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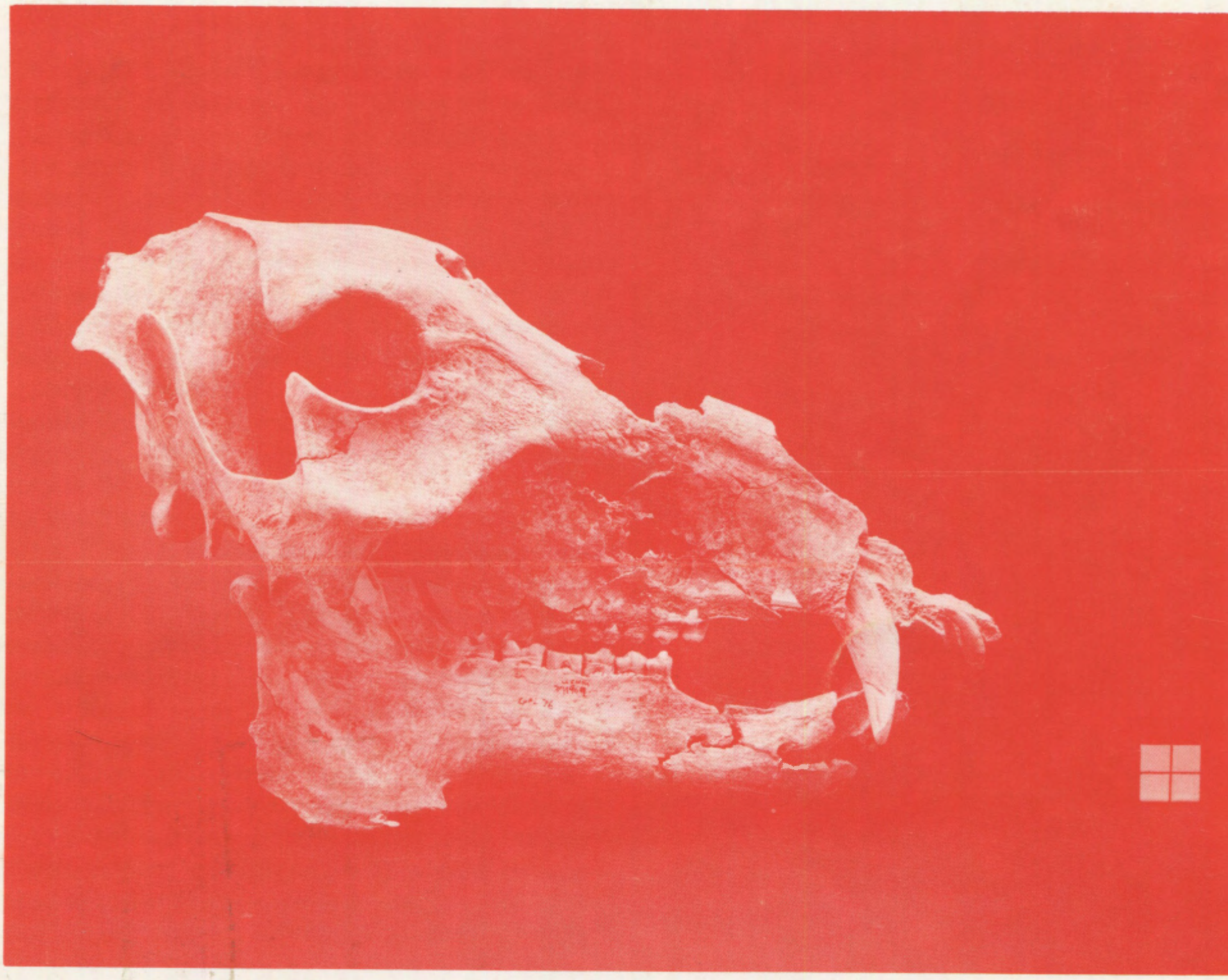
Journal of Caves and Karst Studies



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A COMPUTER APPLICATIONS SYSTEM FOR THE PROCESSING OF CAVE SURVEY DATA

DANIEL A. CROWL*
Wayne State University

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

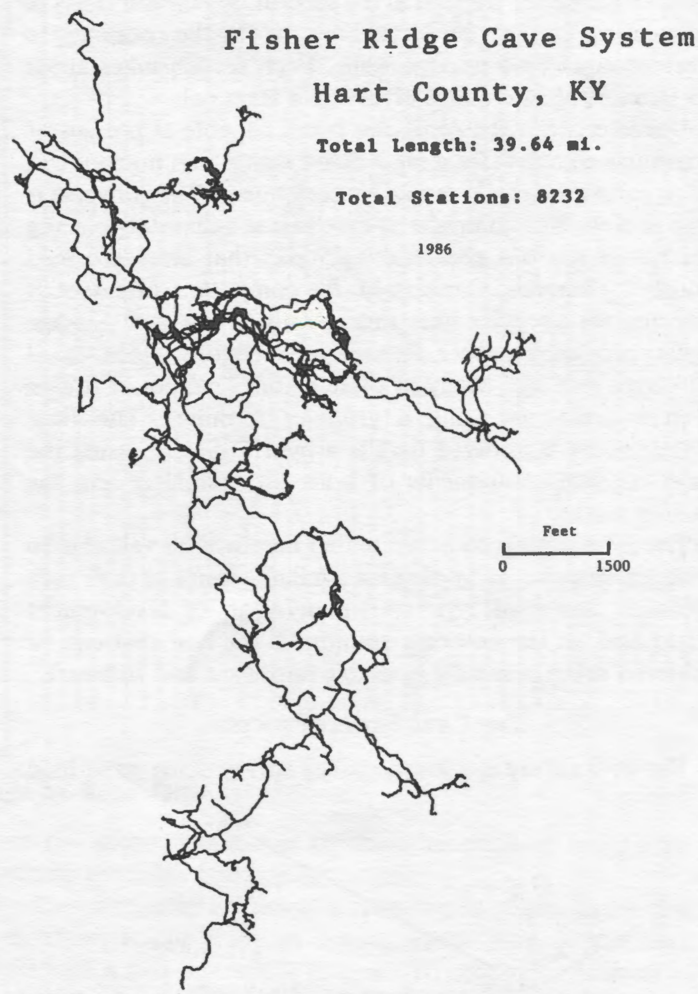

Figure 1. **Line map of Fisher Ridge Cave System.**

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

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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

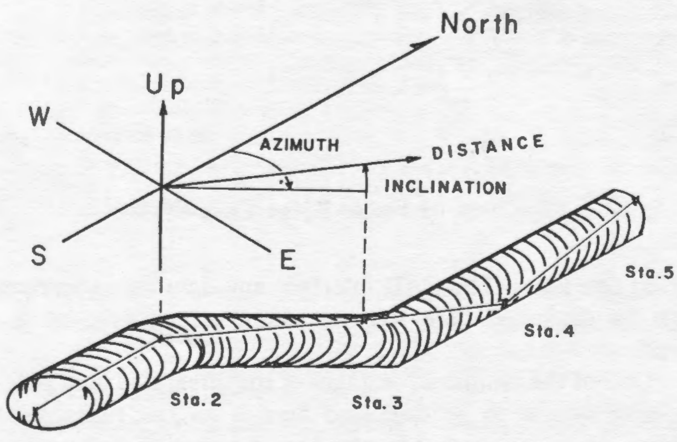


Figure 2. **The Cave Survey Process. (Reproduced by permission from Ganter, 1986.)**

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.

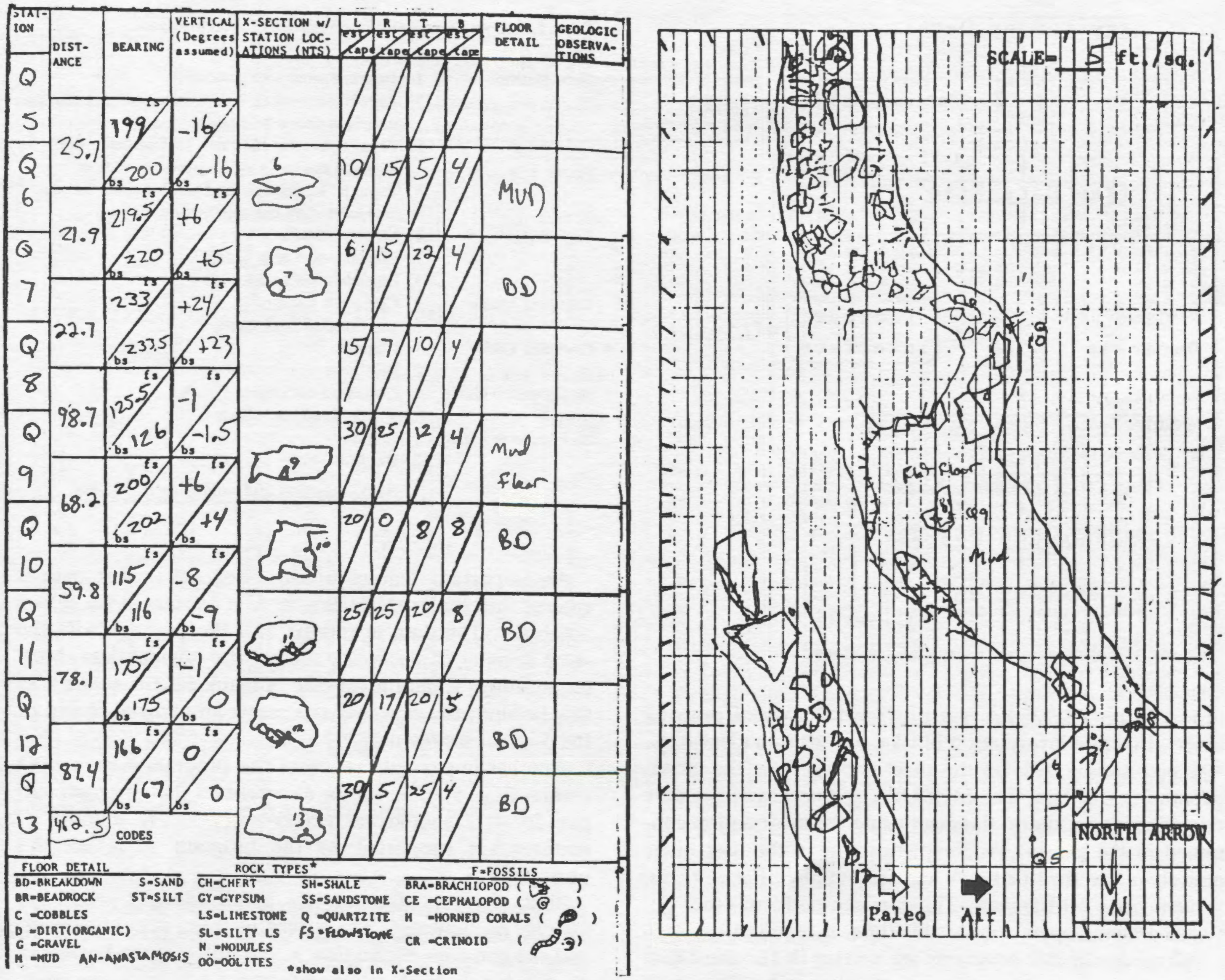
The accuracy afforded by this type of survey is typically a few percent (Ganter, 1986). This is usually adequate for exploratory purposes. However, a problem can arise in loop closure due to accumulated error. The problem is demonstrated in Figure 4. Suppose a survey is performed in a passage that represents 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



STATION	DISTANCE	BEARING (fs / bs)	VERTICAL (Degrees assumed) (fs / bs)	X-SECTION w/ STATION LOCATIONS (NTS)	L	R	T	B	FLOOR DETAIL	GEOLOGIC OBSERVATIONS
Q										
5	25.7	199 / 200	-16 / -16	6	10	15	5	4	MUD	
6	21.9	219.5 / 220	+6 / +5	7	6	15	22	4	BD	
7	22.7	233 / 233.5	+24 / +23		15	7	10	4		
8	98.7	125.5 / 126	-1 / -1.5	9	30	25	12	4	Mud Floor	
9	68.2	200 / 202	+6 / +4	10	20	0	8	8	BD	
10	59.8	115 / 116	-8 / -9	11	25	25	20	8	BD	
11	78.1	175 / 175	-1 / 0	12	20	17	20	5	BD	
12	87.4	166 / 167	0 / 0	13	30	5	25	4	BD	
13	462.5									

CODES

FLOOR DETAIL: BD=BREAKDOWN, BR=BEADROCK, C =COBBLES, D =DIRT(ORGANIC), G =GRAVEL, M =MUD, S=SAND, ST=SILT, AN-ANASTAMOSIS

ROCK TYPES*: CH=CHERT, GY=GYPSUM, LS=LIMESTONE, SL=SILTY LS, N =NODULES, OO=OOLITES, SH=SHALE, SS=SANDSTONE, Q =QUARTZITE, FS=FLOWSTONE

F=FOSSILS: BRA=BRACHIOPOD, CE =CEPHALOPOD, H =HORNED CORALS, CR =CRINOID

*show also in X-Section

Figure 3. **A sample page from a survey notebook. (Original design by Keith Ortiz.)**

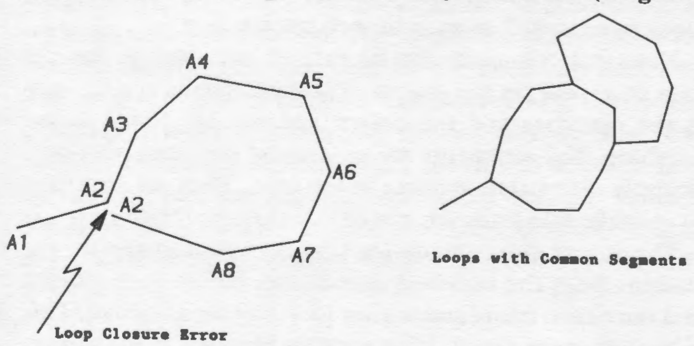


Figure 4. **Loop Closure Problem.**

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-

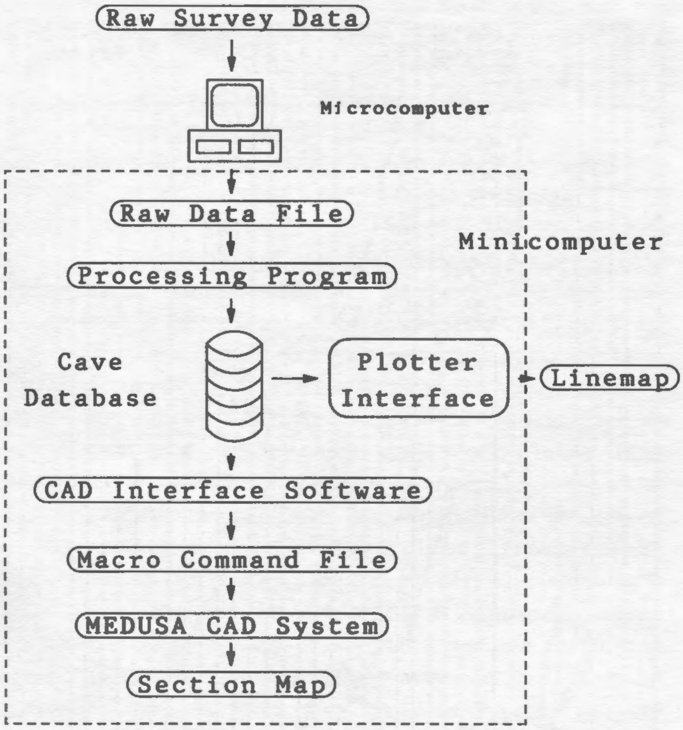


Figure 5. **Schematic of Complete System.**

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 to 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 1. Survey data variations acceptable to the program.

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

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.

Fisher Ridge Cave System

April Fools Trunk continued and the Almost Heaven Dome Drain.
Reid Beauchamp, Steve Miller, Dennis Kendrick, Denny Kendrick. 4/6/85

TAPE: Feet/Tenths COMPASS: Deg., Backsights Corr. CLINOMETER: Deg., Backsights Corr. DECLINATION: 0.00

Continuation of April Fools Truck on the other side of the dome.

STATIONS			**COMPASS**		*CLINOMETER*		TO STATION				*CORRECTED*		****** UNCLOSED ******			******* CLOSED *******		
FROM	TO	TAPE	FRONT	BACK	FRONT	BACK	L	R	T	B	COMP	CLINO	E/W	N/S	VERT	E/W	N/S	VERT
AG2	AG3	46.6	334.5	334.	-4.5	-5.5	6.	15.	15.	8.	334.2	-5.0	-1908.0	-6369.8	-232.0	-1896.9	-6349.4	-233.7
AG3	AG4	71.6	338.	339.	2.5	2.5	13.	12.	24.	2.	338.5	2.5	-1934.2	-6303.2	-228.8	-1923.1	-6282.9	-230.6
AG4	AG5	35.7	335.	334.5	-0.5	0.	3.	21.	20.	4.	334.7	-0.2	-1949.5	-6270.9	-229.0	-1938.4	-6250.6	-230.8
AG5	AG6	74.6	5.	5.5	0.	1.	15.	5.	20.	6.	5.2	0.5	-1942.6	-6196.6	-228.3	-1931.5	-6176.3	-230.1
AG6	AG7	65.2	351.2	352.	-11.5	-11.5	0.	8.	2.	3.	351.6	-11.5	-1952.0	-6133.4	-241.3	-1940.9	-6113.1	-243.1

Ends in a U-tube filled with rock and sand.

Contiune down canyon drain in dome.

STATIONS			**COMPASS**		*CLINOMETER*		TO STATION				*CORRECTED*		****** UNCLOSED ******			******* CLOSED *******		
FROM	TO	TAPE	FRONT	BACK	FRONT	BACK	L	R	T	B	COMP	CLINO	E/W	N/S	VERT	E/W	N/S	VERT
	AG2												-1887.9	-6411.6	-227.9	-1876.8	-6391.2	-229.7
AG2	AH1	15.9	359.	357.	34.	35.					358.0	34.5	-1888.3	-6398.5	-218.9	-1877.2	-6378.1	-220.7
AH1	AH2	34.8	287.	285.	-54.	-53.5	15.	30.	50.	6.	286.0	-53.7	-1908.1	-6392.8	-247.0	-1897.0	-6372.5	-248.7
AH2	AH3	25.5	65.	65.	-11.	-10.	6.	4.	1.	3.	65.0	-10.5	-1885.4	-6382.2	-251.6	-1874.3	-6361.9	-253.4
AH3	AH4	11.4	110.	110.	0.	0.	4.	2.	1.	4.	110.0	0.0	-1874.7	-6386.1	-251.6	-1863.6	-6365.8	-253.4
AH4	AH5	14.7	102.	101.	1.5	1.	3.	3.	1.	4.	101.5	1.2	-1860.3	-6389.0	-251.3	-1849.2	-6368.7	-253.1
AH5	AH6	17.4	134.	134.	-7.5	-5.5	2.	4.	1.	2.	134.0	-6.5	-1847.8	-6401.0	-253.2	-1836.7	-6380.7	-255.0
AH6	AH7	8.8	105.5	105.5	0.5	1.	2.	2.	1.	2.	105.5	0.7	-1839.3	-6403.4	-253.1	-1828.2	-6383.1	-254.9
AH7	AH8	30.9	80.	80.	3.	1.	3.	1.	2.	2.	80.0	2.0	-1808.9	-6398.0	-252.1	-1797.8	-6377.7	-253.8
AH8	AH9	12.7	96.5	97.	2.	2.5	6.	2.	2.	4.	96.7	2.2	-1796.3	-6399.5	-251.6	-1785.2	-6379.2	-253.3
AH9	AH10	8.0	157.	156.5	9.5	7.5	3.	1.	0.	4.	156.7	8.5	-1793.2	-6406.8	-250.4	-1782.1	-6386.5	-252.2
AH10	AH11	26.0	58.	60.	1.5	1.5	3.	2.	0.	4.	59.0	1.5	-1770.9	-6393.4	-249.7	-1759.8	-6373.1	-251.5
AH11	AH12	21.	67.	67.5	0.	1.	8.	2.	0.	2.	67.2	0.5	-1751.6	-6385.3	-249.5	-1740.5	-6364.9	-251.3
AH12	AH13	11.4	23.5	22.5	0.	-1.5	3.	2.	0.	3.	23.0	-0.7	-1747.1	-6374.8	-249.7	-1736.0	-6354.5	-251.4
AH13	AH14	9.4	12.5	12.5	3.	3.5	1.	3.	0.	4.	12.5	3.2	-1745.1	-6365.6	-249.1	-1734.0	-6345.3	-250.9
AH14	AH15	17.6	59.	59.5	-4.	-4.5	15.	6.	1.	3.	59.2	-4.2	-1730.0	-6356.7	-250.4	-1718.9	-6336.3	-252.2

TOTAL TAPED DISTANCE:	THIS SURVEY:	559.200	TOTAL CAVE:	185409.817
TOTAL HORIZONTAL CAVE:	THIS SURVEY:	539.890	TOTAL CAVE:	181107.288
TOTAL STATIONS:	THIS SURVEY:	20	TOTAL CAVE:	6915

Figure 6. **Sample Output from Raw Data Processing.**

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 rerunning 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.

Item
*Station character name
*Station number
*Number of connecting station
Simplified tape distance in feet
Simplified corrected compass in degrees
Simplified corrected inclinometer in degrees
Horizontal distance in feet
Vertical distance in feet
*Left—Right—Top—Bottom readings in feet
*Unclosed Cartesian coordinates in feet
*Closed coordinates

*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.

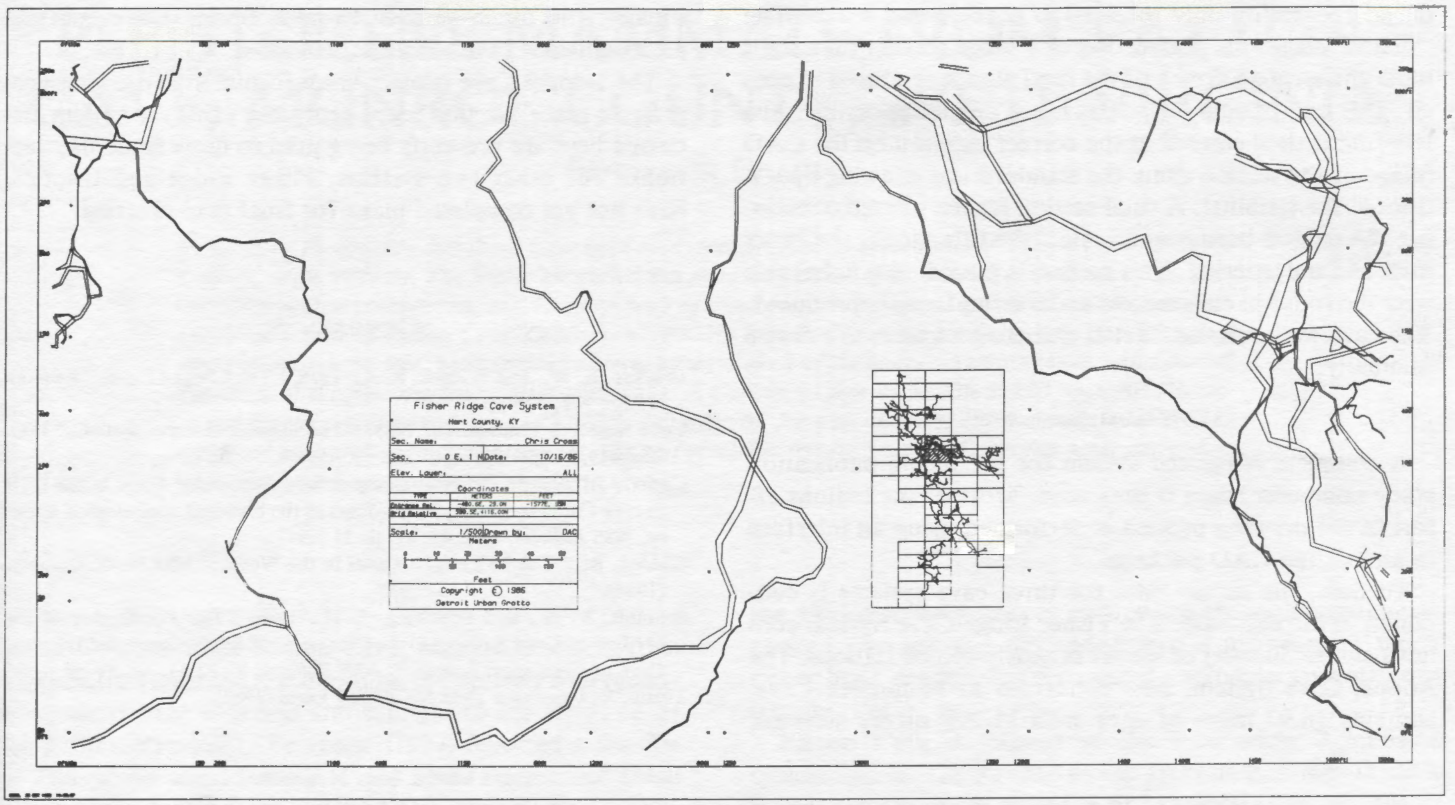


Figure 7. **Sample Map, Fisher Ridge Cave System.**

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 visable 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 produced 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 Roppel 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 Roppel 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

Brucker, R. W., and Watson, R. A., 1976, "The Longest Cave," Random House, NY, 316 pp.

Cave Research Foundation, 1985, "The Mammoth Cave System," P.O. Box 443, Yellow Springs, OH.

Ganter, J., 1986, A Look at Compass and Clinometer Error in the OTR Survey Courses, Abstr., Proceedings of the National Speleological Society, *NSS Bulletin*, Vol. 48, #1, p. 35 (1987).

Gulden, R., "The 30 Longest Caves in the World," *NSS News*, October, (1986).

Schmidt, V. A., and Schelleng, J. H., 1970, "The Application of the Method of Least Squares to the Closing of Multiply Connected Loops in Cave or Geological Surveys," *NSS Bulletin*, V. 32 #3, pp. 51-58.

Thrun, R. Computer code for closing loops (1982).

Grady, Frederick—A Preliminary Account of the Pleistocene Mammals from Patton Cave, Monroe County, West Virginia: *NSS Bulletin* 50: 9-16.

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,* Sanqamona 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).

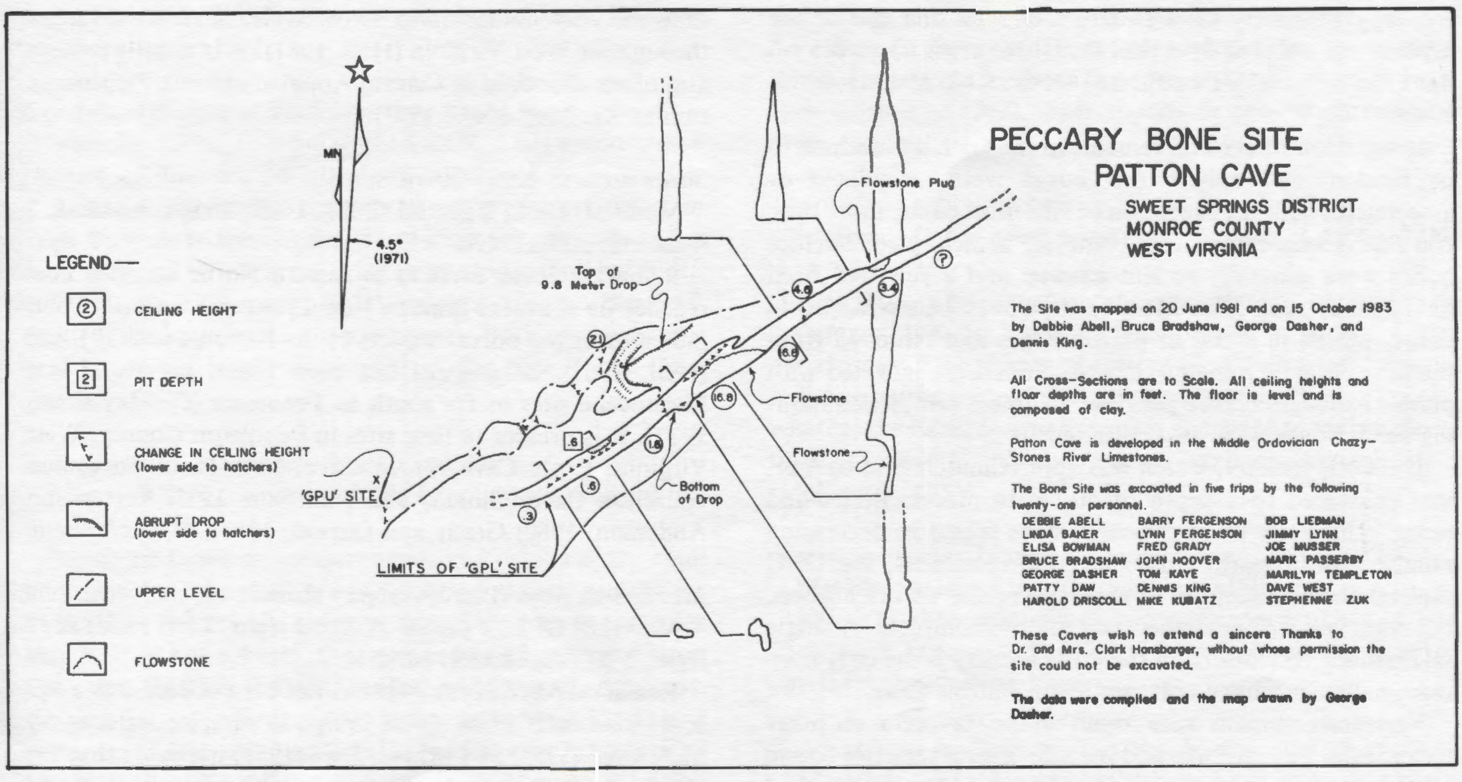


Figure 1.

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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 nonmammalian 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). Patton Cave is the second West Virginia site for *M. hoyi*, the other being the largely unpublished New Trout Cave site.

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 partial skull; 4 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. grisecens, the gray bat. *M. grisecens* 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. grisecens* 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—cheeked 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
Material: GPU, maxillary fragment with P4. MNI = 1.
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 alvoeli for p1, p3-p4. MNI = 1.

Remarks: The pine martin 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 LeConte—Flat-headed peccary

Material: GPL, 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 metacarpal 3 & 4s, 28 separate metacarpals, 25 inominates, 32 femora, 35 tibiae, 12 fibula parts, 4 patellas, 45 tarsals, 18 fused metatarsal 3 & 4s, 39 proximal phalanges, 19 medial phalanges, 20 ungual phalanges, 6 sesimoids, a few hyoid fragments, and numerous rib parts. MNI =22.

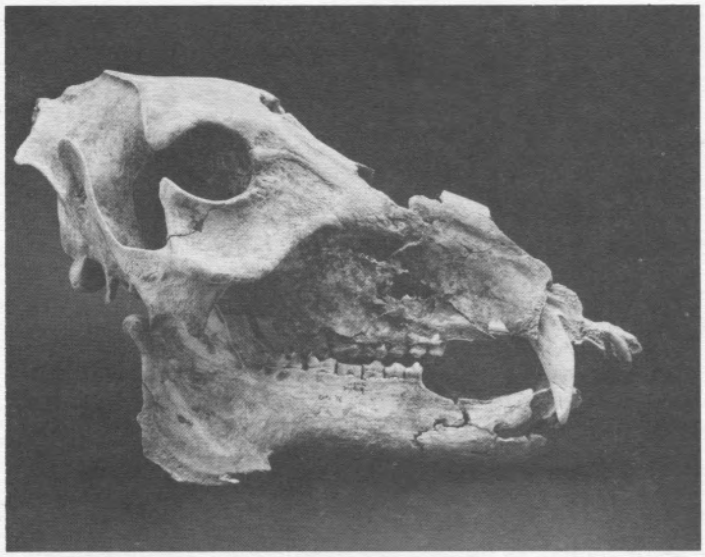

***Figure 2. Platygonus compressus* U.S.N.M. 391969 length = 305 centimeters. Photo by Chip Clark.**

GPU, 12 skull parts, 3 partial mandibles, 2 incisors, 14 canines, 2 premolars, 8 molars, 3 cervical vertebrae, 2 thoracic vertebrae, 3 lumbar vertebrae, 1 caudal vertebra, 3 scapulae, 7 humeri, 9 ulna/radii, 2 carpals, 10 metacarpals, 1 inominate, 1 femur, 9 tibiae, 11 tarsals, 2 fused metatarsal 3 & 4s, 2 proximal phalanges, 1 ungual phalanx, and several rib parts. MNI = 6.

Other sites, 1 left maxilla, 1 canine, 1 thoracic vertebra, 1 metacarpal, and 3 sesimoids. MNI = 1.

Remarks: The GPL collection of *Platygonus compressus* consists of mostly disarticulated bones. One skull (Figure 2 USNM 391969) had an articulated mandible and 14 associated vertebrae. Two humeri were articulated with ulna/radii and four additional groups of from 2 to 5 associated vertebrae were noted. Selected skull and dentition measurements (Table 3) indicate that the Patton GPL sample falls well within the range of *P. compressus*. The measurements indicate that the Patton GPL sample is very similar in size to the sample from Welsh Cave, Kentucky (Guilday et al., 1971). The Patton dentitions are also similar in size to those from Ohio and Michigan, and much smaller than those from Florida and the Southwest (Ray et al., 1970; Eshelman et al., 1972).

The Patton GPL *P. compressus* sample with well-preserved skulls and dentitions allows for age classes to be

Table 3. Age Classes of *Platygonus compressus* from Patton Cave GPL Site (defined in Guilday et al. 1971).

Class	1	2	3	4	5	6	7	8
Skulls	0	0	2	8	3	1	1	0
Mandibles	0	0	3	6	5	2	1	0

Table 2. *Platygonus compressus* **from Patton Cave GPL Site.**

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

determined (Table 2) as in Guilday et al. (1971). The Patton GPL sample is on the whole somewhat younger in ontogenetic age than the Welsh Cave sample. Young adults dominate the Patton GPL sample while very young individuals are absent, thereby indicating a possible preservation bias for adult bone. Gum line notching of lower canines was noted on only 3 specimens in contrast to some Missouri samples (Hawksley et al., 1973). The most prominent example is on one of the ontogenetically oldest individuals.

The well-preserved nature of the bones suggests that the Patton GPL site may represent a natural trap. The topographic features on the surface above the site indicate the former presence of a sinkhole even though no entrance is now present.

The *P. compressus* bones in the Patton GPU site are much more fragmentary and useful measurements cannot be made in most cases, although they do not appear to differ significantly in size from the Patton GPL specimens. In most cases they are also heavily gnawed and may therefore represent remains brought into the cave by carnivores or scavengers. A few other *P. compressus* bones and teeth were found isolated nearby and include the initial find, a left maxilla. *P. compressus* has been found in at least five other West Virginia caves including sites in Greenbrier, Pocahontas, and Pendleton counties (Garton, 1976). Nearly all of these other records represent isolated specimens or parts of single individuals.

Odocoileus virginianus (Zimmermann)—Virginia deer

Material: Other sites, 1 upper molar.

Remarks: The Virginia deer is common throughout West Virginia and its remains often occur in cave sites. The tooth may have been brought into the cave by *Neotoma floridana*.

Sangamona fugitiva Hay

Material: Other sites, USNM 391972 a right M1.

Remarks: A right first upper molar from Patton Cave is virtually identical to, but slightly smaller than, the right M1 in the upper dentition identified by Kurten (1980) as *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

Table 1. Faunal list for Patton Cave.

Scientific Name	Common Name	Minimum Number of Individuals: GPL Site	GPU Site	Other Sites
Sorex cinereus	masked shrew	8		
Sorex arcticus	arctic shrew	3		
Microsorex hoyi	pigmy shrew	7		
Blarina brevicauda	short tailed shrew	4	2	
Parascalops breweri	hairy tailed shrew	3		
Condylura cristata	star nosed mole	6		
Myotis keenii	Keen's bat	1		
Myotis sp.	small brown bats	1		7
Pipistrellus subflavus	pipistrelle bat	1		3
Lasiurus borealis	red bat			2
Leporidae	rabbit or hare			1
Marmota monax	woodchuck	1		
Tamiasciurus hudsonicus	red squirrel		1	
Neotoma floridana	woodrat	1	1	
Peromyscus sp.	deer or white footed mouse	4		2
Phenacomys intermedius	heather vole	1		
Synaptomys borealis	northern bog lemming	2		
Clethrionomys gapperi	red backed vole	3	1	
Microtus pennsylvanicus	meadow vole	23	1	
Microtus xanthognathus	yellow cheeked vole	5		
Zapus hudsonius	meadow jumping mouse	1		
Erethizon dorsatum	porcupine			1
Vulpes vulpes	red fox		1	
Ursidae	bear		1	
Martes americana	pine marten			1
Taxidea taxus	badger			1
Platygonus compressus	flat headed peccary	22	6	1
Odocoileus virginianus	white tailed deer			1
Sangamona gugitiva	furtive deer			1

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 *Platygonus* bones, are within 500 years of each other and, as noted, the *Platygonus* 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 Abell, 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

Burt, W. H. 1969, Mammals of the Great Lakes Region. University of Michigan Press. Ann Arbor, 246 pp.

Churcher, C. S. 1984, *Sangamona:* The Furtive Deer. In Contributions in Quaternary Vertebrate Paleontology. M. R. Dawson and H. H. Genoways (Eds.), Carnegie Mus. Spec. Pub. V. 8, pp. 316–331.

Davies, W. E. 1965, Caverns of West Virginia. West Virginia. Geological and Economical Survey. Morgantown. XIX A. 330 pp. plus 72 pp.

Eshelman, R. E., E. B. Evenson, and C. W. Hibbard. 1972, The Peccary *Platygonus compressus* LeConte from beneath late Wisconsin till, Washtenaw County, Michigan. Mich. Acad. V. 2, pp. 243–256.

Ferguson, L. M. 1977, Fossil Peccary Remains Found. The Carbide Dump, Vol. 11, pp. 18–20.

Garton, E. R. 1976, Manuscript. Notes on the Pleistocene Mammals of West Virginia. WV. Geol. Surv. Open file report.

Garton, E. R. 1977, Late Pleistocene and Recent mammal remains from two caves at Bowden, West Virginia. Proc. W.V. Acad. Sci., V. 53, pp. 110–116.

Grady, F. 1983, The Pleistocene Paleontology of West Virginia's Caves. In Introduction to the Caves of East Central West Virginia. D. Medville, G. Dasher, and E. Werner (Eds.), 1983 N.S.S. Guidebook Elkins, pp. 35–37.

Grady, F., and E. R. Garton. 1981, The Collared Lemming *Dicrostonyx hudsonius* (Pallas) from a Pleistocene Cave Deposit in West Virginia. Proceedings of the 8th International Congress of Speleology, pp. 279–281.

Guilday, J. E. 1962, The Pleistocene local fauna of the Natural Chimneys, Augusta County, Virginia. Ann. Carnegie Mus., V. 36, pp. 87–122.

Guilday, J. E. 1982, Dental variation in *Microtus xanthognathus, M. chrotorrhinus,* and *M. Pennsylvanicus,* (Rodentia: Mammalia), Ann. Carnegie Mus., V. 51, pp. 211–230.

Guilday, J. E., and H. W. Hamilton. 1973, The Late Pleistocene small mammals of Eagle Cave, Pendleton County, West Virginia, Ann. Carnegie Mus., V. 44, pp. 45–58.

Guilday, J. E., and H. W. Hamilton. 1978, Ecological Significance of displaced boreal mammals in West Virginia Caves, Jour. Mamm., V. 59, pp. 176–181.

Guilday, J. E., H. W. Hamilton, E. Anderson, and P. W. Parmalee. 1978, The Baker Bluff Cave Deposit, Tennessee and the late Pleistocene faunal gradient, Bull. Carnegie Mus., V. 11, pp. 1–67.

Guilday, J. E., H. W. Hamilton, and A. D. McCrady. 1971, The Welsh Cave Peccaries (*Platygonus*) and associated fauna, Kentucky Pleistocene, Ann. Carnegie Mus., V. 43, pp. 249–320.

Guilday, J. E., . S. Martin, and A. D. McCrady. 1964, New Paris No. 4 A Late Pleistocene Cave Deposit in Bedford County, Pennsylvania, Bull. Natl. Speleo. Soc., V. 26, pp. 121–194.

Guilday, J. E., and P. W. Parmalee. 1972, Quaternary periglacial records of voles of the genus Phenacomys Merriam (Cricetidae: Rodentia) Quat. Res., V. 2, pp. 170–175.

Guilday, J. E., P. W. Parmalee, and H. W. Hamilton. 1977, The Clark's Cave bone deposit and the late Pleistocene paleoecology of the Central Appalachian Mountains of Virginia, Bull. Carnegie Mus., V. 2, pp. 1 -87.

Hall, E. R. 1981, The Mammals of North America, John Wiley and Sons, New York, 1180 pp.

Hallburg, G. R., H. A. Semken, and L. C. Davis. 1974, Quaternary Records of *Microtus xanthognathus* (Leach), the yellow-cheeked vole, from Northwestern Arkansas and Southwestern Iowa, Jour. Mamm., V. 55, pp. 640–645.

Handley, C. O. 1956, Bones of Small Mammals from West Virginia Caves, Am. Mid. Nat., V. 56, pp. 250–256.

Hawksley, O., J. F. Reynolds, and R. L. Foley. 1973, Pleistocene vertebrate fauna of Bat Cave, Pulaski County, Missouri. Bull. Natl. Speleo. Soc., V. 35, pp. 61–87.

Jones, C. A., J. R. Choate, and H. H. Genoways. 1984, Phylogeny and paleobiogeogeography of short-tailed shrews (Genus *Blarina*). In Contributions in Quarternary Vertebrate Paleontology, M. R. Dawson and H. H. Geonways (Eds.), Carnegie Museum Spec. Pub., V. 8, pp. 56–148.

Kirkland, G. L., Jr. 1977, The rock vole, *Microtus Chrotorrhinus* (Miller) (Mammalia: Rodentia) in West Virginia, Ann. Carnegie Mus., V. 46, pp. 45–53.

Kurten, B. 1980, The stilt-legged deer Sangamona of the North-American Pleistocene, Boreas., V. 8, pp. 313–321.

Kurten, B., and E. Anderson. 1980, Pleistocene Mammals of North America, Columbia University Press, New York, 442 pp.

McKeever, S. 1955, Ecology and Distribution of the Mammals of West Virginia. North Carolina State College.

Miller, G. S., Jr., and G. M. Allen. 1928, The American bats of the genera *Myotis* and *Pizonyx*, U.S.N.M. Bull., V. 144, pp. viii–218.

Ray, C. E., C. S. Denny, and M. Rubin. 1970, A Peccary *Platygonus*

Compressus Leconte from drift of Wisconsinian Age in Northern Pennsylvania, Am. Jour. Sci., V. 268, pp. 78–94.

Whittemore, A. 1979, A History of the Virginia Region, The Region Record, V. 3, pp. 131–295.

Youngsteadt, N. W., and J. O. Youngsteadt. 1980, Prehistoric Bear Signs and Black Bear (*Ursus americanus*) Utilization of Hurricane River Cave, Arkansas, Bull. Natl., Speleo. Soc., V. 42, pp. 3–7.

Davis, Donald G. and Mosch, Cyndi—Pebble Indentations: A New Speleogen from a Colorado Cave: *NSS Bulletin* 50: 17-20.

PEBBLE INDENTATIONS: A NEW SPELEOGEN FROM A COLORADO CAVE

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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 3½ feet high by 3½ feet wide by 4½ 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 1½ inch in diameter. These stones are not merely sticking to the walls, but are partly embedded in closely-fitting indentations up to ¾ inch deep. Some have been pressed laterally into the walls, while others are nested at the bottoms of high-angle grooves up to 2½ 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.

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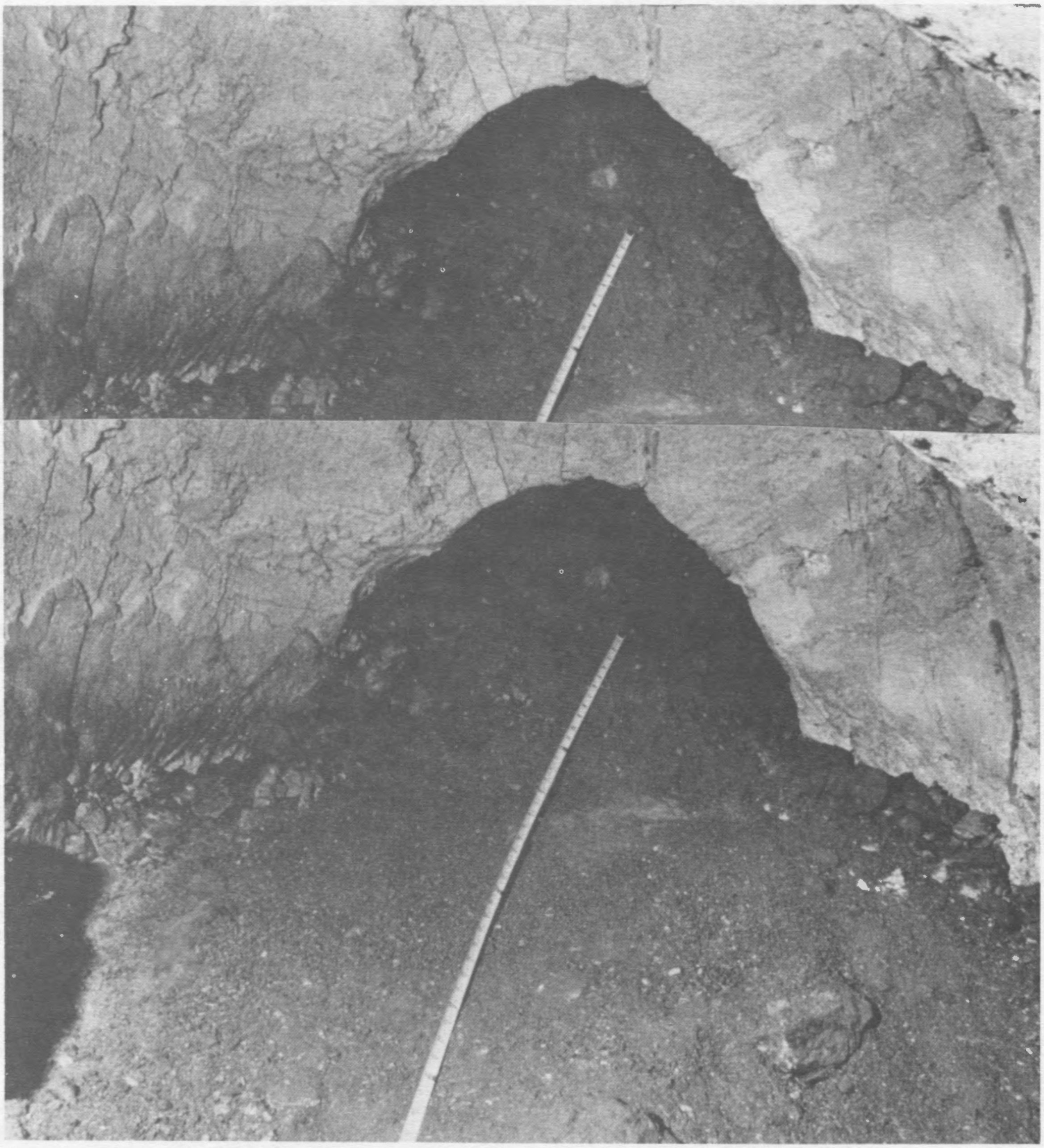

Figure 1. **Alcove containing pebble indentations (note grooves in left wall).**

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

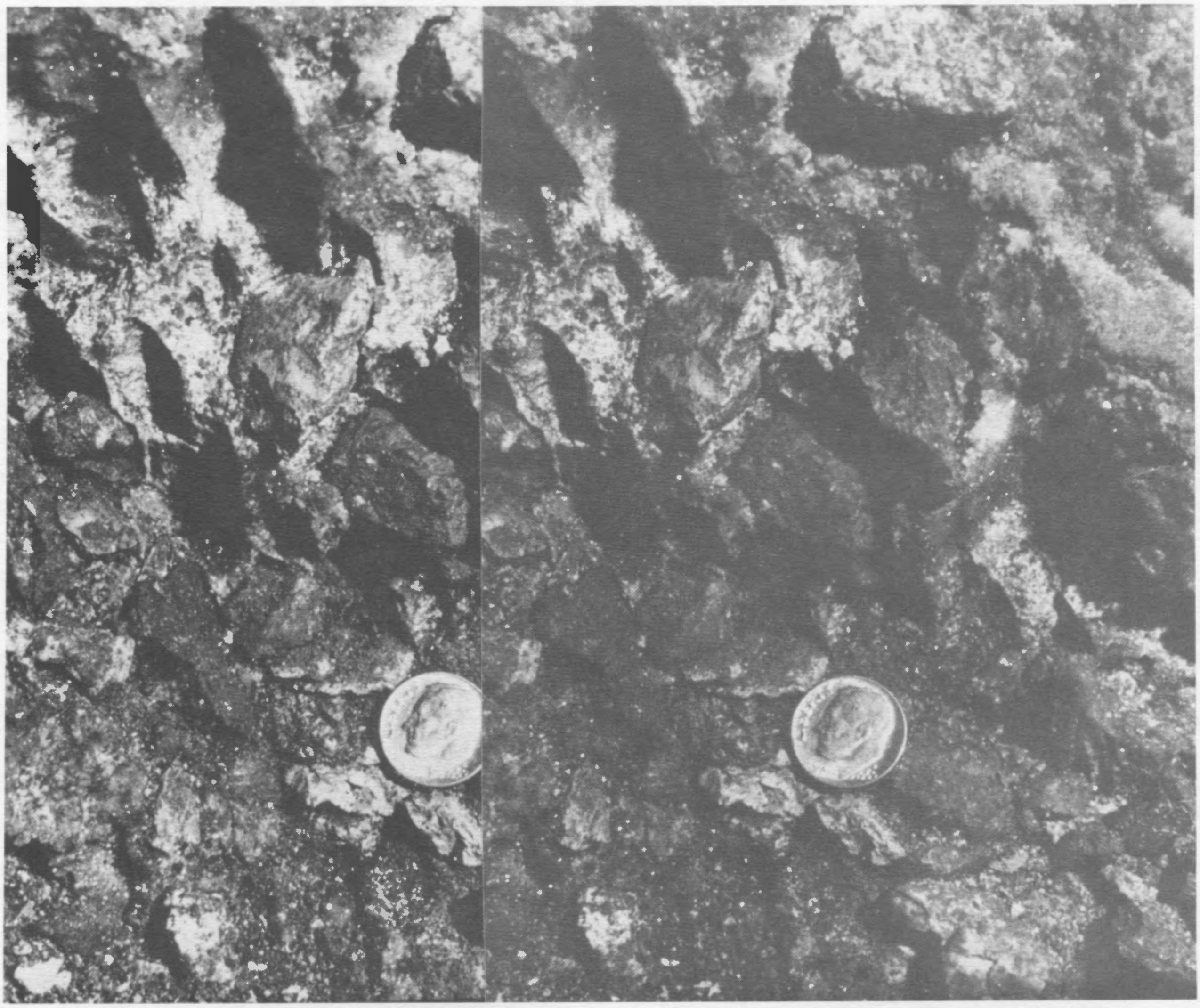

Figure 2. **Grooves with embedded pebbles, right wall of alcove. Illustrations may be viewed stereoscopically for three-dimensional image.**

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 CO_2 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 ½ 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 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 CO_2, H_2S and sulfuric acid could have rendered the condensate corrosive. (A nonvolcanic alternative, the production of CO_2 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 therby 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

Davis, Donald G., 1981, The Deep Creek caves: A thermal/meltwater complex? *Caving in the Rockies*, v23#7, pp. 7–10.

__________, 1982, Rims, rills and rafts: Shaping of cave features by water condensation from air (abstract). *Cave Research Foundation Annual Report*, p. 29.

Lange, Arthur L., 1963, Planes of repose in caves. *Cave Notes*, v5#6, pp. 41–48.

Shopov, Y. Y.—Bulgarian Cave Minerals: *NSS Bulletin* **50**: 21-24.

BULGARIAN CAVE MINERALS

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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 63 papers) were determined in Bulgaria. Twenty of them (Table 1) were discovered first in Bulgarian caves and are new cave minerals.

These minerals are classified in the following manner:

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

Mineral	Year Authors	Formula	Cave
1. ice	?	H_2O	Ledenika
2. calcite	1923 Bonchev G.	$CaCO_3$	Glojenskata
3. nitre	1960 Jovchev J.	KNO_3	Rusensky Lom
4. aragonite	1964 Naidenova E. &	$CaCO_3$	Iskreckata
5. gypsum	1964 Kostov I.	$CaSO_4.2H_2O$	Iskreckata
6. celestite	1964 —II—	$SrSO_4$	Iskreckata
7. dolomite	1964 —II—	$CaMg(CO_3)_2$	Iskreckata
8. huntite	1974 Maleev M.	$CaMg(CO_3)_2$	Mineralenizvor
9. taranakite	1976 Filipov A.	$H_6K_3Al_5(PO_4)_8$ $.18\ H_2O$	Magurata
10. magnesite	1974 Maleev M.	$MgCO_3$	Mineralenizvor
11. hydromagnesite	1979 Filipov A.	$Mg_5(CO_3)_4(OH)_2.$ $4H_2O$	Duhlata
12. *saponite*	1979 Filipov A.	$Mg_3Si_4O_{10}(OH)_2$	Duhlata
13. *brusite*	1980 —II—	$Mg(OH)_2$	Duhlata
14. ardealite	1980 —II—	$Ca_2HPO_4SO_4$ $.4H_2O$	Magurate
15. brushite	1980 —II—	$CaHPO_4.2H_2O$	Magurata
16. apatite	1980 —II—	$Ca_5(PO_4)_3$ (F,Cl,OH)	—II—
17. todorkite	1980 —II—	$BaMn_3O_7.H_2O$	Magurata
18. *maghemite*	1983 Shopov, Rusanov	γ-Fe_2O_2	Minata
19. Goethite	1983 Shopov et al.	α-FeOOH	Shopovs Cave System
20. lepidocrocite	1983 —II—	γ-FeOOH	—II—
21. *akaganeite*	1983 —II—	β-FeOOH	—II—
22. hematite	1983 —II—	α-Fe_2O_3	—II—
23. cerussite	1983 —II—	$PbCO_3$	—II—
24. *baylissite*	1984 —II—	$K_2Mg(CO_3)_2.$ $4H_2O$	—II—
25. vaterite	1984 —II—	$CaCO_3$	—II—
26. malachite	1984 —II—	$Cu_2CO_3(OH)_2$	—II—
27. *devilline*	1984 Shopov	$Cu_4Ca(SO_4)_2$ $(OH)_6.3H_2O$	Shopovs
28. hydrozincite	1984 et al.	$Zn_5(CO_3)_2(OH)_6$	cave
29. *artinite*	1984 —II—	$Mg_2CO_3(OH)_2$ $.3H_2O$	system
30. *giorgeite* ?	1984 —II—	$Cu_5(CO_3)_3(OH)_4$ $.6H_2O$	—II—
31. azurite	1984 —II—	$Cu_3(CO_3)_2(OH)_2$	—II—
32. *$CaCO_3$—II* !	1984 —II—	$CaCO_3$	—II—
33. *H.T.-FeOOH* ? !	1984 —II—	FeOOH	—II—
34. Galena	1984 —II—	Pbs	—II—
35. *giorgiosite*	1984 —II—	$Mg_5(CO_3)_4(OH)_2$ $.5H_2O$	—II—
36. *dypingite*	1985 —II—	$Mg_5(CO_3)_4(OH)_2$ $.5H_2O$	—II—
37. *hydrocerussite*	1985 —II—	$Pb_3(CO_3)_2(OH)_2$	—II—
38. Aurichalcite	1985 —II—	$Cu_2Zn_3(CO_3)_2$ $(OH)_6$	—II—
39. *Schroeckingerite*	1985 —II—		—II—
40. *Sharpite*	1985 —II—		—II—
41. *Wyartite*	1985 —II—		—II—
42. *Rutherfordine*	1985 —II—		—II—
43. rozazite	1985 —II—	$CuZn(CO_3)(OH)_2$	—II—
44. *celerite*	1985 —II—		—II—
45. *pyroaurite*	1985 —II—	$Mg_6Fe_2.CO_3$ $.(OH)_{16}.4H_2O$	—II—
46. *nacaurite*	1985 —II—	$Cu_8(SO_4)_4(CO_3)$ $(OH)_6.48H_2O$	—II—
47. *poznyakite*	1985 —II—	$Cu_4(SO_4)$ $(OH)_6.H_2O$	—II—
48. tyuyamunite	1985 —II—		—II—
49. anglesite	1985 —II—	$PbSO_4$	—II—
50. bornite	1985 —II—	Cu_5FeS_4	—II—
51. thermonatrite	1987 Shopov	$Na_2CO_3.H_2O$	Prilepnata
52. natron	1987 Kolev &	$Na_2CO_3.10H_2O$	
53. gibbsite	1987 Petrov	AlOOH	—II—
54. *acetamide*	1987 —II—	CH_3COONH_2	—II—
55. quartz	1987 Shopov Y	SiO_2	

New cave minerals are italic. New minerals are pointed with !.

Group I: Ore-associated minerals (total of 29)
- I.1 Hydrothermal; nos. 6, 32-34, 50, & 55 in Table 1
- I.2 Hypergenic; nos. 21, 23, 26-31, 35-49 in Table 1

Group II: Karstogenic minerals (formed at low-temperature karst processes, total of 17)
- II.1 Aragonite associated (Shopov and Ivanov, in press); nos. 2, 4, 5, 7, 8, 10-13, 24, & 25 in Table 1
- II.2. Hydroxides; nos. 1, 17-20, & 22 in Table 1

Group III: Guanogenic minerals (total of 6)
- III.1 Phosphates; nos. 9 & 14-16 in Table 1
- III.2 Nitrates; no. 3 in Table 1
- III.3 Organic; no. 54 in Table 1

Group IV: Volcanogenic (total of 3)
- nos. 51-53 in Table 1

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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 Cu^{II} 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 Pb^{II} luminescence of Mn^{II} in hydrothermal calcite. Author photo.**

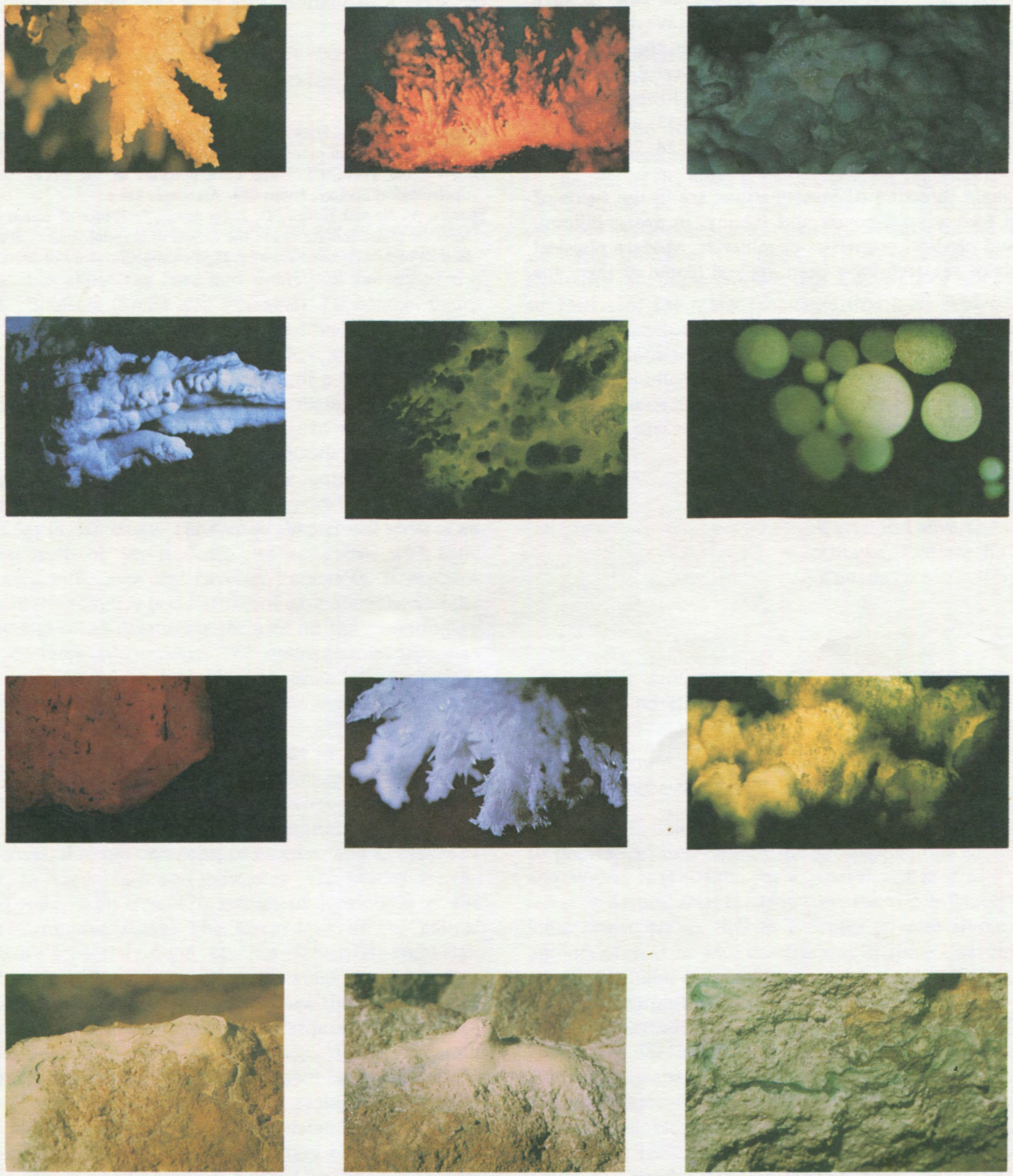
Figure 8. **UV-photography of aragonite flower. Author photo.**

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

Filipov, A. F., 1983, Hydromagnesite, aragonite, fibrous calcite, saponite and brusite formed moonmilk in Duhlata cave, Bulgaria (in Russian).

Hill, C. and Forti, P., 1986, Cave minerals of the world. National Speleological Society, Huntsville, Alabama, 238 p.

Shopov, Y. Y. and Ivanov, G. I. (in press), Influence of cation admixtures on phase equilibrium in the system of (gypsum)-calcite-aragonite-huntite-hydromagnesite-vaterite. Physics and Chemistry of Minerals.

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 millipeds, 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.

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Discovering Landscape in England and Wales. Andrew Goudie and Rita Gardner. London: George Allen and Unwin, 177 p.

Available from: Allen and Unwin, Inc., 9 Winchester Terrace, Winchester, MA 01890. $24.95.

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.

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Geology of Carlsbad Cavern and other caves in the Guadalupe Mountains, New Mexico and Texas, by Carol A. Hill. Bulletin 117, New Mexico Bureau of Mines & Mineral Resources, 1987. 150 pp., illus., $15.00 (+ $1.50 postage & handling).

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 sulfar-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 H_2S (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 H_2S 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 CO_2 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 H_2S 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.

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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."

PROCEEDINGS OF THE NATIONAL SPELEOLOGICAL SOCIETY
ANNUAL MEETING, August 3 - August 7, 1987
SAULT SAINTE MARIE, MICHIGAN
S. J. Stokowski, Jr., EDITOR

BIOLOGY SESSION

Kathy Lavoie, Session Coordinator

THE VERTEBRATE CAVE FAUNA 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

Living vertebrates have been identified from 104 cave localities in 16 West Virginia counties. Included in the fauna are amphibians, reptiles, and mammals representing 17 genera. Among the amphibians are toads, frogs, and several species of salamanders including the West Virginia Spring Salamander, Gyrinophilus 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 Plecotis townsendii virginianus (Virginia long-eared bat). When completed this research will be published as a bulletin of the West Virginia Speleological Survey.

DYNAMICS OF A CAVE PREDATOR-PREY SYSTEM: CO-EVOLUTION OR NOT?

Griffith, David M. University of Illinois, Chicago, IL 60680.

Dynamics of a carabid beetle preying on eggs of Rhaphidophorine crickets are being studied in Mammoth Cave National Park. The main natural experiments are different spatial scales of abiotic and biotic heterogeneity within and between cave sites. Hypotheses are being tested by field and lab experiments. The site with highest beetle density is least variable with RH greater than 85% and 13-14 C. Yet predation rate, based on enclosure rings varies from 0 to 99% over seasons, and spatially parallels substrate moisture. This may not be consistent or intense enough selection for co-evolution. Direct measures of individual predation success and cricket egg-laying rates, along with population estimates, give an 11.4% predation rate. Behavioral experiments show that beetles use specialized behavior to locate eggs and suggest that cricket egg-laying patterns allow some avoidance of predation. Bimonthly samples will show if beetle and cricket fecundities are correlated in ways expected from a co-evolutionary scenario.

ASPECTS OF POPULATION STRUCTURE IN CAVE CRICKETS, HADENOECUS SUBTERRANEUS

Studier, E. H., K. H. Lavoie, D. Nevin, and K. McMillin. Biology Department, 1321 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 sized crickets indicating no seasonal differences in reproductive effort. The fraction of adults varies in a cyclic seasonal pattern reaching a peak in winter (52%) and a minimum in summer (38%). This may reflect seasonal differences in emigration and immigration or, more likely, a marked mortality in winter-to-summer and maturation of sub-adults in summer-to-winter. There is no gender prevalence among sub-adult crickets while the sex ratio of adults shows significantly more females that males. This indicates greater mortality rates among adult males than females. A population crash occurred in Crystal Cave in Winter, 1987, due to an influx of cold air which lowered the relative humidity.

ASPECTS OF REPRODUCTIVE BIOLOGY IN CAVE CRICKETS, HADENOECUS SUBTERRANEUS

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Monthly collection, dissection, and fresh and dry weighings of adult and copulating 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. Males had two spermatophores; the number of ova in gravid females varies from 1 to 30. Mature ova in gravid females were seasonally consistent at 6.0 to 7.4 per cricket, except for eight females collected in winter which averaged 18.1. Cave crickets of both sexes are sexually mature when their hind femur length greater than 20 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 carcass weights and lower crop contents.

JUMPING PARAMETERS IN CAVE CRICKETS, HADENOECUS SUBTERRANEUS

Studier, E. H., K. H. Lavoie, and L. Mason. Biology Department, 1321 East Court Street, University of Michigan-Flint, Flint, Michigan 48502-2186

Cave Crickets of all sizes and both genders were studied primarily in Sophy's and Marion Avenues of 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 gender related differences in any parameter nor was a primary direction taken. Number of hops, time to exhaustion, total distance hopped, and individual hop distances averages (range)are respectively: 8.0 (3-15), 11.2 sec. (6.8-17.8), 334 cm (158-688), and 43.0 cm (22.3-71.7). Individual hop distances did not vary with successive hops. Upon exhaustion, hind legs became rigidly extended. Using four legs, exhausted crickets walked to a hiding place. These data indicate that jumping may exclusively use fast twitch (white) muscle cells.

MICROBIAL INVOLVEMENT IN FOOD DIGESTION BY CAVE CRICKETS, HADENOECUS SUBTERRANEUS

Lavoie, K. H., E. H. Studier, and C. Kennedy. Biology Department, 1321 East Court Street, University of Michigan-Flint, Flint, Michigan 48502-2186

Although data are still tentative, digestive enzymes found in the crops of cave crickets are produced by microbes found in the crops. These microbes include a predominant group of Gram-positive bacteria and a yeast found in all crops of all crickets examined at all times of the year. We are using electrophoretic techniques to compare crop enzymes with enzymes produced by pure cultures of these microbes. Information on the histology of the cricket digestive tract indicate no secretory structures associated with the crop to provide cricket-produced enzymes.

SHELTA CAVE SURVEY

Lee, Devon Marie. 257 Wesson Circle, Redstone Arsenal, AL 35808.

Shelta Cave, which lies under the NSS headquarters building in Huntsville, Alabama, has held the reputation of containing interesting as well as unique fauna. A visual survey of some of the animal life was conducted from December, 1985, until July, 1987, to gain insight into the numbers of organisms presently inhabiting the cave. The cave was visited once or twice a month during the study period. Sightings of crayfish, fish, shrimp, or bats were recorded. Compared to Cooper's previous research in this cave, we found that there has been a reduction in the numbers of these organisms. This study was conducted by Lee and Linda Tucker and Devon and Karl Lee. Horton Hobbs III (Wittenburg University) and Fred Bagley (Fish and Wildlife Service) were essential in offering guidance and support for the project.

GASOLINE POLLUTION IN AN INDIANA CAVE

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During September, 1985, Pless Cave in Lawrence County, Indiana, was contaminated by a 4,700 gallon loss of gasoline from a leaky line at a newly opened gasoline station located two km east-northeast of the single cave-spring entrance. Gasoline fumes were noted by cavers on September 8 and locals reported "dead crayfish" in the stream. On September 17 a decrease in gasoline inventory was noticed by the station owner. The station remained open until September 24 when line failure was confirmed. No gasoline was recovered; most of it probably drained through north sections of the five km long cave. The cave was closed until April, 1987, and some passages still remain unsafe to enter; however, a May 1 visit confirmed biologic recovery in the front 175 m (six Orconectes (Orconectes) inermis inermis and nine Cambarus (Frebicambarus) laevis). No aquatic life was observed in the north passages, suggesting that re-colonization of stygobionts is occurring from the southern sections of the cave.

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 H1V 3R2

Quebec contains caves in many geological settings. Most are small and young. Four major cave regions are: 1) Greenville Marbles, particularly along the Gatineau River north of Ottawa contain many short stream caves. 2) St. Lawrence Lowlands between Montreal and Quebec City, with stream caves and some glacio-tectonic caves in flat lying limestones. One, Grotte de Boischatel, underlies a suburb of Quebec City and is greater than 1000 m long. 3) Anticosti Island and the Mingan Islands, Gulf of St. Lawrence, containing limestones and clayey limestones which display karst but have caves that are fully flooded. 4) Gaspe Peninsula, where limestones are common but cave discoveries few. Speos de al Fee contains 500 m of ancient, complex passages. Grotte de St. Elzear is an ancient pothole with important Quaternary faunal deposits.

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 dolomite and 80,000 square kilometers of gypsum. Most lithologic types (oolitic limestone, chalk, crystalline limestone, etc.) occur. The rocks range in age from Archean to Cretaceous and 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 great majority are short and of small dimensions. Large cave development is limited or prohibited throughout the arctic regions by the presence of permafrost. In southern interior Canada (the prairie region, Ontario, much of Quebec) the topographic relief is low and there is much disruption by past glacial activity. Glacial disruption is also intense in the mountain terrains but it is here (especially in the Rockies and on Vancouver Island) that 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 N 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: 1) the Arctic Islands. These contain extensive limestone, dolomite, gypsum, and salt diapirs. Cold, permafrost, and aridity limit karst development; no significant caves have been reported. 2) a belt of lowland, plateau, and hill terrain underlain by dolomite and gypsum that extends along the western 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 MacKenzies) contains caves up to 3,000 m long. Dodo and Carcajan 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, crawlways 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 (21% of Ontario caves). Entrances are up to 15 m high by 25 m wide and funnel down rapidly. Most are 10 to 50 m long and the longest are about 110 m. 2) Crevice caves, usually a roofed fissure (21%). These are fairly straight passages 0.3 to 1 m wide, 3 to 10 m high, and 10 to 30 m long. The largest are about 100 m long. 3) Solution caves in marble, limestone, or dolostone (55%). These range from small crawl caves to systems over 2-km long. The six 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 carbonates of these mountains. Nakimu Caves were explored and commercialized at the turn of the century and contain an exciting streamway. Elsewhere, the main exploration has only been in the last twenty years. Castleguard Cave 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 Crowsnest 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 Maligne where a large river sinks in a lake bed, resurging 16 km away and 400 m lower at constricted 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. Lack of trails combined with difficult bush make access on foot or skis difficult. The helicopter is the most efficient means of access.

Lengths of 20 km and depths of 500 m have been recorded for the largest systems, the most spectacular being Close-to-the-Edge Cave with an entrance shaft 260 m deep.

The extensive mountainous region north of Jasper offers great opportunities for cave discovery. On average, one major cave is being found every year or so. The great thickness of thrusted limestone in the Canadian Rockies suggests that caves over 1,000 m deep may yet be found.

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 1979 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 caves 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 with state funds and installed inside caves. Outreach to the owners of Virginia's caves was undertaken by circulation of a newsletter. This attempts to instill pride in ownership 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 cave resources is a continuing challenge. The current program direction is toward influencing upper elementary school students.

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

Brown, 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 purpose is to generate 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. It contains 480 acres on which are located five caves including Hendrie River Water Cave, the longest in Michigan. The karst drainage is between a perched swamp and a base-level stream. It probably developed primarily post-Wisconsin glaciation and the fall of glacial Lake Algonquin. The rocks are middle Silurian limestones and dolomites of the Burnt Bluff Group, including the type locality for the Fiborn limestone facie.

Bats (M. lucifugus, M. keeni) 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 MODEL

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

The American Cave Conservation Association has made public education concerning caves 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 1987 have been entered into a computerized data base. Frequency and subject analysis reveals cyclic variations and provides an indicator of 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 a 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 years, 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 22201

Since the initial development of the Organ Cave radio described in Speleonics #3 (v.1 #3, Fall, 1985), methods of improving the performance of the cave 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 Q. A design incorporating feedback has been demonstrated on the 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.

IMPROVISED 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 ORDOVICIAN 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 Ordovician Dubuque and Galena Formations and Iowa's equivalent Dubuque, Wise Lake, and Dunleith Formations host the largest caves in the Upper Mississippi Valley karst. These caves form a linear array across Fillmore and Winneshiek Counties (the "holey line") and can be divided into two groups. The first group consists of joint-controlled maze 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 entrances. U/Th disequilibrium data, from accessible caves, are beginning to show patterns of intermittent speleothem growth which are related to the glacial history and geomorphic development of the area.

COLLIFORM BACTERIA AND NITRATE LEVELS
IN THE BURNSVILLE COVE DRAINAGE BASIN, VIRGINIA

Chess, 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 Cove and its underlying Butler Cave-Sinking Creek System was studied to investigate levels of nitrate and colliform bacteria in surface and underground streams. Nitrates varied seasonally with high concentrations in the fall and winter and low levels in the spring and summer, implying that vegetation and bacterial organisms are controlling the nitrate concentrations. Bacteria levels were found to correlate with discharge, implying that stream sediments and surface soils are the sources of the organisms. Bacterial concentrations do not vary with depth into the cave system implying a steady state population in 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 960 to 1050 m (uncertain due to poor data for one now quarried) 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 that for any population studied previously, indicating a high degree of entrance development. The method appears applicable to small populations and is robust against uncertainties in data.

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

Groves, Christopher G. Department of Environmental Science, University of Virginia, Charlottesville, VA 22903

Laurel Creek (Monroe County, West Virginia) drains an area of about 50 square kilometers and flows over rocks of the Mississippian Mauch Chunk Series (predominately 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 Cave-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 1.01 m^3/s) the creek experiences an increase in pH, alkalinity, and Ca^{++}, Mg^{++}, SO_4^{2-}, and NO_3^-. SiO_2 decreases and Na^+, K^+, and the mole ratio of Ca^{++}/Mg^{++} remain relatively constant. Laurel Creek remains undersaturated with respect to calcite. Calcite is dissolved form the cave system at a rate of 4.12 mg/l hr, causing enlargement at a rate of 0.41 m^3/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. Less common 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 lengths: Weather cycles of high and low pressure zones; solar and lunar tides and radiation; the jet stream and local storms; a mixed group including auroral discharges, earthquakes, atomic blasts, and assorted noises; and finally winter storms at sea. Temperature changes in outside air induce flow in caves with several openings by the "chimney effect." This appears in modified form in caves with one opening. Free flow of air is restricted by inertia of the air, by formation of air layers, by rough passage walls, and by constrictions. Mixed patterns can often be identified.

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, Cookeville, TN 38505

The safe Drinking Water Act has significant ramifications for increasing knowledge of karst aquifers and ground water basins. The Wellhead Protection Program and the Sole Source Aquifer Demonstration Programs will provide funds necessary to delineate recharge areas and ascertain ground water travel time. Through work with the EPA's technical committee and Dames and Moore 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) simplified variable shapes, 4) analytical flow models, 5) geologic/geomorphic mapping, 6) numerical flow transport models, and 7) ground water tracing and 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 P. and Nicholas C. Crawford. Center for Cave and Karst Studies, Western Kentucky University, Bowling Green, KY

The city of Bowling Green, Kentucky, is almost entirely located within the 55 square mile Lost River Drainage Basin. Nearly 600 drainage wells, with depths ranging from 10 to 200 feet, have been drilled in Bowling Green to direct stormwater runoff to the subsurface. Research is currently underway by the Center for Cave and Karst Studies to: 1) identify large voids in these wells 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 examined and recorded by a down-hole video camera. Graphic logs are constructed and voids are correlated between wells. Creason 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 FLUVIOKARST, TENNESSEE

Stokowski, S. J., Jr. Consulting Geologist/Petrographer, Suite A, 10 Clark Street, Ashland, MA 01721

Ground magnetic studies helped locate soil-filled solution crevices and filled sinkholes in a soil-covered fluviokarst on the Newala Fm. (Knox Group) carbonate rocks, Rock-Quarry Dome, Sevier County, Tennessee. The magnetic anomalies that correlated with the difficult-to-detect features exist because of the contrast between the carbonate bedrock and iron-rich terra-rossa soil. High ground-magnetic reading densities along multiple, gridded traverses and corrections for time variations were required. Variations of about two gamma were resolvable. Anomalies of two to ten gamma above the very local background could be correlated across traverses to define linear anomalies. These anomalies were drilled and proved to be linear terra-rossa-filled solution crevices, in one case more than 36.6 m (120 ft.) deep. Intersections of the linear magnetic anomalies correlated with the more conventional, magnetic contour-anomaly patterns indicative of deeper terra-rossa soil, and also with bowl-shaped sinkhole depressions.

STABLE ISOTOPE STUDIES OF EVAPORITES
IN CASTLEGUARD 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 limestones of Middle-Cambrian age, contains evaporite minerals on the walls and within in-situ clastic 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 sulphur isotopic signatures found in most of the gypsum minerals. The sulphur isotropic composition of mirabilites however, suggests that bacteria may be involved in the formation. Examination of the hydration waters of the minerals indicates that evaporation of the mineral-forming water was slight during the precipitation of gypsum but more extensive in the formation of mirabilite, which may have precipitated when ice sheet retreat breached the cave and chimney winds caused extensive evaporation.

INTERNATIONAL EXPLORATION SESSION

Jeff Josefosky, Session Coordinator

1986 CHIQUIBUL EXPEDITION - BELIZE/GUATEMALA: MAY PHASE

Ganter, 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 13.5km (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 Kabal, then moved down-system to investigate two caves found in recons earlier in the year; Cebada Cave and Actun Zactun. The May phase pushed Cebada up and downstream through passage averaging 50m wide. Work then shifted to the system resurgance, 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 make the cave the deepest in Guatemala at 187m. Actun Zactun 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. Cebada 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, Closter, 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, Closter, 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 Anguillian 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 Indiana and Anguillians entered.

THE ENCHANTED RIVER

Skiles, Wes. Rt. 1, Box 158R31, 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-Chrome, 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.

GUILIN KARST, CHINA

Zawlocki, Edward J. Shirogane 4-Chrome, 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. Scenes will also be shown from the commercial 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 majority of the localities, 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 range from recent to perhaps 700,000 years. Among the mammals are at least 25 extinct species including Mammuthus columbi (woolly mammoth), Mammut americanum (mastodon), Symbos cavifrons (musk ox), Smilodon (sabertooth cat), Canis dirus (dire wolf), Panthera onca augusta (jaguar), Tapirus (tapir), Platygonus and Mylohyus (peccary), Miracinonyx inexpectata (cheetah-like cat), Megalonyx jeffersoni (ground sloth), Arctodus pristinus (cave bear),Equus tau (horse), and Desmodus (vampire bat). Also included are many extant species of northern, western, and southern forms indicating the extreme climactic 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, West Virginia. The discovery represents the first record of mastodon from Tucker County, the fourteenth record for West Virginia, extends the geographic range of mastodon in West Virginia, and represents the greatest altitude (2,450 feet, 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, Erethizon dorsatum, were also recovered from the cave. This porcupine became extinct in West Virginia during recent times.

THE EXTINCT SKUNK BRACHYPROTOMA OBTUSATA FROM THREE CAVES IN WEST VIRGINIA

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

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

HUMAN SKELETONS IN BULL THISTLE CAVE, VIRGINIA

Willey, P. and George Crothers. 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 travertine coating the elements, but no difference in rodent 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 CAVE PHOTOGRAPHY

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

For one combination of film speed, flash source, reflector type, and shutter speed, an appropriate f-number = Guide Number (GN) divided by flash-to-subject distance (Dfs) 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):

$$GN\ (flashbulbs) = \sqrt{(0.004 \times M \times Lt \times s)}$$

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

where BCPS = Beam Candlepower-Seconds, Lt = lumen-second output, s = 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:

$$Dfs(fill\ in) = Dfs(main) \times \frac{GN(fill\ in)}{GN(main)} \times \sqrt{(lighting\ ratio)}$$

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, Kenrick. 4414 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 (KNO_3), 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 war efforts 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. Sometime 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 I. A. I. George Consultants, 1869 Trevilian 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 make 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 compass and chain survey of a cave in America. This is the second oldest cave map in America and predates the F. Peck map of Madisons 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

Ibberson, Dale. 445 Hale Avenue, Harrisburg, PA 17104 and Robert Keintz. Anthony Road, RD #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

James Nevin on April 4, 1770. Skull noted 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 1985, while doing research on the history of Indian Echo Caverns, near Hummelstown, Robert Keintz 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 travelers 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: BIRTHPLACE OF A METROPOLIS

Woolworth, Alan R. Minnesota Historical Society, 690 Cedar Street, St. Paul, MN 55101; E. Calvin Alexander, Jr. Dept. of Geology and Geophysics, University of Minnesota (Twin Cities), 108 Pillsbury Hall, Minneapolis, MN 55455; and James Hedges. Big Cove Tannery, Pennsylvania 17212

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 St. Peter sandstone by piping of sand grains from joints.

Reports of 19th century explorers indicate a length exceeding 1,000 feet, making Fountain Cave the longest sandstone soil pipe in the region. It consisted of a winding passageway interrupted at intervals by rooms, mostly of walking or stooping height.

A rockfall at the entrance in about 1880 dammed the stream and partially flooded the cave. Difficulty of exploration after 1880 and the loss of scenic 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 entrance was buried under a city street in 1959.

SURVEY AND CARTOGRAPHY SESSION

John Ganter, Session Coordinator

LARGE CAVE SURVEY MANAGEMENT

Borden, Jim. 590 Wentworth Drive, Acwoth, GA 30101

The Central Kentucky Karst Coalition (CKKC) has been surveying the caves of Toohey Ridge since 1974. The most notable of the caves has been Roppel Cave which was connected to Mammoth Cave in 1983, creating a cave in excess of three hundred miles of passages. The CKKC has surveyed over sixty miles of cave in over 13,000 survey points.

The CKKC has fielded over 375 underground and surface surveys in four different caves. A logging system has been developed which catalogs notes, tracks ties between surveys, differentiates between multiple uses of survey letter designations, and provides accounting and organizational capabilities. All surveys are in one database, notes and trip reports are available to explorers and cartographers, and most survey errors have been detected and corrected. Considering the tens of thousands of volunteer hours, expense, and sacrifice by a strong corps of volunteers, we try to insure the integrity of our efforts.

CONTROLLING SURVEY ACCURACY

Cole, Ray. 3410 Austin Court, Alexandria, VA 22201

In completing a large cave survey like the Caves of the Organ Cave Plateau the first question asked by a potential user of the caver-produced surveys is about the relative accuracy of the passages and geological features. To help control the levels of error and estimate their magnitude requires a combination of accurate surface surveys, cave radio locations, and computer processing. A method was developed for estimating potential survey error based on the string closure adjustments of the highly constrained survey data.

A COMPUTER APPLICATIONS SYSTEM FOR THE PROCESSING OF CAVE SURVEY DATA

Crowl, Daniel A. Dept. of Chemical Engineering, Wayne State University, Detroit, MI 48202

An advanced, computer-based cave survey processing system is described. This system supports the following features:

1. flexible raw data processing supporting a wide variety of survey instrument configurations.
2. user friendly output with full commenting.
3. loop closure
4. full database generation and manipulation. This significantly reduces processing time and provides enormous flexibility for later graphics processing.
5. an interface to a computer aided graphics system enabling production of high quality map sections in a short period of time.
6. quick turn-around of new survey data.

The system is presently being used to support the Fisher Ridge, Roppel, and Crumps cave survey projects. This represents over 25,000 survey stations and 100 miles of cave.

WORKING DRAWINGS FOR SHOW CAVE DEVELOPMENT

Gurnee, Russell H. 231 Irving Avenue, Closter, NJ 07624

Show cave development is the modification of a natural cave to provide a supervised, safe, and satisfying educational experience for the public. There are less than seven hundred caves open to the public in the world today. However, there are three times that many that were opened, modified, then closed. There are no schools or classes to aid the aspiring designer. In fact, most of the caves open to the public have been first-time efforts of the designer, architect, and workmen. Sort of like do-it-yourself brain surgery.

An operational program was used on three projects where the design was the result of the cooperation of individual specialists to achieve the best results. To show the relationship of the designer to the work crew, plans and specifications are available for the following caves:

Harrison's Cave, Barbados, W.I.
Rio Camuy Empalme Cave, Hatillo, Puerto Rico
The Fountain, Anguilla, British West Indies

OHIO CAVE SURVEY

Hobbs, H. H., III. Department of Biology, P. O. Box 720, Wittenburg University, Springfield, OH 45501

For the past eight years the Ohio Cave Survey (OCS) has been an active organization. Physiochemical 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 Wittenburg University Speleological Society journal, "Pholeos."

UNITED STATES EXPLORATION SESSION

Peter Quick, Session Coordinator

SCOTT HOLLOW CAVE

Hindman, Craig and Carol Tiderman. 7600 Pindell 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

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 saltpeter 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 insurgence 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 Eromdiks Cave, Hughes Road Cave, and Mack Ralph Cave.

FISHER RIDGE CAVE SYSTEM

Quick, Peter. c/o PSSC, 288 Airport Road, Ypsilanti, MI 48197

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 Eudora Ridge. Over ten miles of passage have been found thus far in this part of the system.

EXPLORATION OF WIND CAVE NATIONAL PARK

Scheltens, 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 on 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 50 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 helectite 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 as this American epic adventure continues.

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

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

J. Harlan Bretz 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. More than 14 miles of cave were eventually 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, SC 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, SC 28054

The foot mounted Croll can be used in place of a foot mounted Gibbs on a ropewalker climbing system. While discussed in 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 SE, 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

McClurg, David R. 1610 Live Oak Drive, Carlsbad, 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 classified as optimum 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

Padgett, 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 cave 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

Padgett, Allen. Rt. 3, Box 158, Cleveland, GA 30528 and Bruce M. Smith. 1822 Mountain Bay Drive, Hixson, TN 37343

"On Rope" 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 37343

Nylon ropes used in caving and single rope techniques are subjected 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 pull tested to determine remaining strength. The sometimes surprising results demonstrate how care and use can affect rope life and strength.

Index to Volume 47 of the National Speleological Society Bulletin

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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**, begining 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.

Keyword Index

Biologic Names Index

Author Index

Index to Volume 48 of the National Speleological Society Bulletin

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Keyword Index

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Guide To Authors

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 langauge (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.

For general style refer to the present *Bulletin* and the following guides: "Suggestions to Authors" (U.S. Geological Survey), "Style Manual for Biological Journals" (American Institute of Biological Sciences), and "A Manual of Style" (The University of Chicago Press). For assistance in writing an abstract see "A Scrutiny of the Abstract" by K. Landes, Bulletin of the American Association of Petroleum Geologists, vol. 50 (1966), p. 1992. Because good figures are an essential part of any paper, authors are encouraged to see what bad figures look like in the editorial on figures by K. Rodolfo in the *Journal of Sedimentary Petrology*, vol. 49 (1979), p. 1053-60.

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 Systême 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.

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Volume 50 **June, 1988** **Number 1**

CONTENTS

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