations from the survey data provided. Fourth, it performs a loop closure algorithm to distribute loop closure errors. Finally, an output with the new survey is generated and the database is updated.

It is the authors opinion that computer programs should be written to match the data, not vice versa. This philosophy has been applied to the raw data processing stage here. The raw data processing program has been implemented to support a wide variety of data variations. These variations are shown in Table 1.

<table>
<thead>
<tr>
<th>Object</th>
<th>Variations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tape Position</td>
<td>1. Tape connects both stations</td>
</tr>
<tr>
<td></td>
<td>2. Tape is horizontal, inclinometer entry is distance station is above horizontal tape.</td>
</tr>
<tr>
<td></td>
<td>3. Tape connects stations, inclinometer entry is distance station is above previous station.</td>
</tr>
<tr>
<td></td>
<td>4. Tape is horizontal and inclinometer is actual degree reading between stations.</td>
</tr>
<tr>
<td>Tape Units</td>
<td>1. Metric—meters</td>
</tr>
<tr>
<td></td>
<td>2. English—feet and tenths</td>
</tr>
<tr>
<td></td>
<td>3. English—feet and inches</td>
</tr>
<tr>
<td>Compass Usage</td>
<td>1. Corrected backsights</td>
</tr>
<tr>
<td></td>
<td>2. Uncorrected backsights</td>
</tr>
<tr>
<td>Compass Units</td>
<td>1. Degrees</td>
</tr>
<tr>
<td></td>
<td>2. Mils</td>
</tr>
<tr>
<td>Inclinometer Usage</td>
<td>1. Corrected backsights</td>
</tr>
<tr>
<td></td>
<td>2. Uncorrected backsights</td>
</tr>
<tr>
<td>Inclinometer Units</td>
<td>1. Degrees</td>
</tr>
<tr>
<td></td>
<td>2. Percent Grade</td>
</tr>
<tr>
<td></td>
<td>Also variations due to missing backsights.</td>
</tr>
</tbody>
</table>

An important feature of this program is that data is entered into the program exactly as it appears in the survey notebook. The data is entered into the data file with the same number of decimal places as the original data. Most importantly, if data is missing, a blank field is entered. In this fashion, the raw data represents an archival record of the original survey data.

Another important feature of this program is the output format (Fig. 6). The author also believes that program output formats should be reader oriented. A number of features are supported by the program to reflect this philosophy.

First, the program provides a title block capability to identify each survey. The survey instrument configuration and the compass declination is also noted at the bottom of the title block. Each column of output data following below the title block is identified by a heading block. The heading block is reprinted at each branch intersection.

Note that comments can be entered anywhere in the raw data to appear on the output. These comments appear only in the raw data and the output and are not found in the database. The comments are very useful for identifying particularly interesting features in the cave. They are also used to identify side-leads for possible future exploration.

The output also contains the Cartesian coordinates for the station. Both the unclosed coordinates before loop closure and the closed coordinates after loop closure are listed. This is important for determining possible blunders in the survey.

At the end of each survey is a summary block. This block contains the footage and number of stations in the survey and also provides a total for the cave system.

For cave systems exceeding several thousand stations, most of the compute time is spent looking up connecting stations. Two features are incorporated to reduce this time.
First, the search is begun with the most recent stations. Second, a catalog search algorithm is used. Stations are catalogued according to the last character in the station identifier. Compute time savings of as much as 50% have been realized using this approach.

The program is structured to minimize computer processing when new data is added. This avoids the necessity for re-running the complete raw data set for each new addition. The steps in this procedure are as follows. First, the database is read, including the names, location, and connectivity of existing stations. Next, the raw data for the new stations is read and logically combined with the dataset. Finally, a complete loop closure is performed on all the data and the database is updated. Output is produced only for the new data.

**Database Structure**

The structure of the database is shown in Table 2. The items in the database were selected for both necessity, convenience and possible future expansion of the system. The items marked with an asterisk are necessary for operation of the other aspects of the system.

**Table 2. Database structure.**

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Station character name</em></td>
<td></td>
</tr>
<tr>
<td><em>Station number</em></td>
<td></td>
</tr>
<tr>
<td><em>Number of connecting station</em></td>
<td></td>
</tr>
<tr>
<td>Simplified tape distance in feet</td>
<td></td>
</tr>
<tr>
<td>Simplified corrected compass in degrees</td>
<td></td>
</tr>
<tr>
<td>Simplified corrected inclinometer in degrees</td>
<td></td>
</tr>
<tr>
<td>Horizontal distance in feet</td>
<td></td>
</tr>
<tr>
<td>Vertical distance in feet</td>
<td></td>
</tr>
<tr>
<td><em>Left—Right—Top—Bottom readings in feet</em></td>
<td></td>
</tr>
<tr>
<td>Unclosed Cartesian coordinates in feet</td>
<td></td>
</tr>
<tr>
<td><em>Closed coordinates</em></td>
<td></td>
</tr>
</tbody>
</table>

*Indicates those items which are necessary for section map processing.*

The station connectivity is described by two numbers. The first number is the number designation for this station. The second number is the number of the station that it is connected to. A station can appear more than once in this database. If a loop ties into an existing station, then an additional entry is made for that station. The original number designation is repeated.

The tape distance, compass and clinometer readings in the...
database are “simplified.” That is, all possible instrument configurations are reduced to a standard survey shot with the tape connecting both stations and the inclinometer reading the inclination between the two stations. These numbers are not used at present and are only included for possible future expansion.

Both the unclosed and closed coordinates are included with the database. The unclosed coordinates are needed in order to re-run the loop closure routine. The closed coordinates are required for plotting. Each time the loop closure routine is executed, all of the closed coordinates in the database are updated.

At the beginning of the database are three lines of system specific information. This includes the name of the cave system, system footage (both horizontal and actual), the total number of stations, and the maximum distances from the entrance in all four directions.

Non-Interactive Plotting System
Plots can be produced directly from the database using a non-interactive plotting program. This is the usual route when results are needed immediately. This program can only produce a plot of the entire cave system. The user has limited options for controlling the scale and the appearance of stations and/or computer drawn passage walls.

Interface to MEDUSA CAD System
The PRIME MEDUSA CAD system enables a user to generate complex technical drawings of high accuracy from a color graphics terminal. Various options and drawing operations are selected by using a “mouse” on a system defined menu. Once the drawing operations have been completed, the final sheet can be downloaded to a plotter for final drafting.

The MEDUSA system has extraordinary capabilities to perform drawing operations. Besides standard operations such as lines, text, circles, arcs, construction lines, cross-hatching, and so forth, a large number of advanced features are supported. Some of these features are important to the drawing system to be considered here and will be discussed in detail.

First, the MEDUSA system supports 1024 drawing layers. Different parts of the drawing can be stored in different layers, with user control to turn the layers on or off. For the cave drafting system, the station identifiers, the cave walls, the title block, and other drawing features are all located in different layers. Thus, for instance, by turning the station layer off, a map could be produced without them.

Second, MEDUSA has considerable flexibility to perform operations on parts of the drawing. By surrounding a section of the drawing with a special group line, the entire section can be moved, rotated, magnified, deleted, or stored in a separate file for recall elsewhere. For instance, the sheet title block could be moved into a location on the map that is devoid of drawing features, or reduced to fit into a tight spot.

Third, MEDUSA supports the capability to upload drawing images from a library of files. For this application, a complete cave drafting sheet on which all section maps are drawn was predrawn and stored in a library file. The entire sheet is called up from the library at the start of each section. The title block is also stored in this fashion.

Finally, and most importantly, the MEDUSA system allows drawing macros. These macros are simply files containing a complete set of drawing instructions. Any drawing operation that can be performed at the terminal can also be executed from a macro file. This is the hook that allows the cave data to be downloaded to MEDUSA. A FORTRAN program accesses the database and generates a macro file containing the drawing commands for the cave section of interest. For instance, if the user wishes to generate a section map containing just lines between the stations, a macro file is created that contains the necessary line drawing commands. Once created, a macro can be called up and executed from the terminal.

The macro commands necessary to perform the drawing are quite simple. For instance, to draw a line of type “LO” (solid line) from coordinates (0,0) to (0,1) and then to (1,1) requires the following sequence of commands:

NEWL LO
AT 0 0
AT 0, 1
AT 1, 1
ENDL

The “ENDL” command is necessary to terminate and close this line drawing operation.

MEDUSA can efficiently handle large amounts of data on a drawing sheet. For some of the cave sheets drawn, over 20,000 line segments are required. The system handles this quantity of data without excessive delay or terminal I/O problems. It is doubtful whether the PC based CAD systems can provide similar performance.

The above features might appear to present more detail about the MEDUSA system than required. However, they are features found on most CAD systems and, in the opinion of this author, are the minimum features necessary to implement a similar cave map drafting system elsewhere.

The procedure for drawing a selected section map of a cave system is as follows. First, the interactive interface program is invoked. A number of drawing options are selected and the particular cave section is selected. The program accesses the cave database, determines the stations that appear on the section and how they are connected, and produces an output file containing the MEDUSA drawing macro. Each macro file is assigned a unique name based on the section coordinates. Several section macro files can be generated in a single session.
An output for each section is also generated by the interface program. This output contains the station name and its location using a number of different coordinate systems. This is of immense value for determining the location of various stations at final map drafting time.

Next, the MEDUSA CAD package is invoked. A cave drawing section sheet is called from the library and the appropriate section macro is invoked. The drawing operations are visible on the terminal screen as the macro execution proceeds. For sections containing hundreds of stations this operation could take a few minutes.

Finally, a title block is called up from the library and placed in an appropriate area on the sheet. The empty information areas in the title block are filled in using the text capability of MEDUSA.

An additional capability exists to include an index map of all sections of the cave system. The section drawn appears cross-hatched on this index map.

A sample section map created using the above procedure is shown in Figure 7. The section map has been greatly reduced to fit on a standard page. It’s true size is 1 m long by .5 m wide, with a metric scale of 1/500. This entire section map, as shown, required approximately 15 minutes of interactive tube time. The straight passage “walls” shown on Figure 7 were drawn by the computer.

Along the sides of the map are distance identifiers in both metric and English scales. Crosses in the interior of the map indicate selected junctions of the x and y scales. The lower left-hand corner of the map is the relative (0,0) coordinate. Appropriate overlap has been provided to adjacent sections to assist in section connection.

**Final Cave Map Drafting Steps**

In the early stages of this project it was believed that the MEDUSA CAD system could be utilized to draw a complete final map. However, this has been found to be somewhat inefficient. The computer appears to be excellent at some drawing operations and poorer at others. This is compounded by a cave map drawing style that is somewhat artistic in certain aspects. For instance, the cave walls are drawn in a random “wiggly” fashion to project roughness. This effect is very difficult to achieve using the CAD system and can be best achieved by manual drafting techniques.

The final system has been designed to take advantage of the best of both worlds. The computer is best at placing stations on a pre-dawn drawing sheet and drawing text. Manual drafting appears best suited for drawing walls, cross sections and floor detail. These items require some artistic ability that the computer is unable to provide easily.

The system seems to work best as follows. First, a map section is produced containing station markers and computer drawn straight walls. A “blank” section is also pro-
COMPUTER APPLICATIONS

duced containing only the section borders and scales. The "blank" section is placed over the other section on a light table and a rough sketch of the final map is produced in pencil. This map should include as much detail as possible. The lettering is then entered at the correct location on the CAD image of the section using the standard text drawing operations at the terminal. A final section is then plotted containing the section border and scales, the title block, the index map and the lettering. This section is placed on a light table over the rough sketch section and the final map is produced. The cave walls, passage detail and cross sections are drawn manually.

Summary

A complete integrated system for producing publication grade computer maps is presented. Most of the tedious effort in the drawing process is performed using an interface to an existing CAD package.

To date, the survey data for three cave systems is contained in the database. The Fisher Ridge Cave System contains almost 50 miles of survey in nearly 10,000 stations. The Rappel Cave System, now connected to Mammoth Cave, contains 56.97 miles of cave with 12,298 survey stations. Finally, the much smaller Crumps Spring Cave contains 11.29 miles of cave with 2922 stations.

The Rappel Cave project has a formal map drawing program in place. Section maps generated using the system discussed here are presently being used to draw final map sections. The other two systems, Fisher Ridge and Crumps, have not yet completed plans for final map drafting.

REFERENCES

Cave Research Foundation, 1985, "The Mammoth Cave System," P.O. Box 443, Yellow Springs, OH.
Thrun, R. Computer code for closing loops (1982).

Just Published!

N.S.S. Bulletin Cumulative Index
by Ira Sasowsky

* Index to Bulletin vols. 1-45
* Index to Occasional Papers 1-4
* Keyword, Author, and Biology Indices
* Caves indexed by name and state
* 200 Pages, softbound
* $8.00 + $1.00 post & handling

Available from the N.S.S. Bookstore,
Cave Avenue, Huntsville, Al 35810
A PRELIMINARY ACCOUNT OF THE PLEISTOCENE MAMMALS FROM PATTON CAVE, MONROE COUNTY, WEST VIRGINIA

FREDERICK GRADY*

Remains of Pleistocene mammals have been recovered from several localities in Patton Cave, Monroe County, West Virginia. The major excavated site produced bones of at least 22 individuals of the peccary, Platygonus compressus, and 75 individuals of small mammals, several species of which have present ranges north of Patton Cave. Other fossil remains found scattered in several nearby sites include a tooth of the extinct deer, Sanganoma fugitiva, a partial skull of the badger, Taxidea taxus, and a partial mandible of the pine marten, Martes americana. A Carbon 14 date of 13,350 ± 120 years BP was obtained for the main site and one of 22,620 ± 240 years BP for a second site. The main site is believed to represent a now-closed natural trap. Tracks and scratches left by bears and possibly other carnivores were discovered near several of the bone sites.

INTRODUCTION

During a survey of Patton Cave, Monroe County, West Virginia, in June, 1981, remains of the peccary Platygonus compressus were collected and brought to the attention of the author. Previously Ferguson (1977) reported a maxilla of Platygonus and Handley (1956) noted remains of small mammals collected from Patton Cave. Several weeks after the 1981 discovery, survey parties dug through a sediment-choked passage and descended into a pit where a much richer bone deposit was discovered, including several skulls (Grady, 1983).

Patton Cave is located in the Ronceverte 7.5-minute quadrangle at 37°32’36” north latitude and 80°23’56” west longitude, at an elevation of 732 meters (Davies, 1965).

*Department of Paleobiology, National Museum of Natural History, Smithsonian Institution, Washington, D.C. 20560.

Copyright © by the National Speleological Society

THE NSS BULLETIN, JUNE 1988 • 9
A West Virginia Archeology Permit AP-1-81 was obtained in October, 1981, and five expeditions were made into Patton Cave during the next two years. The main site, Grady Patton Lower Site (GPL) (Fig. 1), consists of a passage approximately one meter wide and 10 meters long, beneath a now-closed sinkhole, nearly 1,000 meters from the main entrance to the cave. A horizontal passage intersects the pit approximately 10 meters above the GPL site. This and other obstacles in the cave precluded large scale excavations. A second site, Grady Patton Upper Site (GPU), was located in a nearby horizontal passage and surficial remains were collected from several additional sites in the eastern end of the Football Field Room and in the passage due north of this room. Field notes on file at the United States National Museum (USNM) give additional details of the various sites within the cave.

The Excavations

At the GPL site, all surficial bones were all collected and excavations were conducted at several points. Abundant, well preserved remains of *Platygonus* were found in a matrix of sticky, silty clay that contained occasional pebbles. At an excavated depth of approximately 25 cm, bone became rarer and less well preserved. Where a portion of the deposit had been washed away to a depth of about 120 cm, the sediment was observed to become coarser with depth and bone became increasingly rare 25-30 cm below the surface. An area approximately three square meters at one end of the deposit was covered by a thin flowstone crust up to 0.5 cm thick. Some bones were collected from within and below this crust.

Orientation of skeletal remains in the GPL site seemed to be random and only a few bones were articulated or associated. With the exception of ribs most of the more than 600 *Platygonus* bones were complete or nearly so. Surface bones were generally rodent-gnawed and a few had been damaged by rock falls. Most of the bones were wrapped in tissue, placed in metal or plastic boxes and removed from the cave. Fragile remains such as skulls were jacketed with plaster bandages before packing. Sediment samples containing small bones were also collected.

The GPU locality, which was approximately 3 m by 1 m, was excavated to a depth of 50 cm in places. Bones and teeth, principally of *Platygonus*, were found in decreasing numbers with depth. Like the GPL specimens, the GPU skeletal remains seemed to show no preferred orientation, but were less well preserved and seldom complete. A single salamander vertebra from the GPU locality is the only non-mammalian specimen collected from Patton Cave.

Vertebrate remains were found on the surface at six other localities in Patton Cave and include several taxa not found at the excavated localities. Tracks of a small bear and scratches, probably made by bears, were present near several of the bone sites.

The larger bones, mostly of *Platygonus*, were dried at room temperature and then washed in water to remove adhering sediment. After a second drying, the bones were hardened with a solution of polyvinyl acetate in acetone. Sediment samples washed from larger bones, as well as those collected separately, were screened through 1 mm mesh screens for small bones. Samples of bone from the GPL and GPU sites were submitted to Beta Analytic, Inc., for Carbon 14 dating. GPL was dated at 13,350 ± 120 years BP and GPU was dated at 22,260 ± 240 years BP. These dates indicate a late Pleistocene, Rancholabrean Age for both localities.

The specimens are deposited in the collections of the Department of Paleobiology, National Museum of Natural History, with the exception of one composite skeleton of *Platygonus compressus*, which has been loaned to the collection of the West Virginia Geological Survey at Morgantown, West Virginia.

Species Accounts

*Sorex cinereus* Kerr—masked shrew

Material: GPL, 6 partial skulls; 2 right, 2 left maxillae; 5 right, 6 left mandibles. MNI = 8.

Remarks: *Sorex cinereus* is the most common shrew in the Patton Cave fauna. The well-preserved skull material confirms identification as *S. cinereus* based on the even slope of the premaxilla back from the incisors (Burt, 1969) rather than the very similar *Sorex longirostris*. *S. cinereus* ranges throughout West Virginia (Hall, 1981). It is usually present and often abundant in Central Appalachian late Pleistocene faunas (Guilday et al., 1977).

*Sorex arcticus* Kerr—arctic shrew

Material: GPL, 2 partial skulls; 1 left, 1 right maxillae; 2 right mandibles. MNI = 3.

Remarks: *Sorex arcticus* in eastern North America now reaches its southern limit in New Brunswick and is a good indicator of the boreal aspects of the Patton Cave GPL site (Hall, 1981). *S. arcticus* has been found in several late Pleistocene sites as far south as Tennessee (Guilday et al., 1977). It is present in four sites in Pendleton County, West Virginia: Eagle Cave, Trout Cave, New Trout Cave, and Hamilton Cave (Guilday and Hamilton, 1973; Kurten and Anderson, 1980; Grady and Garton, 1981).

*Microsorex hoyi* (Baird)—pigmy shrew

Material: GPL, 2 partial skulls; 2 right, 1 left maxillae; 7 right, 5 left mandibles. MNI = 7.

Remarks: *Microsorex hoyi* has not been collected as a Recent mammal from West Virginia despite efforts by McKeever (1955) and others. Hall (1981) indicated that the range of *M. hoyi* includes parts of the adjacent states of Virginia and Ohio. This species is well represented in other late Pleistocene sites of Central Appalachia (Guilday et al., 1977).
Blarina brevicauda (Say)—short-tailed shrew
Material: GPL, 1 partial skull; 4 left mandibles. MNI = 4. GPU, 2 left mandibles. MNI = 2.
Remarks: The small sample of Blarina brevicauda from Patton Cave is most similar in size to B. brevicauda kirtlandi, the subspecies now living in West Virginia. One of five measurable mandibles slightly exceeded the maximum size for B. brevicauda kirtlandi from Pennsylvania as indicated by Guilday et al. (1964). It is thus possible that the larger, more northerly subspecies, B. brevicauda brevicauda, is represented by at least part of the Patton collection. In contrast to most other Central Appalachian late Pleistocene sites, B. brevicauda, is represented by very few individuals in Patton Cave. Based on the recent Blarina revision by Jones et al. (1984), the Patton specimens appear to fit into the B. brevicauda talpoides subspecies.

Parascalops breweri (Bachman)—hairy tailed mole
Material: GPL, 1 right, 3 left mandibles; 2 left ulnae. MNI = 3.
Remarks: Parascalops breweri is present throughout West Virginia and is also common in other Central Appalachian late Pleistocene sites (Kurten and Anderson, 1980). According to McKeever (1955), P. breweri is usually found in loose, somewhat moist soil.

Condylura cristata (Linnaeus)—star nosed mole
Material: GPL, 1 right, 1 left mandibles; 4 right, 4 left humerae; 6 left ulnae. MNI = 6.
Remarks: Condylura cristata is currently restricted in West Virginia to the eastern, more montane counties and is usually found in wet areas (McKeever, 1955; Guilday et al., 1964). Both P. breweri and C. cristata have northern affinities, the latter more strictly boreal. Both of these mole species are also well represented in the New Trout Cave fauna.

Myotis keenii (Merriam)—Keen’s bat
Material: GPL, 1 partial skull; 1 tentatively referred left mandible. MNI = 1.
Remarks: Based on measurements and details of the skull and dentition, the skull is Myotis keenii (Miller and Allen, 1928). The tentatively referred mandible has an alveolar length C1-M3 of 6.4 mm, the same as one other from Patton Cave that Handley (1956) identified as Myotis cf. griseccens, the gray bat. M. griseccens does not occur in West Virginia at present and is a southern species reaching as far north as southern West Virginia in eastern North America (Guilday et al., 1977). In view of the high representation of boreal species in the GPL site, the northerly range of M. keenii that includes West Virginia, and the fact that the mandibles of M. keenii and M. griseccens overlap in size, it seems likely that M. keenii is the only large Myotis in the Patton Cave fauna.

Myotis sp.—small brown bats.
Material: GPL, 1 right, 1 left mandibles. MNI = 1. Other sites, 2 right, 7 left mandibles. MNI = 7.
Remarks: Additional Myotis remains were found at the GPL and two other sites in Patton Cave. These 11 mandibles had C1 (alveolus)-M3 measurements ranging from 5.7-6.1 mm, indicating a medium sized species, probably Myotis lucifugus or Myotis sodalis. The largest mandibles of this group could represent small Myotis keenii. M. lucifugus is present throughout West Virginia and has been observed living in Patton Cave.

Pipistrellus subflavus (F. Cuvier)—pipistrelle
Material: GPL, 1 right, 1 left mandibles. MNI = 1. Other sites, 1 partial skull; 3 right, 3 left mandibles. MNI = 3.
Remarks: Pipistrellus subflavus is common in West Virginia caves, and living individuals have been observed in Patton Cave.

Lasiurus borealis (Muller)—red bat
Material: Other sites, 2 partial skulls. MNI = 2.
Remarks: The two partial skulls were found near the GPU site along with an apparently recent skeleton of Lasiurus borealis. L. borealis is not considered to be a cave-inhabiting bat but has been found occasionally in other bone sites (Guilday, 1962). This species is present throughout West Virginia.

Leporidae—rabbit or hare
Material: Other sites, edentulous maxilla, 1 tooth. MNI = 1.
Remarks: This fragmentary material is likely to be Sylvilagus but is large enough to be a small Lepus americanus. Two species of cottontail, Sylvilagus floridanus and Sylvilagus transitionalis, are present in West Virginia, whereas the hare, L. americanus is restricted to higher elevations of several of the eastern counties of the state (McKeever, 1955).

Marmota monax Linnaeus—woodchuck
Material: GPL. 1 incisor, 1 molar. MNI = 1.
Remarks: The woodchuck is a common member of late Pleistocene faunas in the Central Appalachians and lives today throughout West Virginia.

Tamiasciurus hudsonicus (Erxleben)—red squirrel
Material: GPU, 1 partial skeleton. MNI = 1.
Remarks: The skeleton from Patton Cave is a juvenile with DP4 in place. Tamiasciurus hudsonicus is currently
found in the northern and eastern counties of the state, usually at altitudes above 610 meters (McKeever, 1955). It is also found in the New Trout Cave fauna.

**Neotoma floridana** (Ord)—woodrat

Material: GPL, 1 right, 1 left maxillae. MNI = 1. GPU, 1 femur. MNI = 1.

Remarks: *Neotoma floridana* inhabits caves in West Virginia and frequently gnaws on bones. Many of the peccary and other bones from Patton Cave show rodent gnawing that is likely by *N. floridana*. Two cervid teeth may have been brought into the cave by the woodrat.

**Peromyscus** sp.—deer or white footed mouse

Material: GPL, 2 left, 4 right maxillae; 1 left mandible. MNI = 4. Other sites, 1 right, 2 left mandibles. MNI = 2.

Remarks: This material is too fragmentary for specific identification. The specimens are probably *Peromyscus maniculatus* or *Peromyscus leucopus*, both of which are present today in West Virginia and occur in most late Pleistocene faunas in the Central Appalachians.

**Phenacomys intermedius** Merriam—heather vole

Material: GPL, 1 left mandible with m1-m2; 1 M1. MNI = 1.

Remarks: This species is one of the more distinctive members of the late Pleistocene faunas of the Central Appalachians. *Phenacomys intermedius* is not a member of the modern West Virginia mammalian fauna and reaches its southern limit in eastern North America at the St. Lawrence River. It has been recovered from five Pendleton County, West Virginia, cave sites (Guilday and Hamilton, 1978; Guilday and Parmalee, 1972; Grady and Garton, 1981). *Phenacomys intermedius* is another boreal indicator.

**Synaptomys borealis** (Richardson)—northern bog lemming

Material: GPL, 1 right, 2 left mandibles; 2 isolated molars. MNI = 2.

Remarks: This is another northern boreal species which now reaches the White Mountains of New Hampshire as its southern North American boundary. It is frequently a member of late Pleistocene faunas and is usually associated with *Synaptomys cooperi*, not present in Patton Cave. *S. borealis* has been recovered from five other cave sites in West Virginia (Guilday and Hamilton, 1978; Garton, 1977; Grady and Garton, 1981).

**Clethrionomys gapperi** (Vigors)—red-backed vole

Material: GPL, 3 right, 1 left mandible; 7 isolated molars. MNI = 3. GPU, 1 left mandible. MNI = 3.

Remarks: The red-backed vole is a member of the modern West Virginia fauna, occurring throughout the eastern counties in suitable habitat. It is a forest species with boreal affinities, and is present in several Pendleton County, West Virginia, cave sites.

**Microtus pennsylvanicus** (Ord)—meadow vole

Material: GPL, 1 partial skull; 4 palates; 5 right and 5 left mandibles with at least m1; 16 right and 18 left m1s; 19 M3s. MNI = 23. GPU, 1 left mandible. MNI = 1.

Remarks: *Microtus pennsylvanicus* is the most abundant small mammal from Patton Cave. Identification is based on upper dentitions with lower dentitions referred on the basis of size. In contrast to other sites of similar age in West Virginia and adjacent states, Patton Cave apparently lacks *Microtus chrotorrhinus*, which is present in the eastern counties of West Virginia usually in the higher elevations (Kirkland, 1977). Guilday (1982) noted that M3, upon which most identifications were made, does have some overlap between *M. pennsylvanicus* and *M. chrotorrhinus*; since all the M3's showed the most common *M. pennsylvanicus* pattern, however, all were referred to *M. pennsylvanicus*.

**Microtus xanthognathus** (Leach)—yellow—checked vole

Material: GPL, 4 partial skulls; 1 right and 5 left mandibles. MNI = 5.

Remarks: This is an especially significant species, as its current range is northwestern Canada and Alaska (Hall, 1981). It is the second most common microtine rodent in the GPL fauna and is distinct from *M. pennsylvanicus* and *M. chrotorrhinus* on the basis of its much larger size and details of the dentition. It is known from several other late Pleistocene sites in the East, as far south as Tennessee and Arkansas (Guilday et al., 1978; Hallburg et al., 1974). Previous records for West Virginia are Eagle and New Trout caves, both in Pendleton County (Guilday and Hamilton, 1973; Grady and Garton, 1981).

**Zapus hudsonius** (Zimmerman)—Meadow jumping mouse

Material: GPL, 1 left m1; 1 right and 1 left m2. MNI = 1.

Remarks: *Zapus hudsonius* is present throughout most of the eastern half of West Virginia and is frequently found in cave sites in the East. This species was also collected in both Eagle and New Trout caves.

**Erethizon dorsatum** (Linnaeus)—porcupine

Material: Other sites, 1 molar. MNI = 1.

Remarks: A single porcupine molar was found near the GPU site. Historically, the porcupine was a member of the West Virginia fauna but apparently became extinct in modern times due to deforestation (McKeever, 1955). Porcupine remains are present in several Pleistocene and Holocene sites in the state.

**Vulpes vulpes** Linnaeus—Red fox


Remarks: The red fox is currently a member of the West
Virginia fauna though an apparent range extension south from New York since colonial deforestation (Guilday et al., 1978). It is rare as a Pleistocene fossil in eastern sites, New Trout Cave being the only other West Virginia locality.

Ursidae—bear
Material: GPU, 1 proximal phalanx. MNI = 1.
Remarks: This isolated phalanx cannot be identified beyond family level though its small size and geographic occurrence suggest it represents the black bear, *Ursus americanus*. A series of foot prints nearby was probably made by a small bear and numerous scratches near several of the bone sites were likely made by bears as well. These indications suggest utilization of the cave by bears, perhaps for hibernation. Similar signs of bears have been noted in an Arkansas cave by Youngsteadt & Youngsteadt (1980) and bear tracks were noted also in Windy Mouth Cave, Greenbrier County, West Virginia by Whittemore (1979).

*Martes americana* (Turton)—pine marten
Material: Other sites, USNM 39170 1 partial left mandible with c1, p2 and an alveolus for p1, p3-p4. MNI = 1.
Remarks: The pine marten is not a member of the modern West Virginia fauna, reaching only as far south as Pennsylvania. It is a common member of Late Pleistocene faunas in the Central Appalachians (Guilday et al., 1977). Other West Virginia localities are Eagle Cave, Benedicts Cave, and New Trout Cave.

*Taxidea taxus* (Schreber)—badger
Material: GPU, 1 left tibia. MNI = 1. Other sites, 1 partial skull (USNM 391971). MNI = 1.
Remarks: The partial skull consists of most of the brain case, found some distance from the GPU site, and is considered to represent a different individual. Because of erosion and rodent gnawing, few useful measurements can be made on the Patton badger specimens. The badger is a midwestern prairie species and has been found in several middle and late Pleistocene sites in the East (Guilday et al., 1978). Badger remains have been found in New Trout and Hamilton cave, both in Pendleton County.

*Platygonus compressus* Le Conte—Flat-headed peccary
Material: GPU, 22 partial to nearly complete skulls, 20 partial to nearly complete mandibles, 5 incisors, 16 canines, 3 premolars, 4 molars, 35 cervical vertebrae, 79 thoracic vertebrae, 55 lumbar vertebrae, 9 partial to complete sacra, 4 caudal vertebrae, 12 sternebrae, 31 scapulae, 25 humeri, 29 ulna/radii, 10 carpals, 2 fused metacarpals 3 & 4s, 28 separate metacarpals, 25 inominate, 32 femora, 35 tibiae, 12 fibula parts, 4 patellas, 45 tarsals, 18 fused metatarsals 3 & 4s, 39 proximal phalanges, 19 medial phalanges, 20 ungual phalanges, 6 sesimoids, a few hyoid fragments, and numerous rib parts. MNI = 22.
Table 2. *Platygonus compressus* from Patton Cave GPL Site.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Mean (MM)</th>
<th>Observed Range</th>
<th>Sample Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skull length</td>
<td>302.0</td>
<td>300.0-305.0</td>
<td>3</td>
</tr>
<tr>
<td>Condyle to Premaxilla</td>
<td>276.0</td>
<td>267.0-285.0</td>
<td>5</td>
</tr>
<tr>
<td>Height of Occipital</td>
<td>94.1</td>
<td>87.2-102.0</td>
<td>8</td>
</tr>
<tr>
<td>Width Occipital Condyles</td>
<td>51.5</td>
<td>46.1-55.0</td>
<td>12</td>
</tr>
<tr>
<td>P2-M3</td>
<td>75.3</td>
<td>71.5-82.4</td>
<td>11</td>
</tr>
<tr>
<td>M1-M3</td>
<td>47.6</td>
<td>43.5-51.3</td>
<td>16</td>
</tr>
<tr>
<td>p2-m3</td>
<td>78.4</td>
<td>72.2-80.9</td>
<td>8</td>
</tr>
<tr>
<td>m1-m3</td>
<td>48.0</td>
<td>41.8-51.3</td>
<td>16</td>
</tr>
<tr>
<td>Humerus length</td>
<td>191.0</td>
<td>180.0-203.0</td>
<td>12</td>
</tr>
<tr>
<td>Radius length</td>
<td>159.0</td>
<td>153.0-165.0</td>
<td>13</td>
</tr>
<tr>
<td>Ulna length</td>
<td>211.0</td>
<td>205.0-215.0</td>
<td>7</td>
</tr>
<tr>
<td>Femur length</td>
<td>193.0</td>
<td>183.0-200.0</td>
<td>9</td>
</tr>
<tr>
<td>Tibia length</td>
<td>194.0</td>
<td>182.0-201.0</td>
<td>14</td>
</tr>
</tbody>
</table>

Sangamona fugitiva (CM 11044). Kurten also examined the Patton specimen and confirmed its identification. The Patton molar is 17.0 mm long by 18.1 mm wide. *S. fugitiva* is an extinct cervid intermediate in size between *Odocoileus virginianus* and *Cervus elaphus*, and the Patton tooth is the first record of the species in West Virginia. Churcher (1984) recently suggested that *Sangamona fugitiva* is invalid as a taxon, but Kurten (personal communication) and I are of the opinion that *Sangamona fugitiva* is valid.

**Discussion**

A limited amount of excavation has shown that Patton Cave contains a late Pleistocene, Rancholabrean Age fauna. It is not as diverse taxonomically as such well known faunas as Clarks Cave, Virginia, or New Paris Sinkhole #4, Pennsylvania (Guilday et al., 1977; Guilday et al., 1964). Patton Cave has several species indicative of a more boreal fauna than is now present in West Virginia, which is in...
agreement with other faunas of similar age in the Central Appalachians.

The Patton sites collectively share most species with the Welsh Cave, Kentucky fauna (Guilday et al., 1971). Furthermore, the C14 dates of the Patton GPL site and the Welsh site, both based on collagen from Platgyonous bones, are within 500 years of each other and, as noted, the Platgyonous bones from both caves are very similar in size.

Whereas the Patton GPL site probably represents a natural trap, the Patton GPU site and scattered remains elsewhere in the cave may indicate that the bones were accumulated in part, by carnivores. At least one bear was in the cave as evidenced by tracks and scratches. This implies another, now closed, entrance to the cave although it is possible that bears could have accessed the bone sites from the current horizontal entrance.

There is a great deal of sedimentary fill in and around the bone sites in Patton Cave and certainly much more work remains for future investigators.

ACKNOWLEDGEMENTS

Dr. and Mrs. Clark Hansbarger, the owners of Patton Cave, gave permission for the excavations and showed continuing interest in the project. The following individuals assisted in the fieldwork: Debbie Abeil, Linda Baker, Bruce Bradshaw, Elisa Bowman, George Dasher, Patty Daw, Harold Driscoll, Barry Ferguson, Lynn Ferguson, John Hoover, Tom Kaye, Dennis King, Mike Kubatz, Bob Liebman, Jimmy Lynn, Joe Musser, Mark Passerby, Marilyn Templeton, Dave West, and Stephanie Zuk. George Dasher drafted Table 1. The late John Guilday gave significant moral support to this project. Some funds for the Carbon 14 dates were received from The Robertson Association and The Virginia Region of the National Speleological Society. E. Ray Garton put the manuscript on his word processor and made available his unpublished research. This manuscript was critically read by Clayton Ray and Robert Emry, both of whom made many useful suggestions.

REFERENCES


THE NSS BULLETIN, JUNE 1988 • 15
PLEISTOCENE MAMMALS


PEBBLE INDENTATIONS: A NEW SPELEOGEN FROM A COLORADO CAVE

DONALD G. DAVIS*

CYNDI MOSCH**

Claystone pebbles in the margin of a rubble flow have sunk into the limestone wall of a cave alcove, creating pockmarks and grooves. These unusual forms were apparently etched by corrosive moisture, either vadose or condensed from the cave air, permeating the rubble mass.

INTRODUCTION

Speleogens are cave features or forms created by water attack on cave rock surfaces (as opposed to speleothems, features growing by deposition from solutions). Speleogen geometries are basic clues to the histories of caves. Some are indicative of phreatic, or totally-flooded origin (solution pockets, natural spans, spongework); others indicate vadose, or partly air-filled conditions (stream slots, meanders, vertical fluting). Some (scallops) may arise in either phreatic or vadose regimes. It was recently suggested that a third category (atmospheric) be established for cave features created by condensation water (Davis, 1982).

Since speleothems are considered by most cavers more interesting than speleogens, the latter receive less attention, and new speleogens are not often recognized and reported. So far as is known, the pebble indentations recently found in a new section of Fixin' to Die Cave, Garfield County, Colorado, are a unique and previously undescribed speleogen.

CONTEXT OF PEBBLE INDENTATIONS

Fixin' to Die is a complex, long-drained phreatic cave, with more than a mile of surveyed passage, in the Mississippian Leadville Limestone. It is perched in a rim of the White River Plateau in northwestern Colorado, at about 9,800 feet elevation; its interior temperature is about 40°F. The cave lies beneath a thick, largely-impermeable Pennsylvanian marine shale caprock and is drier than is usual for an alpine cave.

Between the marine shale and the upper Leadville are lenses, up to several feet thick, of Molas shale, an iron-rich claystone unit. The Molas represents a fossil karst soil developed on the Leadville in the interval between Mississippian and Pennsylvanian marine deposition. Recently a high-level section of the cave was found where flows of Molas paleokarst claystone rubble issue from alcoves into the sides of several phreatic domes in an inner passage (near the H survey).

DESCRIPTION OF PEBBLE INDENTATIONS

One of these rubble flows, consisting of red and yellow claystone fragments with some weathered chert pieces, originally rested at the angle of repose against the side walls of one alcove. The alcove (Fig. 1) measures about 3 1/2 feet high by 3 1/2 feet wide by 4 1/2 feet long. Remnants along the walls show that the flow has subsided as much as 5 inches from its original level, apparently either by compaction or undermining (there is no channelling or debris-apron outwash to indicate any surface erosion). The vertical bedrock walls between the original and present debris levels are sparsely studded with remnant claystone pebbles* up to 1 1/2 inch in diameter. These stones are not merely sticking to the walls, but are partly embedded in closely-fitting indentations up to 3/4 inch deep. Some have been pressed laterally into the walls, while others are nested at the bottoms of high-angle grooves up to 2 1/2 inches long, etched by gradual lowering of the stones during slow sinking of the rubble slope (Fig. 2). The inclinations of the grooves are variable, but many diverge about 20° from the vertical in the direction of the main room floor, indicating both vertical and lateral components to the motion of the stones.

The vertical grooves are crossed by faint horizontal lines which match the upper edges of the pebbles and which seem to mark intermittent halts in their downward movement. The stones, if lifted from their pockets, are seen to be separated from the bedrock substrate by thin films of red or black clay residue. The overall effect is reminiscent of the interpenetration of stylolite fingers in limestone bedrock, and probably reflects a similar mechanism. Stylolite seams, however, form along bedding planes under pressure, whereas the pebble grooves show that related forms can develop in low-pressure conditions.

*The term "pebble," though usually connoting stream-rounded gravel, is here used for angular fragments of mechanically-disaggregated claystone.
PEBBLE INDENTATIONS

Figure 1. Alcove containing pebble indentations (note grooves in left wall).

ORIGIN AND SIGNIFICANCE OF PEBBLE INDENTATIONS

The claystone pebbles originally were held against the bedrock wall by the rubble mass along whose margins they were situated. While in this position, they were evidently permeated with acidic moisture, making each stone a corrosive stylus which etched a corresponding pocket or groove in the adjoining bedrock. Ultimately most of the pebbles slipped from their indentations, leaving a minority of the deepest-embedded as evidence of the process. There are three possible situations under which this indenting could have happened: (1) During the phreatic enlargement of the cave; (2) by acidic vadose seepage; (3) by acidic moisture condensation from the cave air.

It seems unlikely that the indentations were created during the cave’s phreatic phase, because it is not clear how a phreatic mechanism could cause the pebbles to be etched preferentially into the wall. The usual case is just the opposite: aggressive phreatic water is in contact with the entire cavity, while sediment touching the bedrock tends to armor that rock against solution, causing preferential solution where no sediment is present (Lange, 1963). Moreover, phreatic solution is normally rather uniform and widespread.
through large areas of cave. We have examined several similar rubble slopes short distances away in this section of the cave but have found no other example of indented walls. The mechanism involved must be one which can be closely localized.

This localization would be consistent with the vadose alternative, in which the porous debris flow could have been a conduit for acidic seepage into the alcove containing the flow. The acidity might have come from biological sources in the overlying soil, oxidation of sulfides to sulfuric acid in the Belden or the Molas material itself, or from CO₂ in the cave air. Capillary action among the semi-permeable pebbles might have wicked the moisture to the bedrock, causing the marginal pebbles to be embedded and the entire flow to subside slightly as the underlying floor was attacked. This mechanism would account for the observed effects. However, there is no independent evidence that vadose seepage has ever acted in the area. There are no unequivocal vadose speleogens (vertically-fluted shafts, stream slots) in any part of this or nearby caves. (The caves do contain vadose speleothems locally, but not in or near this particular dome complex.)

The third possibility is that a similar mechanism was activated, not by vadose seepage, but by condensation moisture. There are at least 150 feet of relief in this region of the cave. The high phreatic domes have rounded, leached walls bearing resolutioned and undermined remnants of white crusts and calcified sandy ledge-mantling residues (this same suite of features appears consistently in the highest parts of this cave and Groaning Cave, a larger cave \( \frac{1}{2} \) mile away). In contrast, the pits and other low-level passages are often encrusted with evaporitic gypsum crust and flowers, as well as aragonite frostwork. Such relationships are common in other caves of large vertical extent in

*Figure 2. Grooves with embedded pebbles, right wall of alcove. Illustrations may be viewed stereoscopically for three-dimensional image.*
the Black Hills and Guadalupe Mountains, and probably result from a convective airflow cycle in which moisture evaporates at low levels, cools and condenses in upper levels, and translocates material by seepage from the upper to lower areas.

Such convective evaporation/condensation cycles would be driven by temperature gradients in which pits were warmer than domes, and would be enhanced in areas of thermal activity. In Fixin' to Die and nearby caves there is evidence for early hydrothermal solution (Davis, 1981), and there has been volcanism within a few miles of the caves as recently as about 4,000 years ago. It is thus credible that the pebble-indentation area may have been subject to strong condensation, and also that localized injection of volcanic gases including CO₂, H₂S and sulfuric acid could have rendered the condensate corrosive. (A nonvolcanic alternative, the production of CO₂ by decay of inwashed organic debris, is not significant in these caves.) The debris flow, having much more surface area and greater permeability than the bedrock, would preferentially collect condensation and thereby be enabled to indent and subside into the adjoining limestone without associated vadose solution effects.

However it operated, the indentation process is probably no longer active. The upper part of the grooved zone is overlapped by a thin, translucent-crystalline calcite crust (the darker, sparkling surface in the photos) which covers some pebble grooves and must be of later origin. In several cases this secondary crust abuts closely against embedded pebbles but does not adhere to them; the pebbles may still retain moisture of high enough pH that calcite cannot deposit on them.

Of the three possible explanations for the pebble indentations, neither the vadose nor the condensation-corrosion one can be ruled out at present, although condensation is perhaps less likely to have caused this specific effect in so limited a part of a single dome complex. A phreatic explanation seems least likely. All embedded pebbles observed are of claystone rather than chert; it is likely that only the claystone is permeable enough to permit the moisture exchange required for the etching process.

Pebble indentations are evidently a rare speleogen, and it would be very helpful in confirming their origin if other examples could be found in other caves where fills composed of permeable clasts abut against walls. More examples might in turn be helpful in understanding the histories of the caves.

REFERENCES

Table 1: Checklist of Bulgarian Cave Minerals (as of 1987).

<table>
<thead>
<tr>
<th>Year</th>
<th>Authors</th>
<th>Formula</th>
<th>Cave</th>
<th>Mineral</th>
</tr>
</thead>
<tbody>
<tr>
<td>1923</td>
<td>Bonchev G.</td>
<td>CaCO₃</td>
<td>Magurata</td>
<td>aragonite</td>
</tr>
<tr>
<td>1960</td>
<td>Kostov I.</td>
<td>CaSO₄·2H₂O</td>
<td>Duhlata</td>
<td>giorgeite</td>
</tr>
<tr>
<td>1964</td>
<td>Naidenova</td>
<td>CaMg(CO₃)·H₂O</td>
<td>Duhlata</td>
<td>aragonite</td>
</tr>
<tr>
<td>1964</td>
<td>Iskreckata</td>
<td>CaMg(CO₃)·H₂O</td>
<td>Duhlata</td>
<td>s aponite</td>
</tr>
<tr>
<td>1974</td>
<td>Maleev M.</td>
<td>CaMg(CO₃)·H₂O</td>
<td>Iskreckata</td>
<td>devilline</td>
</tr>
<tr>
<td>1976</td>
<td>Filipov A.</td>
<td>CaSO₄·2H₂O</td>
<td>Duhlata</td>
<td>trevorite</td>
</tr>
<tr>
<td>1979</td>
<td>Filipov A.</td>
<td>CaMg(CO₃)·H₂O</td>
<td>Iskreckata</td>
<td>giorgeite</td>
</tr>
<tr>
<td>1980</td>
<td>Maleev M.</td>
<td>CaMg(CO₃)·H₂O</td>
<td>Iskreckata</td>
<td>giorgeite</td>
</tr>
<tr>
<td>1980</td>
<td>Maleev M.</td>
<td>CaMg(CO₃)·H₂O</td>
<td>Iskreckata</td>
<td>giorgeite</td>
</tr>
<tr>
<td>1980</td>
<td>Maleev M.</td>
<td>CaMg(CO₃)·H₂O</td>
<td>Iskreckata</td>
<td>giorgeite</td>
</tr>
<tr>
<td>1983</td>
<td>Shopov et al.</td>
<td>CaCO₃·2H₂O</td>
<td>Ledenika</td>
<td>lepidocrocite</td>
</tr>
<tr>
<td>1983</td>
<td>Shopov</td>
<td>CaCO₃·2H₂O</td>
<td>Ledenika</td>
<td>lepidocrocite</td>
</tr>
<tr>
<td>1983</td>
<td>Shopov</td>
<td>CaCO₃·2H₂O</td>
<td>Ledenika</td>
<td>lepidocrocite</td>
</tr>
<tr>
<td>1983</td>
<td>Shopov</td>
<td>CaCO₃·2H₂O</td>
<td>Ledenika</td>
<td>lepidocrocite</td>
</tr>
<tr>
<td>1983</td>
<td>Shopov</td>
<td>CaCO₃·2H₂O</td>
<td>Ledenika</td>
<td>lepidocrocite</td>
</tr>
<tr>
<td>1984</td>
<td>Shopovs Y.</td>
<td>CaCO₃·2H₂O</td>
<td>Ledenika</td>
<td>lepidocrocite</td>
</tr>
<tr>
<td>1984</td>
<td>Shopovs Y.</td>
<td>CaCO₃·2H₂O</td>
<td>Ledenika</td>
<td>lepidocrocite</td>
</tr>
<tr>
<td>1985</td>
<td>Celerite</td>
<td>MgCO₃·H₂O</td>
<td>Ledenika</td>
<td>lepidocrocite</td>
</tr>
<tr>
<td>1985</td>
<td>Celerite</td>
<td>MgCO₃·H₂O</td>
<td>Ledenika</td>
<td>lepidocrocite</td>
</tr>
<tr>
<td>1985</td>
<td>Celerite</td>
<td>MgCO₃·H₂O</td>
<td>Ledenika</td>
<td>lepidocrocite</td>
</tr>
<tr>
<td>1985</td>
<td>Celerite</td>
<td>MgCO₃·H₂O</td>
<td>Ledenika</td>
<td>lepidocrocite</td>
</tr>
<tr>
<td>1985</td>
<td>Celerite</td>
<td>MgCO₃·H₂O</td>
<td>Ledenika</td>
<td>lepidocrocite</td>
</tr>
<tr>
<td>1985</td>
<td>Celerite</td>
<td>MgCO₃·H₂O</td>
<td>Ledenika</td>
<td>lepidocrocite</td>
</tr>
</tbody>
</table>

The aim of this work is to supplement the book Cave Minerals of the World (Hill and Forti, 1986) which does not include data for Bulgarian cave minerals. Investigations of cave minerals in Bulgaria began in 1923. During the last 64 years, 55 secondary cave minerals (published in 60 papers) were discovered first in Bulgarian caves and are new cave minerals. These minerals are classified in the following manner:
Figure 1. Calcite helictite in Shopovs Cave System, Bulgaria. Author photo.

Figure 2. Coralloides in Shopovs Cave System. Author photo.

Figure 3. Green calcite colored by CuII in a cave inside of mine. Author photo.

Figure 4. Ultraviolet photography of calcite stalactite in Duhlata cave. Author photo.

Figure 5. Phosphorescence of calcite concretion in cave clay. Author photo.

Figure 6. Photography of phosphorescence of calcite cave pearls (obtained by the New Method for Photography of Luminescence of Shopov, Tscancov and Grinberg) in cave Sharaleiskata. Author photo.

Figure 7. Sensitized by PbII luminescence of MnIII in hydrothermal calcite. Author photo.

Figure 8. UV-photography of aragonite flower. Author photo.

Figure 9. Phosphorescence of hydromagnesite and vaterite (blue-green) in Shopovs Cave System. Author photo.

Figure 10. Amorphous hydrozincite in Shopovs Cave System. Author photo.

Figure 11. Artinite stalactite in Shopovs Cave System. Author photo.

Figure 12. Nacaurite (green) in hydrozincite in Shopovs Cave System. Author photo.
Evolution of investigations of Bulgarian cave minerals has accelerated in recent years. During the years 1923–1974, 7 cave minerals were described; 1974–1982 saw 10 cave minerals described while 1982–1987 saw 38 cave minerals described. The increase in the investigations in the last period is due to the introduction of new powerful diagnostic methods, methodics, and schemes. These allowed the determination of new cave minerals (nos. 32 & 33) and the difficult to determine rare cave minerals (nos. 24, 25, 27-30, & 38-51).

The main direction of investigations are in the fields of mineral formation (Shopov and Ivanov, in press; Filipov, 1983) and physical properties of minerals. Modern physical methods of research have been applied (some of them for the first time on cave minerals) in the Speleology section of the University of Sofia during the last 4 years. For example, the spectra of luminescence of 9 cave minerals have been determined.

REFERENCES


BOOK REVIEWS

Fauna Cavernícola i Intersticial de la Península Ibèrica i les Illes Balears. Xavier Bellés, Monografies Científiques 4, CSIC-Moll, Madrid, 207 p., illus.

Order from: Servicio de Publicaciones del CSIC, Vitruvio 8, 28006 Madrid, Spain. 3650 Spanish pesetas (about $32 U.S.).

This is a gem of a book which should not be overlooked by anyone with an interest in cave animals. As the title indicates, it is about the cave and interstitial faunas of the Iberian Peninsula (Spain and Portugal). Of course, many books have been published on regional and national cave faunas. But this one is the only modern summary of the fauna of the caves and ground waters of a very interesting and naturally defined European biotic region.

The first chapter outlines the history of cave biology in the Peninsula and the scientific exploratory and descriptive work of many Europeans. Many of the more recent accomplishments have been the result of support by the Museum of Zoology in Barcelona. The second chapter will serve as an excellent textbook for students and naturalists with little familiarity with caves and cave environments. It explains these and the adaptive peculiarities of cave animals, and the various and often competing theories on the evolutionary origin of these adaptations. The discussion incorporates modern aspects of the population genetics of adaptation, and conceptual advancements that have come from North American cave faunal studies.

The third chapter, which is the heart of the book, with well over 100 pages, gives an able summary of the remarkably diverse fauna, of over 1,000 species. It ranges from flatworms, through 6 orders of arachnids, 8 orders of crustaceans, through millipedes, centipedes, and 12 orders of insects, to amphibians and mammals. The beetles are the most diverse, with over 120 species of troglobites in the family Catopidae alone. The discussions of the animal groups are accurately done, but not elaborately technical. The abundant illustrations, as line drawings, and both crisp black and white and color photos, show the non-specialist what the animal groups look like. Frequent use of maps shows the distributions of selected groups. The information in this chapter has never before been assembled in one place.

The fourth chapter synthesizes the geological history of the Peninsula and provides an understanding of the environmental theater for the evolutionary play of the cave faunas. Biogeographic regions, defined by the cave faunas, are outlined. Differences are recognized in the modes of origin of the terrestrial and aquatic components of the fauna, and for those of the continental versus the Balearic island areas. The importance of Pleistocene climatic change for cave colonization is recognized. This chapter was the most interesting for me because of its overview on the dynamics of the origins of the faunas. A final short chapter recognizes the world-wide problem of the need for protection and conservation of cave environments.

The text of the book is in Catalan, the regional language of Catalonia, in the northeastern part of the Iberian Peninsula. My initial reaction was that this would limit the readership and utility of the book. But anyone familiar with Romance languages will see that Catalan has components suggestive of the many languages that have evolved from Latin; that is, Spanish, French, Portuguese, and Italian. As a result, I think that the choice of the Catalan language as a “Latin esperanto” will make the book more understandable to a wider audience with interests in the cave faunas of this fascinating part of the world.

Stewart B. Peck
Department of Biology
Carleton University
Ottawa, Ontario K1S 5B6
Canada


This book, written by two British geographers, is intended to provide an overview of the geomorphology of England and Wales. It is written for a general audience with an interest in natural science. However, the text is useful to the karst researcher as well as a source of case studies. The authors present us with descriptions of some classical karst areas of Britain, in addition to a variety of areas exhibiting other geomorphic processes.

Several introductory chapters are devoted to the areal geology of the Island and the processes that created the British landscape. Following these chapters is a selection of 65 short chapters describing somewhat more than 65 sites of unusual geologic interest. Among these are ten chapters that are primarily concerned with karst. Features such as Malham, Cheddar Gorge, Clapham, Gaping Gill, Ingleborough, and the Hutton Roof Crags are discussed and illustrated. An additional twelve chapters are marginally related to karst features and processes. Therefore at least one-third of the book contains data on the karst geomorphology of
the region. The book thus becomes a significant publication to the karst bibliophile.

Each site is described from historic and geologic perspectives. The text is well illustrated with maps, geologic diagrams, and many photographs. No color is used in the book, but this does keep the price down.

I was slightly disappointed that other famous British karstlands are not included. Additional information on such areas as the Yorkshire karst, the Mendips (Wookey Hole), or Peak Cavern would have been nice, but perhaps too much to expect. The book was written for a broader appeal than what would be covered in a treatise on 'British Karstlands.'

The book is not really for the caver but more for the traveler with an interest in sites of geomorphic interest. Some of these, happily, happen to be areas of karstification. For the price it is an excellent buy and proof that useful books do not need to be expensive.

George N. Huppert  
Department of Geography  
University of Wisconsin–La Crosse  
La Crosse, WI 54601


From: New Mexico Bureau of Mines & Mineral Resources,  
Publications Room, B107, Campus Station, Socorro, NM 87801.

Carol Hill's magnum opus on the Guadalupe caves is more specialized and technical than her previous works on cave minerals. It will nevertheless be indispensable to anyone with a serious interest in the geologic history and features of this peculiar and poorly-understood cave area. The data are mainly from Carlsbad Cavern (which Hill correctly avoids calling Carlsbad "Caverns"), but some information is also given on other caves which have heretofore been almost unmentioned outside the caving literature. The volume is well laid out and printed, with very few typographical errors; black-and-white photos, drawings, graphs and tables are distributed throughout, and sixteen well-reproduced color plates are in a center section. An end pocket contains nine large-scale maps and sections, and the six-page bibliography is a valuable reference source.

The "geology" of the title might more precisely have been "speleogenesis and mineralogy," since the book actually focuses on these aspects. Hill begins by reviewing several recently-published speleogenetic theories proposing unusual mechanisms for the Guadalupe caves. While conflicting in many particulars, these proposals agreed in suggesting sulfuric-acid solution or sulfate-replacement as the primary agent of cave development here. Hill has evaluated these theories by geophysical and geochemical testing on a scale which, I believe, is unprecedented in any cave study.

Her results—notably sulfur-isotope composition of the massive gypsum in Carlsbad Cavern—confirm major cave enlargement by sulfuric acid derived from biogenic hydrogen sulfide associated with natural gas deposits. She favors integration of the vertical cave elements by rising waters along deep flow paths established in the Capitan reef complex during late Pliocene and Pleistocene uplift, during the present erosion cycle; superimposed on this are horizontal levels, interpreted as water-table-controlled and reflecting successive lowering of base levels. Hill cites numerous carbon-14, uranium-series, electron-spin resonance, and paleomagnetic dates to establish a sequence of events. She concludes that the Big Room and Lower Cave are about 750,000 to 850,000 years old, and extrapolates speculative ages (on the assumption of water-table lowering averaging .05 cm/yr) of 1.2 my for the higher Bat Cave level and 3 my for higher-elevation caves such as Cottonwood.

Thus far, this scenario is consistent with my own observations of Guadalupe cave features, though other writers have suggested that the apparent water-table levels might have developed instead along brine/freshwater interfaces. Another controversial aspect of Hill's model is the mode of introduction of hydrogen sulfide into the reef. She suggests that gaseous-phase H₂S (produced bacterially from methane and sulfates in the nearby Delaware Basin evaporites) rose from the south into the caves from upcurving beds of the basinal Bell Canyon sandstone intertonguing with the Capitan limestone, or along permeable joints from the same direction. It is not, however, generally agreed that such permeable connections exist between basin and reef; Hill quotes petroleum geologist Harvey DuChene as proposing updip migration of H₂S through the reef aquifer from the east.

Critical readers will note a number of inconsistencies and doubtful points in Hill's book. For example, the stratigraphic sections are ambiguous about the relations of various facies in the backreef/reef/basin complex; Figures 4 and 10 show different relations of the Queen to the Capitan Formation, while Figure 87 shows Castile Gypsum where the fore-reef should underlie the outer reef margin.

Figure 24, "Air-flow direction as inferred from the orientation of popcorn," gives an oversimplified picture. Directional coralloids grow toward the source of drier air, and if the airflow happens to be dominated by a convective loop (as in Carlsbad's Main Corridor), then the flow will always be in one direction. If, however, barometric control dominates, oriented popcorn can grow in the presence of reversing airflow, as in Lechuguilla Cave.

On page 92, Hill calculates that Slaughter Canyon has
been downcut 174 m in more than 32,500 years, for a rate of less than 4.5 cm/yr. I get less than .54 cm/yr from these numbers.

Hill’s nomenclature for cave features is sometimes questionable. She calls aragonite frostwork “anthodites,” which does not agree with the original definition of anthodites in NSS Bulletin #11, p. 31. I would also call Guadalupe boxwork, which does not seem to be a secondary growth, a petromorph rather than a speleothem.

Many of the mechanisms of speleothem growth cited by Hill are speculative, and a few are dubious. For instance, she says that shelfstone growth begins when cave rafts attach to the sides of a pool. In my experience, most shelfstone pools have no cave rafts. And Hill’s list of causes for the large size of Guadalupe speleothems omits an important element: the caves with the most massive decorations also have large entrances above the decorated zone; the resulting good ventilation enhances CO₂ loss and evaporation, thereby contributing to rapid decoration growth.

I agree with Hill’s summary of future research needs, but would add some items. One would be closer investigation of events relating to water-table sequences. The calcified siltstone/cave raft complex—interpreted by Hill as a water-table suite which predated massive gypsum deposition in Carlsbad Cavern—is found as low as about 3,750 feet in the Guadalupe Room and Lower Devil’s Den. Yet gypsum blocks—also interpreted as sub-water table products—are found in Upper Devil’s Den, more than 100 feet higher, and even below the Music Room, about 250 feet higher. Did the water table rise that much between raft and gypsum deposition? Alternatively, was gypsum at higher levels deposited at a different time than the Big Room gypsum, with the raft episode in between?

Also, Hill dates later raft deposits on the Lake of the Clouds balcony at only 50,000 years old. Yet this is nearly 400 feet above the present water table. Is it credible that water stood that high so recently in Lake of the Clouds passage, whereas a stalagmite date indicates that Lower Cave, at about the same level, has been air-filled for more than 600,000 years? It is perhaps possible that pluvial water influx could have flooded Lake of the Clouds passage with a huge perched lake nearly 300 feet deep, but I would like to see that raft date rechecked.

The mechanics of gypsum precipitation from sulfuric-acid cavern solution also need to be much better understood, since the gypsum is the most central evidence of the cave-forming process. There is usually a sharp boundary between insoluble floor residues and overlying, nearly pure gypsum beds. As Hill notes, this suggests that the gypsum was not a direct, immediate product of wall rock dissolution; but if it derives from cavern dissolution at all, why does gypsum concentrate and settle out in chambers like the Big Room only when solutional enlargement has almost ceased? DuChene (oral comm.) has suggested a possible explanation: cave enlargement occurred in rapid episodes closely coupled with tectonic events that progressively uplifted and uptilted the Guadalupe Mountains fault block. Each such event would release cave-forming gas from traps downdip, at the same time rejuvenating groundwater flow so that most of the potential gypsum residue would be removed. As a new equilibrium was approached, both gas and water input would stagnate, and gypsum largely free of residual silt would precipitate from the remnant water body.

Hill suggests, on the basis of late sulfur crusts in parts of Carlsbad Cavern, that pulses of H₂S injection have continued into relatively recent times. This brings up interesting questions: Could such pulses result, not only from seismic events, but from periodic spontaneous releases of gas like those recently causing loss of life around deep African lakes? Might such gas injections happen in the future, and could the scale be large enough to endanger people in the cave? If so, it becomes important to determine the timing of the gas release events.

If Hill’s book has a second edition, it will need to be considerably revised because of recent enormous and continuing expansion of Lechuguilla Cave, three miles from Carlsbad Cavern. This cave now has more than seven miles mapped (one-third the surveyed length of Carlsbad), and has more vertical range and greater areal extent than Carlsbad itself. It will provide what has hereunto been unknown in the Guadalupes—a second example on the scale of Carlsbad, against which assumptions and hypotheses based on the earlier-known cavern can be tested. This should soon come into play as the pattern of Lechuguilla Cave is better understood.

Hill’s work is certainly not the final word on the Guadalupe caves, but it is by far the most comprehensive to date, attempting to relate the cave development to regional geomorphic history, the evolution of intracratonic basins in general, and even sulfide ore deposition in the margins of such basins. I hope it will be seen as a challenge to workers in relevant fields to build and improve on the foundation it provides.

Donald G. Davis
5311 309 Road
Parachute, CO 81635

Author’s Response to Review by Donald Davis, Geology of Carlsbad Cavern and other caves in the Guadalupe Mountains, New Mexico and Texas.

The review by Donald Davis on Carol Hill’s Geology of Carlsbad Cavern and other caves in the Guadalupe Mountains, New Mexico and Texas was both fair and accurate, but the author would like to comment on a few points.
Davis’ remark on the downcutting of Slaughter Canyon (p. 92) is correct: the rate should be < 0.54 cm/yr, not < 4.5 cm/yr. Other known editorial mistakes are: (1) p. 65, right column, paragraph 4, “Kevin and Given’s” should read “Given and Lohman’s”; (2) p. 68, left column, paragraph 2, “600,000 + 20,000 yrs” should be “600,000 + 200,000 yrs.”

Davis’ remark on the growth of shelfstone is also well-founded. A much more accurate explanation is given in Cave Minerals of the World: “Shelfstone growth begins when a thin layer of precipitate material on the top of a cave pool attaches to the edge of the pool. This material may be cave rafts which have floated to the sides of the pool, or it may be material which deposits directly along the pool’s sides.”

The reader is referred to Figure 90 (p. 82) for a clarification of the author’s interpretation of the calcified siltstone/cave rafts with respect to the gypsum blocks. The water table doesn’t have to rise 250 feet to explain the raft-gypsum sequence: the processes going on in Figure 90 are happening on each cave level with respect to time. Therefore the water table only has to lower from its position as seen in (A) of Figure 90 to its position as seen in (B) to create the raft-gypsum sequence; in (A) the cave rafts are formed at the water table before complete passage integration and in (B) the gypsum precipitates out of solution before the water finally lowers from the passage (C).

The suggestion by Davis to recheck the raft date at the Lake of the Clouds has already been done, by Derek Ford and myself. Rafts were collected with depth along a 6’5” drip tube in a raft cone on the Balcony of the Lake of the Clouds (with an overhead ceiling height of about 9 feet above the cone’s apex). Raft ages fit a consistent pattern of 50,000 yrs on the surface of the raft cone to 250,000 yrs at 6’5” (the rafts of the cone go much deeper than this, but the drip tube does not). Thus, the raft cone began to form sometime > 250,000 YBP and the water level remained stable (within a 9’ span) between 250,000 and 50,000 YBP. Whether these dates represent a real water-table level or a perched water-table level is still a matter of speculation. Note (p. 32 of my book) that the Lake of the Clouds has lowered 31.27 cm over the last 20 years (measurements made by Tom Rohrer). An extrapolation of this rate over 250,000 years is 390,875 cm, or almost 4 km! Certainly no one would consider this credible, or take what is going on today at the Lake of the Clouds and make it representative of the past. I think what we might be seeing is a drastic lowering of the water table (or perched water table) during the last 50,000 years, whereas before this time glacial surface conditions were responsible for a much more humid cave environment (see my discussion of Pleistocene climates on p. 92).

I thank Donald Davis for carefully reviewing my book on Carlsbad Cavern and I especially appreciate his last remark as it fully realizes my intent for the book: “I hope it will be seen as a challenge to workers in relevant fields to build and improve on the foundation it provides.”
**ASPECTS OF POPULATION STRUCTURE IN CAVE CRICKETS, HADENOECUS SUBTERRANEUS**

Studier, E. H., E. H. Lavole, D. Nevin, and K. McMinn. Biology Department, 121 East Court Street, University of Michigan-Flint, Flint, Michigan 48502-2186

We determined individual size (hind femur length) by sex for cave cricket populations by season at four caves near Mammoth Cave National Park, KY. There were no marked differences in size distributions between caves. There are no peaks within the smaller size class chosing no sexual dimorphism of Hadenoecus subterraneus.

The fraction of adults varies in a cyclic seasonal pattern for cave cricket populations by season at four caves near Mammoth Cave National Park in May and July of 1987. Crickets were collected from cave walls and ceilings; brought to a wide, smooth part of the cave floor; and encouraged to jump successively to exhaustion. Primary compass direction taken by the crickets, number of hops, time to exhaustion, total distance covered, and individual hop distances were measured. There were no age-related differences in any parameter but was a primary direction taken. Number of hops, time to exhaustion, total distance hopped, and individual hop distances were averaged 

**HE VERTEbrate CAVE TAUROk OF WEST VIRGINIA: PROGRESS REPORT**

Garton, E. Ray, Mammoth Cave, Inc., P.O. Box 700, Barre, Vermont, W 26559 and Frederick Gresdy, 1201 South Scott St., Apt. 123, Arlington, VA 22204

Twenty-eight species have been identified from 106 cave localities in 16 West Virginia counties. Included in the fauna are amphibians, reptiles, and mammals representing 17 genera. Among the amphibians are 19 species of salamanders, including the West Virginia Spring Salamander, Gymnophthalmus subterraneus. This species is only known in North America from General Davis Cave, Greenbrier County. The only reptile represented is the rat snake, Elaphe obsoleta. The mammals represented include the woodrat, Neotoma floridana and several species of bats. Among the bats are the endangered species Myotis sodalis (Indiana Bat) and Plecotus townsendii virginianus (Virginia long-eared bat). When completed this research will be published as a bulletin of the West Virginia Speleological Society.

**ASPECTS OF REPRODUCTIVE BIOLOGY IN CAVE CRICKETS, HADENOECUS SUBTERRANEUS**

Studier, E. H., K. H. Lavole, E. McKenzie, and D. Nevin. Biology Department, 121 East Court Street, University of Michigan-Flint, Flint, Michigan 48502-2186

Monthly collection, dissection, and fresh and dry weights of adult and copulatory pairs of individuals provide data on reproductive biology of cave crickets, Hadenoecus subterraneus in Mammoth Cave National Park, KY. Minimum spermatophore frequency (50%) in male adults occurred in September with essentially all mature males having spermatophores from October through May. Mature ova reached peak frequency in January and February and minimum frequency in July. Male adults averaged 18.1. Cave crickets of both sexes are sexually mature when their hind femur length greater than 10 mm. Compared to non- copulating gravid adults, females contain the same number of mature ova (6.1 ova per female), both sexes have higher wet carcase weights and lower crop contents.

**THE NSS BULLETIN, JUNE 1988 • 29**
CANADIAN KARST SYMPOSIUM

Derek Ford, Session Coordinator

CAVES AND KARST OF QUEBEC AND THE MARITIME PROVINCES

Caron, Daniel. Societe Quebecoise de Speleologie, 4545 Ave. Pierre de Coubertin, CP 1000, succ. M., Montreal, Quebec H3V 3R2

Quebec contains caves in many geological settings. Most are small and few are more than 100 m long. 1) Greenview Marbles, particularly along the Gatineau River north of Ottawa contain many short stream caves. 2) St. Lawrence Lowlands contain short, wide caves and some glaciolimnic caves with short, wide, shallow entrances. 3) Anticosti Island and the Minga Island, Gulf of St. Lawrence, containing limestones and clayey limestones which display karst but have caves that are fully flooded. 4) Gaspe Peninsula, where limestone caves are common, has the Grotte de la Fee containing 500 m of small, complex passages. Grotte de St. Elsaeur is an ancient pothole with important Quaternary fauna and flora. Limestones, dolomites, and gypsum occur in western Newfoundland, central Nova Scotia and Cape Breton Island, and New Brunswick. Short river caves are being found. Large gypsum caves occur near Windsor, Nova Scotia.

INTRODUCTION TO THE KARST AND CAVES OF CANADA

Ford, Derek. Department of Geography, McMaster University, Hamilton, Ontario L8S 4K1

In Canada there are approximately 570,000 square kilometers of limestone and marble outcropping, approximately 600,000 square kilometers of square kilometers of gypsum. Most lithologic types (oolitic limestone, chalk, crystalline limestone, etc.) occur. The rocks range in age from 600,000 to 700 million years. They are found in every geological and topographic province. Surface karst is widespread but usually modest in scale and sparse. Accessible caves are also widely scattered. The greatest caves have been found and the greatest prospects remain.

CAVES AND KARST NORTH OF 60 DEGREES

Ford, Derek. Department of Geography, McMaster University, Hamilton, Ontario L8S 4K1

Extensive limestone, dolomite, and gypsum terrains occur north of Latitude 60 W in Canada. Prospects for discovering very long or deep caves do not appear to be good, but caves that have been discovered are interesting. Three distinct regions are recognized in the northwestern Canadian Arctic. These contain extensive limestone, dolomite, gypsum, and salt diapirs. Cold, permafrost, and aridity limit karst development; no significant caves have been reported from northern Manitoba, southwestern Canada, and the Arctic Islands. Most carbonate terrains occur around the southern edge of the Shield from Great Slave Lake via Great Bear Lake to the Arctic Ocean. Spectacular sinkholes and springs are known but few caves. 3) The western mountain ranges, chiefly the MacKenzie Mountains. The Nahanni karst (at the southern end of the MacKenzie) contains caves up to 3,000 m long. Dodo and Carropan canyons may yield small caves. In the northwest, ancient relic caves are known in the Old Crow basin.

CAVES AND KARST OF ONTARIO

MacGregor, Kirk. 78 King High Avenue, Downsview, Ontario M3H 3B1 and Brad Wilson

Approximately 225 caves are known in Ontario. Because most formed since the Wisconsin glaciation they are small. About 80% are less than 50 meters long and 2% are longer than 1,000 meters. Walking passage is narrow, crawls are common, and passage cross-sections rarely exceed 5 square meters.

Three major types of cave occur: 1) Sea caves formed by wave action in cliffs of coastal caves. Entrances are up to 15 m high by 25 m wide and funnel down rapidly. Many are 10 to 50 m long and the longest are about 110 m. 2) Crevice caves, usually thousands of feet in length. They are found in all geologic zones and consist of cavities in the rock which are connected by small connections. The longest caves in Ontario are solution mazes.

CAVE AND KARST OF THE COLUMBIA MOUNTAINS AND SOUTHERN CANADIAN ROCKIES

Rollins, Jon.

The Columbia Mountains and Southern Rockies are a popular tourist area. Some of Canada's biggest caves have been found in the extensive carbonate rocks of these mountains. Many caves were explored and commercialized at the turn of the century and contain an exciting history. Elsewhere, the main exploration has only been in the last twenty years. Castlecave is Canada's longest, has 8 km of challenging passage from a single entrance, and ends in a blockage of glacier ice 250 m below the Columbia Icefield. Further south, at Crosswet Pass, is the biggest concentration of caves in the Rockies, with Yorkshire Pot and Gargantua being the two biggest fragments of an extensive and largely unexplored cave system. Many major cave systems remain to be entered such as at Malige where a large river sinks in a lake bed, resurfacing 15 km away and 400 m lower at constructed risings.

CAVES OF THE CANADIAN ROCKIES NORTH OF JASPER, ALBERTA

Yonge, C. J. Department of Physics, The University of Calgary, Alberta, Canada

Over the past two decades a number of karst areas have been explored in the mountainous regions of continental western Canada north of Jasper, Alberta. Karst areas in the Canadian Rockies tend to be remote, often more than 25 km from available highways or logging roads, and difficult to approach. Access to caves is most efficient means of access.

The karst area is about 400 square kilometers in area, and extends from 600 to 700 square kilometers of dolomite and limestone. Limestones range in age from Early Cretaceous to Cenozoic. A number of caves are being found. Large gypsum caves occur near Windsor, Nova Scotia. Some of the caves are being found in the southern part of the area, near York and Breton Island, and New Scotia.

CONSERVATION AND MANAGEMENT SESSION

George Huppert, Session Coordinator

THE VIRGINIA CAVE BOARD: BACKGROUND AND CURRENT STATUS

Bradshaw, Evelyn. Chairman 1987-1988, 1732 Byron St., Alexandria, VA 22303

The Virginia Cave Board was established by statute in 1977 and consists of eleven Virginia citizens appointed by the Governor. They serve four-year staggered terms and are a part of the Virginia Department of Conservation and Historic Resources. Their first major task was using eleven criteria to identify cave which should be given special protection. The first report listed 220 such caves and seven karst areas. Three-hundred metal cave-protection signs were purchased and installed inside caves. Outreach to the owners of Virginia's caves was undertaken by circulation of a newsletter. This attempt to limit and protect land use is in recognition of this resource. Some convictions have been obtained under the cave protection act which was also passed in 1979. How to build more public awareness of the unique nature of karst is the major challenge. The current program direction is toward influencing upper elementary school students.

THE BIGHORN PROJECT: A NEW APPROACH TO NSS INVOLVEMENT IN CAVE MANAGEMENT

Broom, Robert. P.O. Box 2, Elbe, WA 98330

The Bighorn Project has held fieldwork camps at Bighorn Caverns, Montana, in 1985 and 1986 and will again in 1987. The project seeks to catalogue the geologic and geomorphologic resource data for the National Park Service to use in managing the cave. This was the first long-term and national level project ever organized and carried out by the NSS. Project volunteers were acquired from all over the U.S. and Canada. The project has been a success because it was well organized and funded, was open to all cavers on a first-come-first-served basis, provided adequate support for the in-cave workers, and was well planned. A comprehensive report with detailed management recommendations was produced.

THE FIBORN KARST PRESERVE

Curl, Rane L. Michigan Karst Conservancy, 2805 Gladstone Avenue, Ann Arbor, MI 48104

The Fiborn Karst Preserve is the first property of the Michigan Karst Conservancy. The preserve is located five caves including Hendrie River Water Cave, the longest in Michigan. The karst drainage is at a perched swamp and a base-level stream. It has developed primarily post-Wisconsin glaciation and the fall of glacial Lake Algonquin. The rocks are middle Silurian limestone and dolomites of the Burnt Bluff Group, including the type locality for the Fiborn limestone facie.
**Bats** (M. lucifugus, M. semen) roost and/or hibernate in the caves, even though the passages are not spacious. Other biology is being investigated.

The Preserve surface is open to the public, including for hunting in season, but written permission and experienced leaders are required for visiting the caves, which are cold, cramped, and subject to collapse or flooding in places.

**FUTURE TRENDS IN CAVE CONSERVATION:**

The American Cave Conservation Association has made public education concerning its primary objective. Several projects have been implemented to achieve this goal. A feasibility study is underway to determine the suitability of Horse Cave, Kentucky, for a National Cave Education Center and Museum. A recent E.D.A. grant has helped with this study. Weekend field trips have been started in the Hart County, Kentucky, area for students and educators. The National Cave Management Training Seminars will continue on demand. The Association’s grant program will resume when funds allow.

**CONSERVATION ARTICLES IN THE NSS NEWS, 1958-1986**

Stitt, Robert R. 1417 9th Avenue West, Seattle, WA 98119

Information on conservation-related articles that appeared in the NSS News from 1958 to 1986 have been entered into a computerized data base. Frequency and subject analysis reveals cyclic periods and provides a basis for changes in conservation issues and activity. The number of articles averaged one per month during the 1960s, dropped to a low of two during the entire year of 1969, then increased to 4 high of forty in 1974, dropping off and tending to stabilize around two per issue in the 1980s. These correspond to levels of activity within the NSS Conservation Committee. Over the past topics that appear most often include Bats, Conservation Task Forces, Conservation Notes, Gates, Wilderness, Vandalism, and Symposia.

**ELECTRONICS SESSION**

Frank Reid, Session Coordinator

**IMPROVING THE ORGAN CAVE RADIO**

Cole, Ray. 3410 Austin Court, Alexandria, VA 22301

Since the initial development of the Organ Cave radio described in Speleohics #3 (v.1 #3, Fall, 1985), methods of improving the performance of the radio while keeping the design simple to duplicate have been examined. One promising technique to improve performance in noisy environments is to reduce the bandwidth by adding feedback to the first stage to produce a higher effective antenna frequency. A design incorporating feedback has been demonstrated on a bench. This design also provides for full transceiver operation with no electrical switching required between transmit and receive. While the autotransformer used in the original design is highly efficient, a slightly different resonant frequency may be present for transmit and receive when using high Q antennas. This problem can be overcome by using separate primary and secondary windings.

**IMPROVED TELEPHONES FOR CAVE RESCUE**

Reid, Frank. P.O. Box 5283, Bloomington, IN 47402

Underground communication is essential when an injured person must be extracted from a cave. The military surplus field telephones favored by U.S. cave rescuers are increasingly hard to obtain. There are several ways to construct inexpensive telephones including designs simple enough to be built in the field in a few minutes from readily available components.

**GEOLOGY AND HYDROLOGY SESSION**

William B. White, Session Coordinator

**MAJOR CAVES OF THE OROVICIAN GALENA CARBONATES**

IN MINNESOTA AND IOWA

Alexander, Jr., E. Calvin. Geology and Geophysics Department, University of Minnesota, Minneapolis, MN 55455 and Richard S. Lively, Minnesota Geological Survey, 2642 University Avenue, St. Paul, MN 55114

Minnesota’s Orovician Dubuque and Galena Formations and Iowa’s equivalents Dubuque, Wise Lake, and Dunleith Formations host the largest caves in the Upper Mississippi Valley karst. These caves form a linear array across Pillsmore and Winnebago Counties (the “boney line”) and can be divided into two groups. The first group consists of joint-controlled massive caves, developed near the Dubuque/Galena contact in Minnesota. They are input points where surface waters sink underground. The second, stratigraphically lower, group of caves includes caves which are developed in the lower Galena formation in Minnesota and the Dunleith Formation in Iowa. These caves are more dendritic in plan view and return groundwater to the surface via vadose streams which emerge as springs at the cave entrance and at the mouth of accessible caves, are beginning to show patterns of intermittent speleothems which are related to the glacial history and geomorphic development of the area.

**COLLIFORM BACTERIA AND NITRATE LEVELS**

IN THE BURNTSILLEY CAVE DRAINAGE BASIN, VIRGINIA

Chees, Daniel L. and William B. White. Materials Research Laboratory, The Pennsylvania State University, University Park, PA 16802

Karstic drainage basins contain surface and underground streams. The underground streams are easily polluted from the surface through sinking streams and vertical infiltration through sinkholes.

**RURAL BURNSVILLE CAVE and its underlying Butler Cave**

Sinking Creek Stream was studied to investigate levels of nitrate and colliform bacteria in surface and underground streams. Nitrate varied seasonally with high concentrations in the fall and winter and low values in the spring and summer, implying that vegetation and bacterial organisms are controlling the nitrate concentrations. Colliform bacteria levels were found to correlate with discharge, implying that stream sediments and surface soils are the source of the organisms. Bacterial concentrations do not vary within the cave streams rather than a die-off with distance underground.

**ENTRANCELESS CAVES OF THE FIBORN KARST PRESERVE, MICHIGAN**

Curl, Rane L. Department of Chemical Engineering, University of Michigan, Ann Arbor, MI 48109

The method of Curl (1966) was applied to data for number of entrances and lengths of caves in the Fiborn Karst Preserve, Michigan, to predict the number and length of entranceless caves. Five known caves, longer than 10 m, have a total length from 1800 to 1000 m (uncertain due to poor data for one new discovery) and 13 to 17 entrances (due to definition uncertainties). Between two and four entranceless caves with a total length from 120 to 220 m are predicted. Results are nearly independent of the uncertainties in length and entrances. Data and theory agree at the 10% level of significance. The estimated "karst constant" is ca. 0.014 m⁻¹, larger than for any population studied previously, indicating a high degree of entrance development. The method applies to small populations and is robust against uncertainties in data.

**GEOCHEMICAL EVOLUTION OF A CORDUAY CAVE STREAM: LAUREL CREEK, MONROE COUNTY, WEST VIRGINIA**

Groves, Christopher G. Department of Environmental Science, University of Virginia, Charlottesville, VA 22901

Laurel Creek (Monroe County, West Virginia) drains an area of about 50 square kilometers and flows over rocks of the Mississippian Mauch Chunk Series (predominantly shales and sandstones) and the subjacent Greenbrier Group (predominately limestones). Upon reaching the Greenbrier, the creek flows for about 3 km upon a bed of quartz alluvium, sinks into the Laurel Creek-Cross Road Cave System, and resurges at a spring after about 2 km of subsurface flow. Chemical analyses of waters along this section show that (at a spring discharge of 1.61 m³/s) the creek experiences an increase in pH, alkalinity, and Ca++, Mg++, SO₄²⁻, and HCO₃⁻. SIO₂ decreases and Na⁺, K⁺, and the mole ratio of Ca++/Mg++ remain relatively constant. Calcium is dissolved from the cave system at a rate of 4.12 mg/l, causing enlargement at a rate of 0.41 m²/day.

**AIR MOVEMENT IN CAVES**

Lewis, Warren C. 2225 Oxford Street, Rockford, IL 61103

The principal cause of air movement in caves is a change in barometric pressure or a change in virtual temperature of the outside air. Lesser causes of air movement are surface winds, underground streams, internal convective forces, and harmonic resonance. Barometric pressure changes fall into five categories according to wave length, ranging from the pressure zones to storms at sea. Temperature changes in outside air induce flow in caves with several openings by the "chimney effect." This appears to be the only source of air in caves. Air movement at the entrance is restricted by inertia of the air, by formation of air layers, by rough passage walls, and by obstructions. Mixed patterns can often be identified.

The NSS BULLETIN, JUNE 1988 • 31
implications of the new safe drinking water act for protecting karst ground waters

ogden, albert e. center for the management, utilization, and protection of water resources, tennessee technological university, box 5082, clarksville, tn 37040

the safe drinking water act has significant ramifications for increasing knowledge of karst aquifers and ground water basins. the act mandates that the state of tennessee and the sole source aquifer demonstration programs will provide funds necessary to delineate recharge areas and ascertain ground water travel time. through the use of geophysical techniques and data bases and between consultants, we have devised seven methods of delineating wellhead protection areas. in a general order of increasing time input these include: 1) arbitrary fixed radius, 2) calculated fixed radius, 3) simulated variable shapes, 4) analytical flow models, 5) geologic/geomorphic mapping, 6) numerical flow transport models, and 7) ground water age dating. the sole source aquifer program will initiate studies for delineating critical aquifer protection areas in sole source aquifers. a substantial number of new karst aquifers may be recommended for designation as a means of obtaining investigative funding for preserving the quality of wells, springs, and troglobitic species.

use of video well-logging in a karst aquifer, bowling green, kentucky

reeder, philip f. and nicholas c. crawford. center for cave and karst studies, western kentucky university, bowling green, kentucky

the city of bowling green, kentucky, is almost entirely located within the 55 square mile lost river drainage basin. nearly 95% of the area, with depths ranging from 10 to 200 feet, have been drilled in bowling green to direct storm water runoff to the subsurface. research is currently underway by the center for cave and karst studies to facilitate voids identification and voids which eventually may be excavated to allow exploration and 2) delimit zones of maximum concentration of voids for locating future drainage wells.

the voids are identified and recorded by a down-hole video camera. graphic logs are constructed and voids are correlated between wells. creasen cave, first detected by geophysical techniques, was examined with the camera through a 3-inch borehole. an entrance 30 inches in diameter was drilled which yielded over 300 feet of cave. video well-logging is an important tool for studying karst aquifers in the region.

ground magnetic evidence of solution crevice intersections at sinkholes in soil-covered fluviolokarst, tennessee

stokowski, s. j., jr. consulting geologist/petrographer, suite a, 10 clark street, ashland, wa 01721

ground magnetic studies helped locate soil-filled solution crevices and filled sinkholes in a soil-covered fluviolokarst on the nesalva farm (exon group) carbonate rocks, rock quarry dome, savier county, tennessee. the magnetic anomalies that correlated with the difficulty of detecting them center on the contacts between the carbonates and iron-rich terr-rossa soils. high ground magnetic anomalies are obviously very large gamma numbers as the very local background could be correlated across traverses to define linear anomalies. these anomalies were drilled and proved to be linear terr-rossa-filled solution crevices, in the case more than 36.6 m (120 ft) deep. intersections of the linear magnetic anomalies correlated with the more conventional, magnetic contour anomalies pattern indicative of deeper terr-rossa soil, and also with bowl-shaped sinkhole depressions.

stable isotope studies of evaporites in castlegardar cave, columbia icefields, canada

yonge, c. j. and h. r. krouse. department of physics, the university of calgary, alberta, canada.

castleguard cave is both an active and fossil drainage route for meltwater from the columbia icefields. the fossil portion of the cave, formed within limestone of middle cambrian age, contains evaporite minerals on the walls and within in-situ clay sediments. to help resolve the origins of the sulphate minerals, stable isotope measurements of sulphur, oxygen, and hydrogen were carried out on gypsum and mirabilite.

oxidation of bedrock pyrite to sulphuric acid can account for the sulphate mineralization. sulphur isotope measurements in most of the gypsum and mirabilite indicate that bacteria may be involved in the formation. examination of the precipitated water indicated extensive overgrowth of the carbonate bedrock which was slightly during the precipitation of gypsum but more extensive in the formation of mirabilite. this may have precipitated from inflow water which eventually breached the cave and chimney winds caused extensive evaporation.

international exploration session

1986 chiapas expedition - belize/guatemala: may phase

gantzer, john. dept. of geography, 302 walker bldg., the pennsylvania state university, university park, pa 16802

in march and may of 1986, a two-phase expedition, led by dr. tom miller and funded primarily by national geographic, continued explorations begun in 1984. each phase mapped 13.9 km (8.4 mi), with all survey data reduced and drafted on-site. water, soil, and rock samples were collected and analyzed. the march phase worked old leads in actun ebajal, then moved downstream to investigate two caves found in recnos earlier in the year; cabada cave and actun zatun. the may phase pushed cabada up and downstream through passages ranging 50m wide. work then shifted to the system resurgency, xibalba, located in guatemala. after working upstream from a 200m wide entrance for 4km (2.5 mi) in passage reaching 100m width, a steep ramp led to a doline entrance to an old lead. passage was then pushed downstream to connect with xibalba after several kilometers of deep river passage. biological sampling revealed a new species of blind crab and extensive insect fauna. cabada cave, at 15km (9.2 mi) is now the longest in central america.

exploration and study of ensueno cave

gurnee, russell and jeanne. 231 irving avenue, claster, nj 07624

at the request of the cordero family in hatillo, puerto rico, a team of specialists was assembled from the national speleological society and sociedad espeleologica de puerto rico to explore, map, and study ensueno cave between february 18 and 24, 1987.

the purpose of the exploration was to determine if ensueno cave is suitable for development, map it, and determine ways to develop the site, observing conservation and land use planning techniques.

a publication presenting the results of the study will include reports from participants, a site plan for the ensueno cave property, a biological report, a geological report, environmental planning procedures, a cave map, a trail design, cost estimates for the cave development, and other factors to be considered before beginning the construction stage.

exploration and study of fountain cavern

gurnee, russell and jeanne. 231 irving avenue, claster, nj 07624

at the request of the government of anguilla, british west indies, a study team was assembled through the national speleological foundation to explore fountain cavern. the objective was to prepare a study report giving a map, specifications for developing the cave, and estimated costs. the study includes a site plan for the national park, proposed visitor traffic flow, building dimensions, road placement, and a tunnel proposal. the study publication is being written for the anguillan government in preparation for the park and cave development as an historic site for visitors.

fountain cavern contains arawak indian petroglyphs as well as two fresh water pools and an opening in the ceiling through which both early indians and anguillians entered.

the enchanted river

skiles, w.a. rt. 1, box 15803, high springs, fl 32643

the enchanted river covers the 1986 exploration of the caves of puerto rico, the encantado expedition.

caving in japan

zawlocki, edward j. shirogane 4-chome, 10-12-202, minato-ku, tokyo, 108, japan

the present state of japanese caving, and the caving community will be discussed. included topics will be caving organizations, caving methods, karst accessibility, and the caves themselves. special emphasis will be placed on the commercial caves of japan and how they differ from those in the u.s. slides from caves throughout japan will be shown.

guillin karst, china

zawlocki, edward j. shirogane 4-chome, 10-12-202, minato-ku, tokyo, 108, japan

scenes from a recent trip to the karst institute will be shown. coinciding with my visit was a visit by a team from nhk, the japanese national broadcasting company. together we followed the route of one of guilin province's underground rivers from it's first human access point to the li river. use of the cave water will be discussed. the scenes will be shown from a boat tour down the li river and from some of the commercial caves.
PALEONTOLOGY AND ANTHROPOLOGY SESSION

Fred Grady, Session Coordinator

THE QUATERNARY VERTEBRATES OF WEST VIRGINIA: PROGRESS REPORT

Garton, E. Ray. Mammoth Geo, Inc., P.O. Box 200, Barrackville, WV 26559 and Frederick Grady 1201 South Scott Street, Apt. 123, Arlington, VA 22204

Fossil and skeletal remains of Quaternary (Pleistocene and Holocene) vertebrates have been identified from 90 localities in 19 West Virginia counties. The greatest amount of the fossils (77 versus 13) are cave deposits. Included in the remains are reptiles, amphibians, birds, fish, and mammals representing 98 genera. The age of the deposits ranges from recent to perhaps 700,000 years. Among the mammals are at least 25 extinct species including Mammutthus columbi (woolly mammoth), Mammut americanum (mastodon), Symbos cavifrons (must ox), Salidodon (saber tooth cat), Canis dirus (dire wolf), Panthera onca augusta (Jaguar), Taripus (tapir), Platygonus and Mylohyus (peccary), Mircrocinonyx insignes (cheetah-like cat), Acr不通stis (cave bear), Equis tauro (horses), and Desmodus (vampire bat). Also included are many extant species of northern, western, and southern forest indicating the extreme climatic changes that occurred during the Pleistocene of West Virginia.

MASTODON, MAMMUT AMERICANUM, REMAINS RECOVERED FROM BIG SPRINGS CAVE, TUCKER COUNTY, WEST VIRGINIA

Garton, E. Ray. Mammoth Geo, Inc., P.O. Box 200, Barrackville, WV 26559, Frederick Grady 1201 South Scott Street, Apt. 123, Arlington, VA 22204, and Alan R. Carpenter, Rt. 6, Box 72-J, Fairmont, WV 26554

A single tooth cusp of the extinct Pleistocene Probosidean Mammut americanum (mastodon) was recovered from Big Springs Cave, Tucker County, Virginia. The Virginia mastodon represents the first record of mastodon from Tuckers County, the fourteenth record for West Virginia, extends the geographic range of mastodon in West Virginia, and represents the greatest altitude (10,747 meters) of mastodon yet discovered in the state. The mastodon became extinct near the end of the Pleistocene about 10,000 years ago. Remains of porcupine, Erethistta dorsatus, were also recovered from the cave. This porcupine became extinct in West Virginia during recent times.

THE EXTINCT SKUNK BRAHYPOTOMA OBUTSATA FROM THREE CAVES IN WEST VIRGINIA

Grady, Fred. 1201 South Scott Street, Apt. 123, Arlington, VA 22204

The extinct skunk Brahypoemota obtutsata is known from deposits in three West Virginia caves, New Trout, Hamilton, and Woman Hole all in Pendleton County. The finds at New Trout and Hamilton Caves consist of single lower jaws while that from Woman Hole is a first lower molar. The deposits in these caves range in age from late Irvingtonian to late Rancholabrean suggesting that Brahypoemota obtutsata was a long time resident of Pendleton County, West Virginia.

HUMAN SKELETONS IN BULL THISTLE CAVE, VIRGINIA

Willey, P. and GeorgeCrothers. Anthropology Department, University of Tennessee, Knoxville, TN 37996-0720

Bull Thistle Cave is a small pit cave that contains human bones that probably date between 1300 and 1600 AD. The bones were discovered in 1985. In 1986 a survey crew from the Virginia Division of Historic Landmarks explored and mapped the cave and studied the bones. At least eleven individuals (two children, one adolescent, and eight adults) are among the bones exposed on the cave deposits. This age distribution is similar to that of village burials from the same period. Some bones show indications of diseases and anomalies. Because the remains are in place, the element distribution by location in the cave could be studied. There are significant differences in the location of major and minor elements, and trivariate coating the elements, but no difference in cedent chewing. Because the cave is the best preserved example of a burial cave in the region, efforts are underway to preserve and protect it.

PHOTOGRAPHY SESSION

Bill Belle, Session Coordinator

GUIDE NUMBERS FOR CAVES PHOTOGRAPHY

Bartholomew, Roger V. 910 Laurel Street, Rome, NY 13440

With a combination of film speed, flash output, reflector type, and shutter speed, an appropriate f-number = Guide Number (GN) divided by flash-to-subject distance (f/st) in feet.

A GN is most precisely determined by choosing the best photo from a series of photos each taken with a different GN. When the film records the entire flash (slow shutter speed):

GN (flashbulb) = \sqrt{(0.304 \times N \times f/st \times e)}

GN (flashcube or electronic flash) = \sqrt{(0.063 \times BCPS \times e)}

where BCPS = Beam Candlepower-Seconds, Lt = lumen-second output, e = film speed, M = reflector factor (ranges from 1 to 12)

The formulas can be used to calculate unknown GN's from known GN's.

Also: GN(fill-in) = \frac{GN(min)}{GN(fill-in) \times \sqrt{(filling ratio)}}

Multiple flash photos with open shutter or with synchronized slaves requires that each flash to subject distance be kept constant. Multiple flash with open shutter and auto-exposure electronic strobes allows variable flash to subject distances.

PREPARING A PHOTO SALON MONOCHROME PRINT

Day, Emmick. 444A East Burns, Tucson, AZ 85711

One of the beauties of black and white photography is the amount of interpretation left open to the photographer in the darkroom during the printing process. This presentation will feature a detailed discussion of the printing of a difficult, but promising, negative which will be entered in the 1987 Photo Salon. Each step will be represented by an 8 x 10 print to be circulated among the attendees. Selection of paper contrast, burning and dodging techniques, and so forth will be discussed in detail. The goal is to show how the photographer's original conception is ultimately realized in the darkroom.

SPELEAN HISTORY SESSION

Jack Speece, Session Coordinator

THE SALTPETER CAVES OF WEST VIRGINIA: PROGRESS REPORT

Garton, E. Ray. Mammoth Geo, Inc., P.O. Box 200, Barrackville, WV 26559

Saltpeter, potassium nitrate (KN03), was the principal ingredient of gunpowder until the close of the Civil War. Evidence of mining for saltpeter has been reported from 44 natural limestone caves in nine West Virginia counties. Many of these caves were mined during the Revolutionary War, War of 1812, and the Civil War. The importance of West Virginia's saltpeter caves to these wars is largely unknown and unreported in the historical accounts of these conflicts. During the 18th and 19th centuries, saltpeter and the mining of saltpeter was central to the politics and economics of this young country. However, for all the importance of saltpeter, the exact nature of its origins and exactly how it was used in the manufacture of gunpowder is still largely unknown. Sometimes during or soon after the end of the Civil War the saltpeter industry died as nitrates became more readily available from foreign sources or nitrogen fixation technology.

SALTPETER ACTIVITY OF JOHN JAMES DUFOUR

George, Angelo A. I. George Consultants, 1869 Trevillian Way, Louisville, KY 40205

John James DuFour (1763-1827), a Swiss immigrant to America is 1796, is considered the father of American viniculture. By January, 1805, Dr. Samuel Brown and Thomas Hart, Jr., of Lexington, Kentucky, commissioned him to mine saltpeter at Great Saltpeter Cave in present Rockcastle County, Kentucky. DuFour introduced a two stage method of saltpeter manufacturing. I suspect he also implemented the pipe line and pumping system in the cave. He increased saltpeter production from 1,000 pounds per week to 1,000 pounds per day. By late 1811, Charles Wilkins had copied the DuFour engineered constructions in his own Mammoth Cave.

While at Great Saltpeter Cave, DuFour produced the first known glass bottles and sold saltpeter in a cave in America. This is the second oldest cave map in America and predates the F. Peck map of Madison's Cave by several months and the Frederick Ridgely map of Mammoth Cave by six years.

ANOTHER CAVE FOUND ON THE 1770 SCULL MAP OF PENNSYLVANIA

Ibsoner, Dale. 445 Hale Avenue, Harrisburg, PA 17104 and Robert Reine. Anthony Road, Rt #2, Box 15, East Berlin, PA 17316

The earliest known American map showing caves is William Scull's "Map of the province of Pennsylvania," which was printed by the NSS BULLETIN, JUNE 1988 • 33
James Nevin on April 4, 1770. Skull noted to be at least three caves on this map which he simply labeled as "CAVE." Researchers have identified two of these as Durham Cave in Bucks County and Dragon Cave in Berks County.

In 1855, while doing research on the history of Indian Echo Caverns, near Hummelstown, Robert Kelton found a third "CAVE" at the exact location of Indian Echo Caverns while searching an enlarged section of the Scull map. That Scull noted this cave on his map is not surprising since the cave was well known to settlers and early explorers in the late 1700s, having a large natural entrance on the banks of a navigable stream.

Cave locations may have been missed on this map because the map is crowded and printed at a small scale, making reading difficult.

Fountain Cave, in what is now Saint Paul, Minnesota, was a landmark on the upper Mississippi River throughout the 1800s. It developed in poorly consolidated sand grains from joints.

A rockfall at the entrance in about 1880 dammed the stream and partially flooded the cave. Difficulty of exploration after 1880 and the moderate values due to nearby urban development caused Fountain Cave to fall from public favor. The gorge through which the stream flowed after leaving the cave became used as a dump, the cave was incorporated into the city sewer system, and the springs of the cave were used for the city's water supply.

CAVE SYSTEM in Hart County, Kansas, has been an active organization. Physicochemical and biological sampling have been important aspects of the OCS as well as surveying. The caves of the state have never been documented other than lists made by a few individuals, thus much above ground as well as subterranean field work has been and continues to be a necessary part of the OCS. At present, 107 caves have been mapped or are in various stages of completion. Many of the maps have been published in the Wittenberg University Speleological Society journal, "Phoebus."

OHIO CAVE SURVEY

Hobbs, H. R., III. Department of Biology, F. O. Box 720, Wittenberg University, Springfield, OH 45501.

For the past eight years the Ohio Cave Survey (OCS) has been an active organization. Physicochemical and biological sampling have been important aspects of the OCS as well as surveying. The caves of the state have never been documented other than lists made by a few individuals, thus much above ground as well as subterranean field work has been and continues to be a necessary part of the OCS. At present, 107 caves have been mapped or are in various stages of completion. Many of the maps have been published in the Wittenberg University Speleological Society journal, "Phoebus."

UNITED STATES EXPLORATION SESSION

Peter Quick, Session Coordinator

SCOTT HOLLOW CAVE

Hindman, Craig and Carol Tiderman. 7600 Pinell School Road, Fulton, MD 20759.

The discovery, exploration, survey, and paleontological finds of Scott Hollow Cave, Monroe County, West Virginia, will be discussed. We will present a visual tour of the cave as seen on a typical cave trip. Potential miles of passage are indicated by dye traces. Efforts to locate and gain access to the cave via a second entrance are continuing.

CAVES OF HUGHES VALLEY

Lundquist, Charles A. University of Alabama in Huntsville and William W. Varnedoe. The Huntsville Grotto of Hughes Valley is cut into Brinkley Mountain south of the Tennessee River near Huntsville, Alabama. It carries Hughes Creek which flows from east to west. The north slope of the valley has entrances to well-known Hughes Spring Cave and Hughes Cave. The latter was the site of a salt peter operation during the Civil War and must be one of the most heavily visited caves in the state. The water in Hughes Cave is known from dye tracing to flow south under Hughes Valley and under Mack Ralph Mountain, an East-West ridge which lies south of Hughes Valley. It resurges in Skidmore Cave. The east end of Hughes Valley also has a large resurgence which drains to Skidmore Cave. This situation has motivated successful efforts to open and explore additional caves in the valley. Caves newly opened since January, 1986, include Broomfield Cave, Hughes Road Cave, and Mack Ralph Cave.

FISHER RIDGE CAVE SYSTEM

Quick, Peter. c/o FSSC, 288 Airport Road, Tyeplaint, WI 54197.

The Fisher Ridge Cave System in Hart County, Kentucky, was discovered in 1981. Since then its survey has grown to 42 miles in length with over 7,800 stations placed. New discoveries are continually being made. In the last two years exploration has focused in the southern parts of Fisher Ridge and the northeastern parts of Rainbow Ridge. Over ten miles of passage have been found thus far in this part of the system.
EXPLORATION OF WIND CAVE NATIONAL PARK

Scheldens, John P. 303 North River Street, Hot Springs, SD 57747

During the past 20 years exploration in Wind Cave has revealed an amazing series of discoveries that have disclosed the third largest cave in the western hemisphere. Highly integrated passage systems in multiple levels wind and twist for miles in a labyrinth fashion sometimes approaching within a few feet of their beginning with no connection. The passages in Wind Cave vary from the minute to the monstrous. They are nearly 20 miles in length and 700 feet in vertical extent.

Wind Cave houses unique crystal formations which are some of the most bizarre discovered anywhere. These include several cubic miles of boxwork, six-foot high helictite bushes, 12-inch diameter aragonite, and huge quartz geodes. The barometric winds of the cave (measured at over 70 miles-per-hour) indicate that only a fraction of the cave has been discovered. Many miles of virgin passage still lie ahead at this American epic adventure continues.

EXPLORATION HISTORY OF THE MYSTERY-RIMSTONE RIVER CAVE SYSTEM, PERRY COUNTY, MISSOURI

Walsh, Joseph. 681 Green Earth Drive #8, Fenton, MO 63026

J. Harlan Brett investigated Harrington Cave, Perry County, Missouri, in 1954. Indicating the vast, unexplored karst area there, he wrote, "there is an unsolved problem in cave histories in Perry County."

Part of the "problem" was Mystery Cave, which was first entered by organized cavers in 1963. More than 17 miles of passage have been explored there and Harrington and Lost and Found Caves have been physically integrated into the system. A second vast cave system was discovered to the east of Mystery in 1968. Explorers have surveyed there and several "middle system" caves were discovered between Mystery and Rimstone. Exploration continues but much remains unknown. A vast new downstream section of Rimstone has been discovered and middle system caves such as Maple Leaf have yielded more cave.

VERTICAL SESSION

Bill Bussey, Session Coordinator

USE OF THE MAR-MEX ESCAPELINE IN CAVING

Bussey, Bill. P.O. Box 3742, Gastonia, NC 28054

The Mar-Mex Escapeline is the first squeeze brake type rappel device to be available commercially. While offered as a simple, safe, lightweight emergency descending device for firemen, rescue personnel, mountain climbers, construction workers, travelers, and homeowners, cavers might find it useful in normal exploration. The device, while squeezing the rope in a groove between two plates, also guides it through a slot mounted on the side of the descender. This gives the device an added factor of safety. Manufacturer-supplied test data are available as well as personal impressions of the device used under actual field conditions.

LIVING WITH THE FOOT CROLL

Bussey, Bill. P.O. Box 3742, Gastonia, NC 28054

The foot mounted Croll can be used in place of a foot mounted Gibbs on a ropewalker climbing system. While discussed in a Nylon Highway #22 and at the Safety and Techniques Session at the 1986 NSS Convention, updated impressions on using the device for over a year are now available. The device has been tested by time and use. Thus personal impressions of the unique characteristics of the ascender are now known and can be substantiated.

USING A SAFETY GIBBS WITH A JUMAR SYSTEM

Cuddington, Bill. 3412 Hutchens Avenue St, Huntsville, AL 35801

Because of their configuration, Jumar-based climbing systems, such as the Mitchell and Third Phase, have been unable to incorporate an attached free running safety device. These safety devices, most commonly a tethered Gibbs or un-sprung cam ascender, are regularly used in other ropewalker type climbing systems. Lack of a third point of contact in the Jumar based systems, resulting in a lack of redundancy, has long been a disadvantage to these rigs. There is now a way to mount a Gibbs ascender to Jumar systems which will provide the needed redundancy for safe use. Use of this safety does not affect the versatility or comfort of Jumar based systems.

SURVEY OF DESCENDING DEVICES:

FiguRE 8, LONG HORN, PETZL BOBBIN, AND RACK

McCiurg, David K. 1610 Live Oak Drive, Carlbad, NM 88220

A variety of descending devices are currently being used by cavers and those who regularly use single rope techniques. The most common of these devices in use are the figure 8, long horn, the Bobbin (widely available in the U.S. as a Petzl model), and the rack. No descending device can be considered as optimum, and for all situations encountered, each device has peculiar strengths and weaknesses, which affect proper application in pits of different depths and other characteristics.

THE NEW PETZL RACK

Fadgett, Allen. Rt. 3, Box 158, Cleveland, GA 30528

Recent reports in international caving publications point to a rediscovery or resurgence in the use of the rappel rack by Europeans. It appears that European cavers, who generally use single rope techniques and equipment that are different than those usually used by North Americans have begun to use the rack in larger numbers. As a result, one of the larger manufacturers of European caving gear, Petzl, has come out with its own rappel rack. Incorporating five bars, including two "captive" bars, the Petzl rack sports several novel features which will be of interest to North American cavers.

HOW "ON ROPE" WAS WRITTEN: NOW THE STORY CAN BE TOLD

Fadgett, Allen. Rt. 3, Box 158, Cleveland, GA 30528 and Bruce M. Smith. 1822 Mountain Bay Drive, Hixson, TN 37433

How "on rope" was written is the hot-off-the-press book on North American single rope techniques published by the NSS. What started out to be a rather simple project grew into a major part of the lives of the authors. The book took over twice as long to finish and grew to twice as many pages as initially anticipated. The authors have many observations, thoughts, impressions, and interesting anecdotes of what they learned in this four year project. Suggestions of interest to future writers of "techniques" publications include what not to do, what to do, and the certain problems to be prepared for.

AGING ROPE TEST RESULTS

Smith, Bruce M. 1822 Mountain Bay Drive, Hixson, TN 37433

Nylon ropes used in caving and single rope techniques are subject to a wide variety of conditions over their useful lives. Since lives of people are totally dependent on these ropes it is important to know how much breaking strength a rope has after being subjected to normal and, in some cases, abnormal use. Previous studies have shown that new ropes which have received no use and have been properly stored for long term periods, break at half their rated strength upon testing. In this study, ropes of various types, ages, and varying levels of use, with known, documented histories were pulled tested to determine remaining strength. The sometimes surprising results demonstrate how care and use can affect rope life and strength.

The NSS Bulletin, June 1988 • 35
Index to Volume 47 of the National Speleological Society Bulletin

Ira D. Sasowsky
Department of Geosciences
The Pennsylvania State University
University Park, PA 16802

This index contains references to all articles and other items of importance published in volume 47 parts 1 and 2 including the abstracts from the 1985 N.S.S. convention. These abstracts are identified by an "(ABS)" preceding the title in the citation. This index is designed to be placed at the rear of volume 47, part 2.

The index consists of three parts. The first of these is a **keyword index**, which starts on page 2. Keywords include: unique words from the article title, cave names, geographic names, and descriptive terms. The second part is a **biologic names index**, beginning on page 20. These terms are Latin names of organisms discussed in articles. The third part is an alphabetical **author index**, starting on page 23. Articles with multiple authors are indexed under each author.

Citations are of the following form: names of all authors in the order which they appear in the journal; title of the article or abstract; volume number and part number (separated by a colon); beginning and ending page (separated by a dash); and year of publication from the cover of the issue. Volume number and year are included in the citation so that their format will match that of the cumulative index of volumes 1 through 45 which was recently published. Within an index group, such as Archaeology, the earliest article is cited first, followed by consecutive articles.

This index was prepared on an IBM 4341 computer running a VM/CMS operating system. Indexing was performed by the IBM KWIC/KWOC program as modified by William H. Verity at The Pennsylvania State University Center for Academic Computing. Formatting was accomplished using the SCRIPT text formater, and Generalized Markup Language, with camera-ready copy produced on a Xerox 2700 laser printer.

The author wishes to thank William H. Verity for his assistance. Kathryn F. Connors assisted in proofreading the final index. Computer funds were provided by the College of Earth and Mineral Sciences, The Pennsylvania State University.
Aboriginal

Abrupt

Adaptive

Adirondack Mtns.

Agronomy

Age

Air Flow

Agronomy

Air Flow

Alabama

Applications

Applications

Applications

Alarming

Applications

Applications

Applications
Alpine Karst

Applications

Applications

Applications
American Association of Geographers

Applications
Angel Cave

Applications
Annie Dean Cave

Applications
Annual Variation

Applications
Anthropology

Applications

Applications

Applications

Applications

Applications

Applications

Applications

Archaeological Period

Archaeological Period

Archaeological Period

Archaeological Period

Archaeological Period

Archaeological Period

Archaeological Period

Archaeological Period

Archaeological Period

Archaeological Period

Archaeological Period
Bats (cont.)


Battle of Little Mtn.

Bearer Mtn.

Beaumont Cave

Belau

Belmont Fault Zone

Bengor Limestone

Barite

Barometric


Baselevel

Bats


Evolutionary Patterns in Cave Caribid Beetles, 47:1,59-59,1985.

Behavior


Belau

Belford Spring Cave

Belize

BFR Cave

Big Bone Cave

Big Sink Cave

Big Sulphur Cave

Big Well Cave

Bioenergetics

Biography


Kane,T.C., (ABS) Evolutionary Patterns in Cave Caribid Beetles, 47:1,59-59,1985.


A discussion on adaptive evolution.


Kane, T.C. and Richardson, R.C., Regressive evolution: An historical perspective, 47:2,71-77, 1985.


Christiansen, K., Regressive evolution in Collembola, 47:2,89-100, 1985.


Bluegrass, Inner


Boatwright Cave


Boca del Inferno


Bonaire Cave


Bones Human


Bonneyard


Book


Boulder Caves


Boundary Cave


Bowing Green


British Cave Research Association


Buck Creek


Bugsunn Rockshelter


Buzzards Polly Cave


Calcite


Californig


Camps Gulf Cave


Canyons


Canyons


Cayman Islands


Cane Creek


Captain Symmes

Carbon Dioxide

Carlsbad Caverns

Carneal Cave

Carlsbad Caverns

Carbon Dioxide


Central Arizona


Chemistry


Cherokee


Chick Cave


Chimney Mtn.


Circadian


Civil War


Classification


Colahit


Cocksipits


Coffman's Cave


Colin's Crack Cave


Collapse


Colorado


Commercial Caves


Colorado Cave


Colorado Cave


Computer (cont.)


Conclusions


Conference Report


Conservation


Conspiracy


Cool Spring


Cool Spring Cave


Copper


Corinth Church Cave


Cooperstown Caves


Correlates


Cover Beds


Crawford Upland

Cricket

Crop Content

Cueva Clara de Empalme

Cueva de los Angeles

Cueva del Rio Encantado

Cumberland Plateau
Kane,T.C., (ABS) Evolutionary Patterns in Cave Carabid Beetles, 47:1,59-59, 1985.


Dan Yr Ogof

Dark River Cave

Darwin
Kane,T.C. and Richardson,R.C., Regressive evolution: An historical perspective, 47:2,71-77, 1985.

Dating

Davis Tire Cave

Deathtrap Cave

Decibel Cave

Depth, Minimum

Development

Diakon Cave

Differential Migration

Discovery

Distribution

Diving


Drib Cave

Drainage


Dry Cave

Dry Ford Cave

Durham Cave

Duttons Cave

Eagle Cave

Eau Claire River

Ecology


Education

Edwards Aquifer


Edwards Group

Environment


Epigean


Epley Cave

Equipment


Evaluation

Evolution

Christiansen,K., (ABS) Regressive evolution in Colombia, 47:1,60-60, 1985.


Christiansen,K., Regressive evolution in Colombia, 47:2,69-100.


Evolution Patterns

Expenses

Exploration


Faulding

Fauna


Fauna List
Christiansen,K., Regressive evolution in Colombia, 47:2,89-100.


Evaluation
Foraging

Forest Park Area
Fossil Forest Creek Basin
Garrison Chapel Karst

Fossil Karst
Davison,W.D.,Jr., (ABS) An overview of the karst of the Sultanate of Oman, 47:1,64-64,1985.

Fossil

France

Gano Spring

Garrison Chapel Karst

Geochemistry

Geography

Geology

Geochemistry

Geography

Geology

Geochemistry

Geography

Geology

Geochemistry

Geography

Geology

Geochemistry

Geography

Geology

Geochemistry

Geography

Geology
Hydrogeology (cont.)


Hydrology


Infrared Spectroscopy


Inner Blue Grass


Inner Space Cavern


Inspiration Cave


Interior Low Plateaus


Intrasynclinal Laminations


Invertebrates


Invertebrates


Jamaica


Jabbar, A.K. Anticline


Jaguar


Jewel Cave


Jewel Cave


Jewel Cave


Jewel Cave


Iodine 129

Jimsonweed Cave

John Guilday Cave Preserve

Joini Cave

Kast Classification

Karst, Mechanical

Kelly Cave

Kenadu Spring

Kentucky


Kane,T.C., (ABS) Evolutionary Patterns in Cave Carabid Beetles, 47:1,59-59, 1985.


Kentucky (cont.)


Crawford,N.C., (ABS) Health advisory issued for Bowling Green, Kentucky due to hazardous fumes rising from caves, 47:1,64-64, 1985.


Key Cave

Kinnin Cave

Lake Opinicon

Lakes Spring

Lamarche
Kane,T.C. and Richardson,R.C., Regressive evolution: An historical perspective, 47:2,71-77, 1985.

Land Use

Landmark

Large Rooms

Largest

Law

Lawrence Cave

Lemastus Cave

Letter


Level

Lindsay Spring

Libsany Cave

Lisa
Christiansen,K., Regressive evolution in Collombola, 47:2,89-100.


Little Min.

Locomotion

Logan’s Greensnake Cave System

Logistics

Look

Lost Caves
Lost John

Lost River
Crawford, N.C., (ABS) Health advisory issued for Bowling Green, Kentucky due to hazardous fumes rising from caves, 47:1,64-64, 1985.

Lovell Cave

Ludwig

Magnesite

Mammoth Cave

Mammoth Cave System

Management

Manganese Oxides

Manufacture

Martia Tick Cave

Mbobo Mkulu Cave

McElroy Cave

Mechanisms

Memoir

Menica's Glory Hole

Migrations

Mill Bluff Cave

Millers Cave

Mine Flurospar

Mineralogy

Minimum

Mining


Mudo Cave

Middle Woodland


Moonmilk and Linyphiid Spiders

Mortality

Mountains

Moye's Glory Hole
Davison, W.D., Jr. (ABS) An overview of the karst of the Sultanate of Oman, 47:1,64-64, 1985.

Mycology

Mynors, J. and Soto, J., Natural temporal variability of thermal waters associated with the crop of the cave selenite, 47:1,58-58, 1985.

Mystic Cave

N.S.S. Bulletin Vol. 47 Index
Minnesota


Mississippi Hull Hole
Davison,W.D., Jr., (ABS) An overview of the karst of the Sultanate of Oman, 47:1,64-64,1985.

Missouri

Monroe County

Mooysty Creek

Moon Cave

Moonmilk

Morocco
Magniez,G.J., Geomorphologic evolution of Stensellida (Crustacea Isopoda) assemblages of underground waters, 47:2,118-122,1985.

Morphology

Morphometrics

Motivation

Mullamullang Caves

Muskogean

Mutation

Nance Spring

National Park

Natural Bridge Caverns

Natural Bridge Sinks Cave

Nebraska

Nesquehoniensis

Net

Neutral

Neutrality

Nebraska

New

New Mexico

New York

Newsome Sinks

Newton Cave

Nickel

North Carolina

Northern Marianna Islands

Nullarbor Plain

Oakville Cave

Ode Britt Cave

Oman

Davison,W.D., Jr., (ABS) An overview of the karst of the Sultanate of Oman, 47:1,64-64,1985.

Organic Matter

Overview

Davison,W.D., Jr., (ABS) An overview of the karst of the Sultanate of Oman, 47:1,64-64,1985.

Owens Cave

Pacific


Pagan Island

Paintings

Paleobiology

N.S.S. Bulletin Vol. 47 Index
Paleomagnetism
Myrlojo,J.E., Carew,J.L., and Bar-
ton,C.E. (ABS) Paleosols and karst
development, San Salvador Island, Ba-

Paleontology
Bush,G. and Green,D., (ABS) Precinct
#1 Cave, Rockcastle County, Ken-
Grady,F., (ABS) Second annual report on
the paleontology of the caves at the
John Guilday Cave Preserve, 47:1-69-69,
1985.
Grady,F., (ABS) A preliminary report on
the fauna from Wormhole Cave, Pen-
dleton County, West Virginia, 47:1-69-
Paleosols
Myrlojo,J.E., Carew,J.L., and Bar-
ton,C.E. (ABS) Paleosols and karst
development, San Salvador Island, Ba-

Paradise
Williams,D., (ABS) Adventures in para-

Partitioned
Vore,D., (ABS) A partitioned semantic
net design for field computer appli-

Passage
White,W.B., (ABS) Speleogenesis: A geo-
chemical - mass transport model, 47:1-67-67,
1985.

Pattern, Cave
George,A.L., (ABS) Geographic distribu-
tion of Kentucky saltwater sites, 47:1-68-

Paula
Williams,D., (ABS) Adventures in para-

Pendleton County
Grady,F., (ABS) A preliminary report on
the fauna from Wormhole Cave, Pen-
dleton County, West Virginia, 47:1-69-69,
1985.

Pennsylvania
White,W.B., Scheetz,B.E., Atkinson,S.D.,
Iberson,D., and Chess,C.A., Mining-
ology of Rohrer's Cave, Lancaster

Pendleton County
Grady,F., (ABS) A preliminary report on
the fauna from Wormhole Cave, Pen-
dleton County, West Virginia, 47:1-69-

Pendleton County
Grady,F., (ABS) A preliminary report on
the fauna from Wormhole Cave, Pen-
dleton County, West Virginia, 47:1-69-

Pennsylvania
White,W.B., Scheetz,B.E., Atkinson,S.D.,
Iberson,D., and Chess,C.A., Mining-
ology of Rohrer's Cave, Lancaster

Speece,J.H., (ABS) Durham Cave, Penn-

Pennroyal Plain
Webster,J. and Crawford,N.C., (ABS)
Sinkhole collapses induced by changes

Pennroyal Plateau
Kane,T.C., (ABS) Evolutionary Patterns
in Cave Carabid Beetles, 47:1-59-59,
1985.

Pennroyal Sinkhole Plain
Forsythe,P., (ABS) Ten years of Western
Kentucky Speleological Survey cavi-

Perkins Spring Cave
Dyas,M.D., The Western Kentucky Spe-
leological Survey - A progress review,

Personality
Bunnell,D.E. and Vesely,C.A., Caving
practices, involvement in caving, and
personality in NSS cavers: A survey

Petroglyphs
Paulkner,C.H., (ABS) Petroglyph Caves of
the Southeastern United States, 47:1-65-

Pinecone
White,W.B., Scheetz,B.E., Atkinson,S.D.,
Iberson,D., and Chess,C.A., Mining-
ology of Rohrer's Cave, Lancaster

Photogrammetry
Minich,H., (ABS) The Skydusy Hollow
photogrammetric mapping project, 47:1-65-

Phreatic
Myrlojo,J.E. and Carew,J.L., (ABS) Lim-
its on time and depth for the develop-
ment of phreatic solution features, 47:1-65-

Pine Mountain
Bishop,C., (ABS) Pine Mountain over-

Pinecones
White,W.B., Scheetz,B.E., Atkinson,S.D.,
Iberson,D., and Chess,C.A., Mining-
ology of Rohrer's Cave, Lancaster

Pitfall Traps
Lisowski,E.A., (ABS) Ecological corre-
lates of terrestrial cave-dwelling invertebrates in large river passages in

Plausibility
Poulsen,T.L., Evolutionary reduction by
neutral mutations: Plausibility argu-

Plotting
Bartholomew,R.V., (ABS) A FORTRAN
survey program with plotting rou-

Polje
Dougherty,P.H., Conference Report,
Association of American Geogra-
hers, April, 1985, Detroit, Michi-
gan, 47:1, 33-33, 1985.

Pollinators
Fulton,R.E., Abstract of M.A. thesis:
Reproductive ecology of Agave Deser-

Pollution
Greer,J., (ABS) Microbial Ecology of Two

Schindel,G.M., (ABS) Evaluation tech-
niques and conclusions for uncontrol-
led hazardous waste area investi-

Polygenic
Wilkening, H., The evolution of polygenic
systems, studied on epigene and cave populations of Astyanax Fasci-

Ponape
Williams,D., (ABS) Adventures in para-

Rossetti
Ash,D.W. and Wilson,W.L., (ABS) The
development of secondary porosity by extending hydrogen sulfide gas in
the Guadaloupe Mountains of New

Potato Cave
Dyas,M.D., The Western Kentucky Spe-
leological Survey - A progress review,

Precinct #11 Cave
Bush,G. and Green,D., (ABS) Precinct
#11 Cave, Rockcastle County, Ken-

Precipitation
Devison,W.D.Jr., (ABS) An overview of the

Prehistoric
Munson,P.J., Tankersley,K.B., Wat-
son,P.J., and Munson,C.A., (ABS)
Prehistoric selenite mining in the

Turner,K.R., (ABS) Human bones in Al-

Preliminary
Grady,F., (ABS) A preliminary report on
the fauna from Wormhole Cave, Pen-
dleton County, West Virginia, 47:1-69-

Preservation
Hall,C.L., (ABS) Bugtussle Rocksroller:
An Unusual Archaeological Site in

Preservation Food
Lavoie,K.H., King,L.S., and Simonoucl,
(ABS) Possible food strategies used by the cave rat, Neotoma Floridana, 47:1,59-59, 1985.

Printer Graphic Driver
Thrun,R., (ABS) PGD - Printer Graphic

Processes
Skef,B., Why all cave animals do not
look alike - A discussion on adaptive

Progreso
Dyas,M.D., The Western Kentucky Spe-
leological Survey - A progress review,

Pseudokarst
Rogers,B.W. and Legge,C.J., (ABS) Sea
cave development along the central

Psuedokarst
Richards,B., (ABS) Boulder caves of Cali-

Puerto Rico
Lisowski,E.A., (ABS) Ecological corre-
lates of terrestrial cave-dwelling invertebrates in large river passages in

Downey,K., (ABS) Underwater explora-
tion of Rio Encantado, Puerto Rico,

Gurnee,J. and Dunn, R., (ABS) Rio Can-
my Cave Exploration: Development,

N.S.S. Bulletin Vol. 47 Index

Role

Roquist Creek

Rota Island

Royal Spring

Rudimentation
Kane, T.C. and Richardson, R.C., Regressive evolution: An historical perspective, 47:2,71-77, 1985.

Rupestrian Art

Russell Cave Spring

Safety
Crawford, N.C., (ABS) Health advisory issued for Bowling Green, Kentucky due to hazardous fumes rising from caves, 47:1,64-64, 1985.

Saint Genevieve Formation

Sapin Island

Salt peter


Salt peteer - Moon Cave System

Salt Cave (cont.)

San Marcos Springs

San Salvador Island

Sanitation

Santer Spring

Savage Cave

Savage System

Scott Cave

Scott Cave No 3

Scott County

Sea Caves

Sea Level

Secondary


Sedimentation

Selinite

Selma-Plateau

Sensitization

Sensation Seeking

Sharon Grove Caves

Shetla Cave

Sing Chatlett Cave

Significance

Silurian Escarpment

Silver Springs

Sinkhole Plain

Sinkholes

Size, Passage

Skinframe Sinks System

Skydusky Hollow

N.S.S. Bulletin Vol. 47 Index
Speciation

Species, New

Speleothems

Speleogenesis


Speleology

Speleothems

South Dakota

South Pacific

Southeast

Southwest

Spa, Health

Spain

Survey (cont.)
Survey, Sociological
Surveying
Sustaining
Sweet Potato Cave
Switzerland
Symmes, J.C.
Talus Caves
Tapi
Tarankite
Tawi Atair
Davison, W.D., Jr., (ABS) An overview of the karst of the Sultanate of Oman, 47:1,64-64, 1985.
Taylor Bluff Cave
Technique
Temperature
Tennessee

Tennessee (cont.)
Terminology
Texas
Textures
Theory
Therapy
Thermal
Thomas Cave
Three Dimensional
Tiger Cave

Time

Time Keeping

Time, Minimum

Tracers

Tracing

Transport

Tree Limb Casts

Troglobites

Troglohomorphy

Trot Cave

Trot Rock Ranch

TruK

Turkey Cott Cove

Twin Level Cave

Umm Er Radhuma Formation

Under Nose Cave

United States

N.S.S. Bulletin Vol. 47 Index
Urban

Urbanisation

Use

Utilization

Vaughan Spring

Vegetation

Wades

War

Washington

Wasia Group

Water Quality

Watt Cave

Welch’s Cave

Wells

West Indies

West Virginia


Western Kentucky Speleological Survey


White River Plateau

Wildflowers

Wind Cave

Wormhole Cave

Wyandotte Cave

X Ray

Yap

N.S.S. Bulletin Vol. 47 Index 19
A discussion on adaptive

A discussion on adaptive

A discussion on adaptive

Amblyopsid


Amblyopsis Rosae


Amblyopsis Speleus


Amphipoda


Anoplodrhyss


Antrozous Pallidus


Aphaniops


Araneae


Asellus Aquaticus


Asteranax


Asteranax Fasculatus


Asteranax Mexicanus


Blaniulus


Caecidotea Stygia


Canis Armbusteri


Carabid

Kane,T.C., (ABS) Evolutionary Patterns in Cave Carabid Beetles, 47:1,59-59,1985.

Cerion


Ceytophorus Oblongus


Characidae


Chilogaster Agassizi


Collombola

Christiansen,K., (ABS) Regressive evolution in Collombola, 47:1,60-60,1985.

Crustacea


Decapoda


Diplopoda


Drosophila


Duvallius


Duvallius Exaratus


Eptesicus Fuscus


Folsomia

Christiansen,K., Regressive evolution in Collombola, 47:2,89-100.

Friesia

Christiansen,K., Regressive evolution in Collombola, 47:2,89-100.

Gammarus


Gammarus Minus


Gammarus Pseudolimnaeus


Geotrechus

**Halenoecus Subterraneus**

---

**A discussion on adaptive**

---

**Insecta**

---

**Isopoda**

---

**Linyphiid**

---

**Linyphid**

---

**Microopterin**
Huppop, K. The role of metabolism in the evolution of cave animals, 47:2, 136-146, 1985.

---

**Myotis Grinnicns**

---

**Myotis Lucifugus**

---

**Nepenthes**

---

**Niphargus**

---

**Odonatia**

---

**Ondatra Annectens**

---

**Oniscotdea**

---

**Orcorocges**

---

**Oscillorhynchus Virens**

---

**Polystomus Terricolus**

---

**Proteus Angulatus**

---

**Protostoma**

---

**Remipedia**

---

**Rhadin Rubra**

---

**Saiatoria**
Huppop, K. The role of metabolism in the evolution of cave animals, 47:2, 136-146, 1985.

---

**Schaefferia**
Christiansen, K., Regressive evolution in Collombola, 47:2, 89-100.

---

**Smilodon**

---

**Speleoneutes Lucayensis**

---

**Speosordus**

---

**Speonoma Diecki**

---

**Sphingobus**

---

**Stenasellids**

---

**Synuraella Ambulans**

---

**Troglocaris Anopthalmus**

---

**Typhilina Pearsei**
Typhlichthys Subterraneus

Typhlomolge

Typhlotritron Spelaeus

Urodela
Author Index

Aggar, M.

Ash, D.W.

Atkinson, S.D.
Bartholomew, R.V.

Baron, C.E.

Bishop, C.

Briggs, T.S.

Bennell, D.E.

Bush, G.


Caccone, A.

Carew, J.L.

Carroll, D.

Ches, C.A.

Christiansen, K.
Christiansen, K., (ABS) Regressive evolution in Collombala, 47:1,60-60, 1985.

Clark, T.

Conner, G.A.

Cooker, D.

Crawford, N.C.
Crawford, N.C., (ABS) Health advisory issued for Bowling Green, Kentucky due to hazardous fumes rising from caves, 47:1,64-64, 1985.


Crothers, G.M.

Cukierski, M.A.

Cukierski, M.A.

Culver, D.C.

Davis, D.G.

Davison, W.D., Jr.

Doughtery, P.H.


Downey, K.

Dyse, M.D.

Eddwards, J.

Elliott, W.R.


Fabryka-Martín, J.T.

Faulkner, C.H.

Feldhake, D.J.

Fernandez, P.L.

Finch, R.C.

Fong,D.W.

Forsythe, P.

Freeman, G.E.

Fulton, R.E.

Gaudet, C.L.

Geggie, J.F.

George, A.L.

George, A.L.

Grady, F.

Grady, F.

Grady, F.

Green, D.

Gruea, J.

Gruesa, C.

Gruesa, C.

Grow, S.R.

Gunn, J.

Gurneea, J.

Halls, C.L.

Harrison, T.M.

Hobbs, H.H.

Hoffelt, J.F.

Huppert, G.N.

Huppert, G.N.

Huppert, K.

Ibbertson, D.

Kane, T.C.
Kane, T.C., (ABS) Evolutionary Patterns in Cave Carabid Beetles, 47:1,59-59, 1985.

Kane, T.C.
Kane, T.C. and Richardson, R.C., Regressive evolution: An historical perspective, 47:2,71-77, 1985.

Kane, W.

Kasting, E.H.

Kasting, E.H.

Knouse, J.H.

Lamprecht, G.

LaRock, E.

Lavoie, K.H.

Lavoie, K.H.

Lundquist, C.A.

Legge, C.J.

Lewis, W.C.

Linn, J.

Lisowski, E.A.

Lubeck, K.

Lundquist, C.A.

Maguire, G.J.

N.S.S. Bulletin Vol. 47 Index


Munson, C.A.


Munson, P.J.


Myroie, J.E.


Nussbaum, G.G.


O'Dell, G.


O'Dell, P.


Ogden, A.E.


Omeroid, S.C.


Parafall, J.


Pender, M.M.


Poulsom, T.L.


Quick, R.A.


Quinlan, J.F., Jr.


Rice, B.


Richardson, R.C.

Kane, T.C. and Richardson, R.C., Regressive evolution: An historical perspective, 47:2,71-77, 1985.

Rogers, B.W.


Romero, A.


Rudolph, D.G.


Schneid, G.M.


Seaver, J.P.


Skelet.


Skiles, W.


Soto, J.


Spangler, L.E.


Speece, J.H.


Staatsma, S.


Studier, E.H.


Turner, R.T.


Tankersley, K.B.


Turner, R.K.


Turner, M.


Thrun, R.


Tucker, T.E.


Turner, K.R.


Turner, M.


Turner, R.T.


Varner, J.W.


Venoi, C.


Vesely, C.A.

Vestal, R.

Villar, E.

Vore, D.

Wares, X.

Warren, H.

Watson, P.J.

Watson, R.A.

Webb, J.A.

Weber, F.

Webster, J.

Wheeler, B.

White, W.B.


Whittemore, A.

Wilkens, H.

Willey, P.

Williams, D.


Wilson, W.L.


Yager, J.

Zachariasen, G.

Zecharias, Y.B.
This index contains references to all articles and other items of importance published in volume 48 parts 1 and 2 including the abstracts from the 1986 N.S.S. convention. These abstracts are identified by an "(ABS)" preceding the title in the citation. This index is designed to be placed at the rear of volume 48, part 2.

The index consists of three parts. The first of these is a keyword index, which starts on page 2. Keywords include: unique words from the article title, cave names, geographic names, and descriptive terms. The second part is a biologic names index, beginning on page 12. These terms are Latin names of organisms discussed in articles. The third part is an alphabetical author index, starting on page 13. Articles with multiple authors are indexed under each author.

Citations are of the following form: names of all authors in the order which they appear in the journal; title of the article or abstract; volume number and part number (separated by a colon); beginning and ending page (separated by a dash); and year of publication from the cover of the issue. Volume number and year are included in the citation so that their format will match that of the cumulative index of volumes 1 through 45 which was recently published. Within an index group, such as Archaeology, the earliest article is cited first, followed by consecutive articles.

This index was prepared on an IBM 4341 computer running a VM/CMS operating system. Indexing was performed by the IBM KWIC/KWOC program as modified by William H. Verity at The Pennsylvania State University Center for Academic Computing. Formatting was accomplished using the SCRIPT text formatter, and Generalized Markup Language, with camera-ready copy produced on a Xerox 2700 laser printer.

The author wishes to thank William H. Verity for his assistance. Computer funds were provided by the College of Earth and Mineral Sciences, The Pennsylvania State University.
Brush Creek
Able,A.S. and Crawford,N.C., (ABS) Geo-
logic controls on surface and subsur-
face streams in a karst aquifer in War-
ren County, Kentucky, 48:1, 36-36, 1986.

Buckner Cave
Contner,G.A., Stratigraphic sections in
the St. Genevieve Formation (Mid-
dle Mississippian) exposed in Garri-
son Chapel Karst Area caverns -
western Monroe County, Indiana,

Bureau of Land Management
Goodbar,J., (ABS) Cave management in
the Bureau of Land Management

Hammell,B., (ABS) Cave management:
The Bureau of Land Management ap-

Calaveras County
Rollins,L., (ABS) Hydrochemical pro-
ces in a marble cavern: Cave City,

Carlsbad Caverns
White,W.B., (ABS) Lifemiscence of cave
calcite deposits: A current appraisal,

California
Briggs,T.S., (ABS) Micro whip-scorpions

Rogers,B., Legge,C., and Decker,F., (ABS)
Reconnaissance geology of Mercer
Caverns, California: A strike orient-

Rollins,L., (ABS) Hydrochemical process-
es in a marble cavern: Cave City,

Saukalka,B. and Richards,B., (ABS)
Floodkarst development in lacust-
rine deposits in the Shoshone area,

Carlsbad Caverns
Hill,C.A., (ABS) Carlsbad Cavern and
other caves in the Guadalupe Moun-
tains, New Mexico: A sulfuric acid
speleogenesis related to the oil and
gas fields of the Delaware Basin,

Davis,D.G., Discussion: The deflected sta-

Cartography
Peereman,(ABS) Cave mapping sys-

Ganter,J., (ABS) Producing communica-

Cave City Cave
Rollins,L., (ABS) Hydrochemical process-
es in a marble cavern: Cave City,

Cave of the Domes
Coleman,M.W., (ABS) The karst / paleo-
kart relationship to collapse breccia

Caverns
Sprouse,T.T., (ABS) Origin of the solution
cavities in Hell's Canyon, Idaho,

Channels
Jones,W.K. and Harper,J.M., (ABS)
Channel sediment size and slope of

Chester Escarpment
Conner,G.A., Stratigraphic sections in
the St. Genevieve Formation (Mid-
dle Mississippian) exposed in Garri-
son Chapel Karst Area caverns -
western Monroe County, Indiana,

Chrome Cave
Briggs,T.S., (ABS) Micro whip-scorpions

Classic Cave
Hedges,J., (ABS) Clay vermiculations in
Iowa, Pennsylvania and West Vir-

Clay
Hedges,J., (ABS) Clay vermiculations in
Iowa, Pennsylvania and West Vir-

Clear Fork Cave
Able,A.S. and Crawford,N.C., (ABS) Geo-
logic controls on surface and subsur-
face stream diversion in a karst
aquifer in Warren County, Ken-

CMS Cave Mapping System
Peereman,S., (ABS) Cave mapping sys-

Cold
Honea,D., (ABS) Crevasse caves in Ant-

Collapse
Coleman,M.W., (ABS) The karst / paleo-
kart relationship to collapse breccia

Collapse Cave
Rogers,B., Legge,C., and Decker,F., (ABS)
Reconnaissance geology of Mercer
Caverns, California: A strike orient-

Collapse Cavern
Wahl,R., (ABS) Demographics of Mortal-
ity in a Free-Tailed Bat (Tadarida
Brasiilienis) maternity colony,

Compass
Ganter,J., (ABS) A look at compass and
clinometer error in the OTE survey

Computers
Peereman,S., (ABS) Cave mapping sys-

Connoret
Kastning,E.H., (ABS) Karstic regions and
speleogenetic diversity of New En-

Conservancy
Wilson,W.L., (ABS) The Indiana Karst
Conservancy: Standing between the

Conservation
Brown,B., (ABS) The Bighorn research

Hundley,B., (ABS) Cave management:
The Bureau of Land Management

Conservation (cont.)
Wilson,W.L., (ABS) The Indiana Karst
Conservancy: Standing between the

Contaminants
Crawford,N.C., (ABS) Tracing the flow of
contaminants in karst aquifers,

Contributors
Harris,A.H., (ABS) The contribution of
New Mexican caves to Pleistocene

Control
Wilson,W.L., (ABS) Base level control of
cavernous flow paths: A negative
test of the Gardner model,

Caves
Able,A.S. and Crawford,N.C., (ABS) Geo-
logic controls on surface and subsur-
face streamline diversion in a karst
aquifer in Warren County, Ken-

Coons Cave
Conner,G.A., Stratigraphic sections in
the St. Genevieve Formation (Mid-
dle Mississippian) exposed in Garri-
son Chapel Karst Area caverns -
western Monroe County, Indiana,

Cope, E.D.
Grady,F., (ABS) Edward Drinker Cope's
contributions to speleology,

Corn Caves
Jagnow,D., (ABS) Western Oklahoma

Corrosion
Rollins,L., (ABS) Hydrochemical process-
es in a marble cavern: Cave City,

Crawford Upland
Conner,G.A., Stratigraphic sections in
the St. Genevieve Formation (Mid-
dle Mississippian) exposed in Garri-
son Chapel Karst Area caverns -
western Monroe County, Indiana,

Crevasse Caves
Honea,D., (ABS) Crevasse caves in Ant-

Crockett's Cave
Jagnow,D., (ABS) The geology of Crock-
ett's Cave, a New Mexico gypsum

Crusts
Peck,S.B., Bacterial deposition of iron
and manganese oxides in North

Palmer,M.V., (ABS) Siliceous crusts on

Crystal Lake Cave
Peck,S.B., Bacterial deposition of iron
and manganese oxides in North

Cuba
Brown,T.S., (ABS) Micro whip-scorpions

Cueva de la Llorona
Pate,D., (ABS) Purificacion III: Cueva de

Cueva del Brinco
Sprouse,T.T., (ABS) Sistema Purifica-

Cumberland Caverns

Cumberland Plateau

Dan-Yr-Ogof


Deflected


Delaware Basin

Deposits

Devil's Sinkhole

Directions

Discourse

Divergence

Diversity

Doyle Valley Entrance

Dyes

Ecology

Elk River

Elk River Cave

Endelitite

Engineering

Environment

Environmental Protection Agency

Environmental Protection Agency

Environment

Error

Europe

Evolution


Excavation


Exploration


Exploration (cont.)

ABS;Origins;History;Association for Mexican Cave Studies;


Extinct

Eye


Falling Springs Cave

Fauls

Fauna

Federal

Floods

Flow


Fluvial

Fort Stanton Cave

France

Free Tailed Bats

Friars Hole

N.S.S. Bulletin Vol. 48 Index
N.S.S. Bulletin Vol. 48 Index
Lava Tubes

Left It Pit

Level Crevice Cave

Life

Limestone

Location

Longest Cave, Gypsum

Lost River Cave

Lost River Cave System

Luminescence

Maine

Matheur Cave

Malpais Mtns.

Mammals
Wright,H.E., Jr, Book review : On the track of Ice Age mammals, by A.J. Sutcliffe, 48:2-64,64,1986.

Mammoth Cave


Management


Management (cont.)


Manganese

Mapping


Maps

Marble

Marble Caverns

Massachusetts

Maturity

McCrady,E.

Membership

Mecur Cave

Mexico


Microgravity

Middle East

Mineralogy


Sevenair,D.P., Reply to Donald G. Davis, 48:2-63,63,1986.

Mississippian

Model

Montana

Morphometrics

Mortality

Mt. Everest

Muenster Cave

My Cave

National Speleological Society


New England

New Hampshire

New Mexico


Normal Drive Sinkhole

Northwest Cave Research Institute

Oil

Oklahoma

Old Timer’s Reunion

Pseudokarst


Purificacion

Purificacion

Pseudokarst

Purificacion

Purificacion

Pseudokarst

Purificacion

Purificacion

Purificacion

Purificacion

Purificacion

Purificacion

Purificacion

Purificacion

Purificacion

Purificacion

Purificacion

Purificacion

Purificacion

Purificacion

Purificacion

Purificacion

Purificacion

Purificacion

Purificacion

Purificacion

Purificacion

Purificacion

Purificacion

Purificacion

Purificacion

Purificacion

Purificacion

Purificacion

Purificacion

Purificacion

Purificacion

Purificacion
Reconnaissance
Rogers, B., Legge, C., and Decker, P., (ABS)
Reconnaissance geology of Mercer Caverns, California: A strike orient­

Regions
Kastning, E.H., (ABS) Karstic regions and
speleogenetic diversity of New Eng­

Regression
Kane, T.C., (ABS) Eye pigments of cave
Crustaceans and their relevance to
theories of regressive evolution

Relationship
Coleman, M.W., (ABS) The karst / paleo­
kart relationship to collapse breccia
pipe formation, 48:1,36-37,1986.

Remote Sensing
Webster, J.W. and Crawford, N.C., (ABS)
Microgravity as a tool for cave map­

Removal
Reeder, P.P. and Crawford, N.C., (ABS)
The utilization of geologic structure in
a karst region for the removal of

Reply
Seveaiz, P.J. Reply to Donald G. Davis,

Review
Elliott, W.B., Book review: Cave Life,
Evolution, and Ecology, by D.C. Cul­
White, E.L., Book review: Sinkholes:
Their Geology, Engineering, and
Environmental Impact, by B.F. Beck
(eds.), 48:1,33-33,1986, see also Erra­
Day, M., Book review: Limestone Geomor­
phology, by S. Trudgill, 48:1,33-33,
1986.
Wright, H.E., Jr., Book review: On the track
of Ice Age mammals, by A.J. Sutcliffe,
48:2,64-64,1986.
Huppert, G.N., Book review: New direc­
tions in karst, by Paterson, Keith,
and Sweeting, 48:2,64-65,1986.
Willey, P., Book review: Seminole Sink

Rhode Island
Kastning, E.H., (ABS) Karstic regions and
speleogenetic diversity of New Eng­

Ridge Walking
Groves, C.G. and Crawford, N.C., (ABS)
High tech ridge walking: The loca­
tion and exploration of Robinson
Cave, Bowling Green, Kentucky,

Robinson Cave
Groves, C.G. and Crawford, N.C., (ABS)
High tech ridge walking: The loca­
tion and exploration of Robinson
Cave, Bowling Green, Kentucky,

Roos Island
Hines, D., (ABS) Caves of caves in Anti­

Runoff
Reeder, P.P. and Crawford, N.C., (ABS)
The utilization of geologic structure in
a karst region for the removal of

Saint Genevieve Formation
Conner, G.A., Stratigraphic sections in the
St. Genevieve Formation (Mie­
dle Mississippian) exposed in Garri­
sen Chapel Karst Area caverns -
western Monroe County, Indiana,

Salamander Cave
Conner, G.A., Stratigraphic sections in the
St. Genevieve Formation (Mid­
dle Mississippian) exposed in Garri­
sen Chapel Karst Area caverns -
western Monroe County, Indiana,

Sea Level
Myroie, J. and Carew, J., (ABS) Sea level
control of cave development in the

Sediment
telial sediment size and slope of

Segments
Jameson, R.A., (ABS) Structural seg­
ments and segment analysis, 48:1,37-37,
1986.

Seminole Canyon State Historical
Park
Ralph, R., Bement, L.C., and Turpin, S.A.,
(ABS) Seminole Sink: Excavation of a

Seminole Sink
Ralph, R., Bement, L.C., and Turpin, S.A.,
(ABS) Seminole Sink: Excavation of a

Shaft
Willey, P., Book review: Seminole Sink
(41VV620): Excavation of a vertical shaft tomb, Val Verde, Texas,

Sinkholes
White, E.L., Book review: Sinkholes:
Their Geology, Engineering, and
Environmental Impact, by B.F. Beck
(ed.), 48:1,32-33,1986, see also Erra­

Sistema Purificacion
Sprout, T.T., (ABS) Sistema Purifica­
cion: Camp Challenger, 48:1,40-40,
1986.

Slope
telial sediment size and slope of

Snedecor Cave
Jameson, R.A., (ABS) Segment analysis in
the North Canyon of Snedecor

Solution Pockets
Ogden, A.E., (ABS) Origin of the solution
cavities in Hell's Canyon, Idaho,

South Dakota
Pock, S.B., Bacterial deposition of iron
and manganese oxides in North

Southwestern
Briggs, T.S., (ABS) Micro whip-scorpions
in Southwestern caves, 48:1,34-34,
1986.

Spectroscopy
White, W.B., (ABS) Luminescence of cave
calcite deposits: A current appraisal.

Speleogeneesis
Medill, D.M. and Storage, W.K., Struc­
tural and stratigraphic influences on
the development of solution conduits
in the upper Elk River valley, West

Coleman, M.W., (ABS) The karst / paleo­
kart relationship to collapse breccia
pipe formation, 48:1,36-37,1986.

Hill, C.A., (ABS) Carlsbad Cavern and
other caves in the Guadalupe Moun­
tains, New Mexico: A sulfuric acid
speleogenesis related to the oil and
gas fields of the Delaware Basin,

Jameson, R.A., (ABS) Structural seg­
ments and segment analysis, 48:1,37-37,
1986.

Jameson, R.A., (ABS) Segment analysis in
the North Canyon of Snedecor

Jagnow, D., (ABS) The geology of Crock­
it's Cave, a New Mexico gypsum

Kastning, E.H., (ABS) Karstic regions and
speleogenetic diversity of New Eng­
Speleogenesis (cont.)
Rogers,B., Legge,C., and Decker,P., (ABS) Reconnaissance geology of Mercer Caverns, California: A strike orient­
Speleogens
Speleology
Speleothems
Jagnew,D., (ABS) The geology of Crockett's Cave, A New Mexico gypsum
Rogers,B., Legge,C., and Decker,P., (ABS) Reconnaissance geology of Mercer
caverns, California: A strike orient­
Davis,D.G., Discussion: The deflected stalactites of Dan-Tr-Ogof,
Speleothems
White,W.B., (ABS) Luminescence of cave calcite deposits: A current appraisal,
Spout
Veni,G. and Crawford,N.C., Origins of water-sources in karst
Stanton’s Cave
Coleman,M.W., (ABS) The karst / paleo­
karst relationship to collapse breccia pipe formation, 48:1,36-37-1986.
State Parks
Ralph,R., Bement,L.C., and Turpin,S.A., (ABS) Seminole Sink: Excavation of
a vertical shaft tomb, Val Verde, Texas, 48:1,34-34,1986.
State Parks
Storm Water
Reeder,P.P. and Crawford,N.C., (ABS) The utilization of geologic structure in a karst region for the removal of
Stratigraphy
Conner,C.A., Stratigraphic sections in the St. Genevieve Formation (Mid­
dle Mississippian) exposed in Garri­
sen Chapel Karst Area caverns -

Stratigraphy (cont.)
Streams
Jones,W.K. and Harper,J.M., (ABS) Channel sediment size and slope of
Strike Oriented
Rogers,B., Legge,C., and Decker,P., (ABS) Reconnaissance geology of Mercer
Caverns, California: A strike orient­
Structural
Structure

Techniques
Raines,T., (ABS) Origins of AMCS cav­
Groves,G. and Crawford,N.C., (ABS) High tech ridge walking: The loca­
tion and exploration of Robinson Cave, Bowling Green, Kentucky, 48:1,41-41,1986.
Temperature
Hedges,J., (ABS) Clay vermiculations in Iowa, Pennsylvania and West Vir­
Templeton, H.M.
Matthews,L.E., (ABS) The cave papers of Edward McCrady, Henry T. Kirby­
Tennessee
Matthews,L.E., (ABS) The cave papers of Edward McCrady, Henry T. Kirby­
Texas
MacDowell,A., (ABS) A comparison of Murrah Cave with other Val Verde
County cave sites, 48:1,34-34,1986.
Ralph,R., Bement,L.C., and Turpin,S.A., (ABS) Seminole Sink: Excavation of
a vertical shaft tomb, Val Verde, Texas, 48:1,34-34,1986.
Wiley,P., Book review: Seminole Sink (41V620): Excavation of a vertical shaft tomb, Val Verde County, Tex­
Thermal Waters
Todorokite
Trap Door Cave

Triple J Cave

Uses

Utilization

Vandalism

Variation

Vermiculations

Vermont

Vertebrates

Vertical

Warm River Cave

Warren County

Water Spouts

Wayne Cave

Weber Cave

West Virginia


Wisconsin

Yucatan

Yugoslavia

Zoologist
**Biologic Names Index**


**Crenothrix** Peck, S.B., Bacterial deposition of iron and manganese oxides in North American caves, 48:1,26-30,1986.


**Dasyurus Bellus** Grady, F. (ABS) Quaternary vertebrate fossils from Organ Cave, West Virginia, 48:1,41-41,1986.

**Equus Complicatus** Grady, F. (ABS) Quaternary vertebrate fossils from Organ Cave, West Virginia, 48:1,41-41,1986.

**Erethizon Doratnum** Grady, F. (ABS) Quaternary vertebrate fossils from Organ Cave, West Virginia, 48:1,41-41,1986.


**Mammal Americanum** Grady, F. (ABS) Quaternary vertebrate fossils from Organ Cave, West Virginia, 48:1,41-41,1986.


**Myohus Nasutus** Grady, F. (ABS) Quaternary vertebrate fossils from Organ Cave, West Virginia, 48:1,41-41,1986.


**Mylotis Griscens** Grady, F. (ABS) Quaternary vertebrate fossils from Organ Cave, West Virginia, 48:1,41-41,1986.


**Smilodon** Grady, F. (ABS) Quaternary vertebrate fossils from Organ Cave, West Virginia, 48:1,41-41,1986.


**Ursus Arctos** Grady, F. (ABS) Quaternary vertebrate fossils from Organ Cave, West Virginia, 48:1,41-41,1986.

12

N.S.S. Bulletin Vol. 48 Index


Bement, L.C.


Buecher, B.


Carew, J.


Colman, M.W.

Conner, G.A.

Conner, G.A., (ABS) Stratigraphic sections in Badaracco, W.J.

Conner, G.A.


Crawford, N.C.


Crawford, N.C.


Culver, D.C.


Davis, D.G.


Day, M.


Decker, P.


Ebberts, D.


Elliot, W.R.


Ganter, J.


Ganter, J.

Goodbar, J.


Grady, F.


Grady, F.


Groves, C.G.


Harper, J.M.


Huppert, G.N.


Jagnow, D.


Jameson, R.A.


Jones, W.K.


Kane, T.C.


Kastning, E.H.


Knutson, S.


Leggs, C.


Lorah, M.M.


MacDowell, A.


Matthews, L.E.


Medville, D.M.

Peerman, S.
Ogden, A.E., Sprouse, P. (ABS)
Queisser, J.C., Mylroie, J.
Palmer, M.V.
Pate, D.
Peck, S.B.
Peerman, S.
Queisser, J.C.
Raines, T.
Raines, T., (ABS) Origins, History; Association for Mexican Cave Studies;
Ralph, R.
Rael, T.
Reddell, J.R.
Reeder, P.P.
Richards, B.
Rogers, B
Rollins, L.
Safford, M.
Sadowsky, I.D.
Sevair, J.P.
Sprouse, P.
S Zukalski, B.
Tipton, V.M.
Turpin, S.A.
Veni, G.
Wahl, R.
Walsh, M.
Webster, J.W.
White, E.L.
Wright, H.E., Jr.
Wright, H.E., Jr., Book review: On the track of Ice Age mammals, by A.J. Sutcliffe, 48:2,64-64,1986.
The NSS Bulletin is a multidisciplinary journal devoted to speleology, karst geomorphology, and karst hydrology. The Bulletin is seeking original, unpublished manuscripts concerning the scientific study of caves or other karst features. Authors need not be associated with the National Speleological Society.

Manuscripts must be in English with an abstract, conclusions, and references. An additional abstract in the author's native language (if other than English) is acceptable. Authors are encouraged to keep in mind that the readership of The Bulletin consists of both professional and amateur speleologists.


Each paper will contain a title with the author’s name and address. This will be followed by an abstract and the text of the paper. Acknowledgements and references follow the text. References are alphabetical with senior author’s last name first, followed by the date of publication, title, publisher, volume, and page numbers. See the current issue of The Bulletin for examples.

Authors should submit two copies of their manuscript (include only copies of the illustrations) to the appropriate specialty editor or the senior editor. The manuscript must be typed, double space on one side of the page. Authors submitting manuscripts longer than 15 typed pages may be asked to shorten them. All measurements will be in Système Internationale (metric). Other units will be allowed where necessary if placed in parentheses and following the SI units.

Figures and lettering must be neat and legible. Figure captions should be on a separate sheet of paper and not within the figure. Most figures will be reduced, hence the lettering should be large. Once the paper has been accepted for publication, the original drawings (with corrections where necessary) must be submitted to the editor. Black-and-white photographs must be sharp, high contrast, and printed on glossy paper. Color prints will be printed at authors expense only.

All submitted manuscripts are sent out to two specialists for review. Reviewed manuscripts are then returned to the author for consideration of the referee’s remarks and revision (where necessary). Revised manuscripts are returned to the appropriate editor who then recommends acceptance or rejection. Upon acceptance, the author should submit all photographs and original drawings to the editor.

Once the paper has been typeset and laid-out, the senior author will be sent one set of proofs for review. Any corrections other than printer errors will be done at the author’s expense. A reprint order form will be sent with the proofs. At this time all authors will be requested to contribute page charges of $25 per page to help defray the cost of publication. The actual cost to the society is about $100 per page. Acceptance of manuscripts for publication is not contingent upon payment of page charges.
CONTENTS

A COMPUTER APPLICATIONS SYSTEM FOR THE PROCESSING OF CAVE SURVEY DATA
Daniel A. Crowl ...................................................... 1

A PRELIMINARY ACCOUNT OF THE PLEISTOCENE MAMMALS FROM PATTON CAVE, MONROE COUNTY, WEST VIRGINIA
Frederick Grady .................................................. 9

PEBBLE INDENTATIONS: A NEW SPELEOGEN FROM A COLORADO CAVE
Donald G. Davis and Cyndi Mosch ........................................ 17

BULGARIAN CAVE MINERALS
Y. Y. Shopov ....................................................... 21

BOOK REVIEWS
Stewart B. Peck, George N. Huppert, Donald G. Davis, and Carol Hill .......................................................... 25

ABSTRACTS; 1987 NSS CONVENTION
S. J. Stowkowski .................................................... 29

INDEX TO VOLUMES 47 and 48
Ira D. Sasowsky .................................................... Center