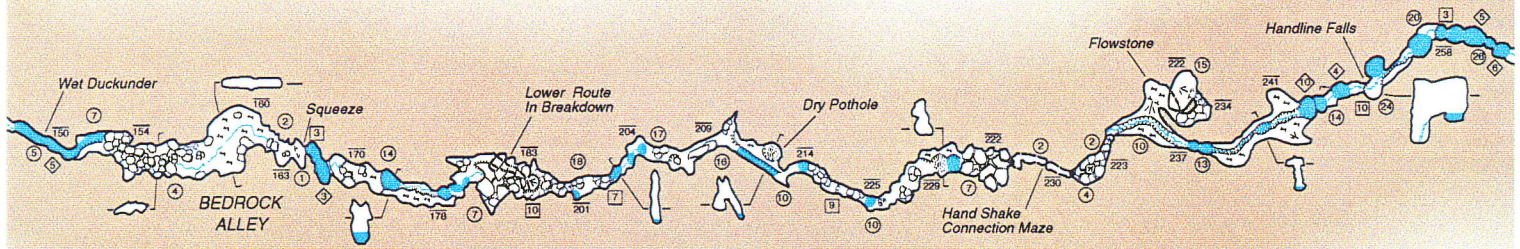
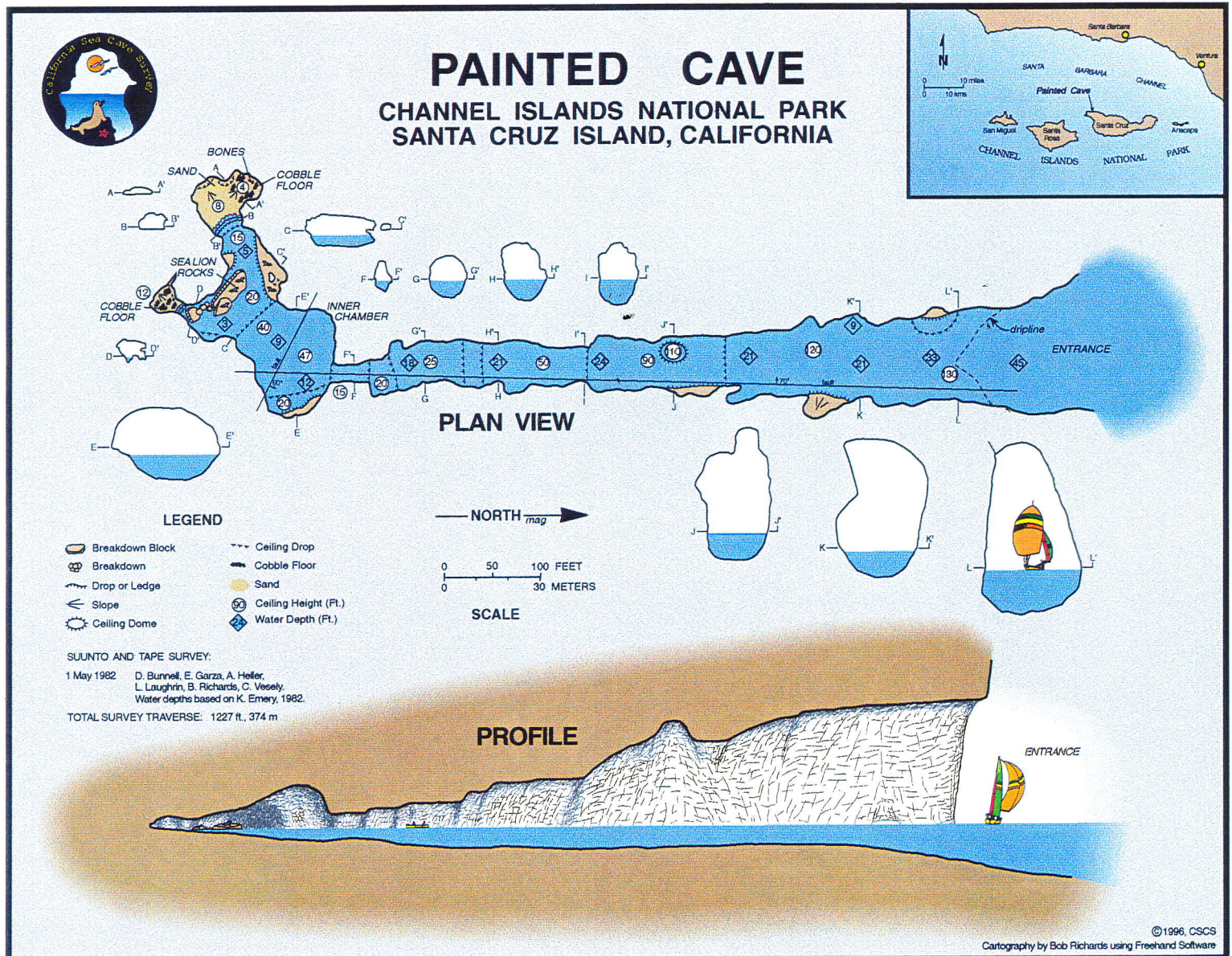


# COMPASS & TAPE

Volume 13, Number 2, Issue 42



## Computer Graphics Issue





# Survey and Cartography Section



**The Survey and Cartography Section (SACS)** is an internal organization of the NSS that is devoted to improving the state of cave documentation and survey, cave data archiving and management, and of all forms of cave cartography.

**Membership:** Membership in the Section is open to anyone who is interested in surveying and documenting caves, management and archiving of cave data and in all forms of cave cartography. Membership in the National Speleological Society is not required.

**Dues:** Dues are \$4.00 per year and includes four issue of *Compass & Tape*. Four issues of the section publication are scheduled to be published annually. However, if there are fewer, then all memberships will be extended to ensure that four issues are received. Dues can be paid in advance for up to three years (\$12.00). Checks should be made payable to "SACS" and sent to the Treasurer.

**Compass & Tape:** This is the Section's quarterly publication and is mailed to all members. It is scheduled to be published on a quarterly basis, but if insufficient material is available for an issue, the quarterly schedule may not be met. *Compass & Tape* includes articles covering a wide range of topics, including equipment reviews, techniques, computer processing, mapping standards, artistic techniques, all forms of cave cartography and publications of interest and appropriate material reprinted from national and international publications. It is the primary medium for conveying information and ideas within the U.S. cave mapping community. All members are strongly encouraged to contribute material and to comment on published material. Items for publication should be submitted to the Editor.

**NSS Convention Session:** SACS sponsors a Survey and Cartography session at each NSS Convention. Papers are presented on a variety of topics of interest to the cave mapper and cartographer. Everyone is welcome and encouraged to present a paper at the convention. Contact the Vice Chair for additional information about presenting a paper.

**Annual Section Meeting:** The Section holds its only formal meeting each year at the NSS Convention. Section business, including election of officers, is done at the meeting.

**Back Issues:** SACS started in 1983 and copies of back issues of *Compass & Tape* are available. The cost is \$1.00 each for 1-2 back issues, \$0.75 each for 3-6 back issues and \$.50 each for more than six back issues at a time. Back issues can be ordered from the Vice Chair.

**Overseas Members:** SACS welcomes members from foreign countries. The rate for all foreign members is US\$4.00 per year and SACS pays the cost of surface mailing of *Compass & Tape*. If you need air mail delivery, please inquire about rates. All checks MUST be payable in US\$ and drawn on a U.S. bank.

**Chair:** Carol Vesely  
817 Wildrose Avenue  
Monrovia, CA 91016-3022  
(818) 357-6927

**Secretary:** George Dasher  
5096 W. Washington Street - #101  
Cross Lanes, WV 25313  
(304) 776-8048

**Vice Chair:** Roger Bartholomew  
910 Laurel Street  
Rome, New York 13440  
(315)-336-6551

**Treasurer:** Bob Hoke  
6304 Kaybro Street  
Laurel, MD 20707  
(301) 725-5877

**Editor:** Pat Kambesis  
3473 Regalwoods Drive  
Doraville, GA 30340  
(770) 491-8587

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## From the Editor

We said it would happen some day, that computer-drafted maps would be of the same quality and visual impact as traditional hand-drafted maps; that eventually, one might even win the medal at the Cartographic Salon. Well, that time is here - now. For two years in a row, a computer-drafted map has walked away with the Medal. The award-winning cartographer is Bob Richards who also designed and graciously donated the beautiful, color cover of this issue of *Compass & Tape*. Bob has also cut loose with some of his trade secrets in this issue's feature article on computer graphics.

If you think that mud, passage dimensions and equipment are the only things that put a kink in the survey trip, then Jim Coke's article on underwater cave mapping will put those concerns in a different perspective. By the way, Jim is the cartographer responsible for those awesome underwater cave maps that we see in the map salon from time to time. His article will give us "dry" cavers a greater appreciation for sub-aqueous mapping.

As you know, everything changes: survey standards and equipment, computer technology, interest rates. And then there is declination - that pesky little shift in the earth's magnetic field - the one that if ignored could ultimately mess up the closures on your long-term survey project. Well, rather than wimp out and put magnetic north on all of your maps, check out Ira Sasowsky's article on dealing with magnetic declination - over the internet no less!

Got mud in your blood, and all over your compasses and survey paper? Though you can't purge the mud from those places you can at least make it easier to wash off. Philip Moss, frequent mapper of sleezy-wet horror holes (and current NSS board member) offers some equipment suggestions. Though these recommendations are of little use at NSS board meetings, they will make life easier for those who like to grovel in the gravel and wallow in the mud.

With all of these great articles, there wasn't a whole lot of extra room to publish more caves maps. As a compromise, the Cartographers Corner does feature excerpts from cave maps - with a focus on cross sections.

One more thing - **the Survey and Cartography Section now has a Web Page** which will be available for your viewing pleasure by the end of April. Check the NSS home page for the SACS icon.

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**Publishing Editor: Pat Kambesis  
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## SUBMISSIONS

All types of materials related to cave survey and survey data, cartography, and cave documentation are welcome for publication in *Compass & Tape*. Manuscripts are accepted in ANY form but are most welcome on 3.5 inch diskettes either IBM compatible or Mac format or via email. Typed material is next best although we will accept handwritten material as long as it is legible. Artwork in any form, shape or size is also welcome.

Send all submissions for *Compass & Tape* to:

Patricia Kambesis  
3473 Regalwoods Drive, Doraville, GA 30340  
770-491-8587  
E-mail: pkambesis@aol.com

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The editor reserves the right to select which of the submitted materials will be used for publication. Of the material selected, the editor reserves the right to delete redundant or inappropriate material, to correct errors of spelling, grammar, or punctuation, and to edit for clarity, so long as such alterations do not change the meaning or intent of the author(s). In the event that significant changes are contemplated, the author(s) will be consulted and given the opportunity to review the changes prior to publication.

1998 NSS Convention, Sewanee, Tennessee

Survey and Cartography Session

# CALL FOR PAPERS

This is a call for papers for the Survey and Cartography session at the 1998 NSS Convention. The session is informal and it provides a good way to tell other cave mappers what you are doing, and to discuss problems related to mapping and cave surveying. Most cave surveyors have either developed useful techniques that may benefit others, or are encountering problems that someone else may have solved. In either case an informal session presentation would be appropriate.

The session is informal and the audience is friendly. There are no requirements to provide fancy visual aids or to provide a written paper (other than an abstract to include in the Convention Program). Of course, the *Compass & Tape* Editor would be glad to receive any written papers for publication.

Presentations can be on any topic related to any aspect of cave mapping, and the material can be for folks with any level of mapping experience. A partial list of potential presentation topics includes:

- Cave mapping applications of high-accuracy GPS and digital mapping technology
- How to keep cave mud off your survey instruments (while still going into the cave)
- How to keep Suunto fogging to a minimum in cold, wet caves
- How to resolve blunders without another trip to the cave
- How to set and maintain mapping standards in a project
- Keeping track of survey data in a large project
- Mapping standards (accuracy, symbols, etc.)
- New and improved computer programs for mapping (compare, describe, complain, ...)
- New tools and toys to aid in mapping or cartography
- Representing complex vertical caves on a 2-dimensional map
- Use of computers to actually draw cave maps (techniques, pros, cons, ...)
- Use of computers to interactively view cave maps (views, colors, rotation, perspective, ...)

The above list is obviously incomplete. If you are doing something that you think would be of interest to other cave surveyors, please consider doing a presentation on it.

When you submit your abstract, please let the session coordinator, Roger Bartholomew, know what equipment you will need for your presentation. You can assume that the usual 35mm slide projector and viewgraph machine will be available, but don't make any other assumptions. There is a possibility that we may also have an overhead projector that can be connected to a laptop computer. Check with Roger if you are interested in using it.

If you plan to do a presentation, you should send an abstract of not over 250 words to Roger Bartholomew, who is coordinating the session, so he can insure that the abstract gets into the Convention Program and to help schedule set up the session schedule. Please be sure that your abstract includes a summary of your conclusions and results, not simple a statement of what you are going to talk about. Roger's address is 910 Laurel St., Rome NY 13440. His phone is (315)336-6551.

**The deadline for receiving abstracts is May 15.** If you want to submit your abstract via email you can send it to Bob Hoke (the alternate session coordinator) at [bobhoke@smart.net](mailto:bobhoke@smart.net).

## Survey & Cartography Section Minutes

by George Dasher

The 1997 annual meeting of the Surveying and Cartography Section (SACS) of the National Speleological Society was held on Thursday, June 26th, 1997, in conjunction with the NSS' annual Convention, at the Sullivan Elementary School in Sullivan, Missouri; the Section meeting was held in the nearby fire hall. Attending were the following 19 members and friends of the Section: Aaron Addison, Roger Bartholemew, Lang Brod, Hubert Crowell, Don Coons, George Dasher, William Elliott, Bob Gulden, Bob Hoke, Pat Kambesis, Ray Keeler, Howard Kalnitz, Kirk MacGreger, Hazel Medville, Dave Taylor, Fred Wefer, Arnie Weisbrot, Carl Weisbrot, Mike Yocum

Chairman Carol Vesely was not present at the meeting. Vice-Chairman Roger Bartholemew allowed the treasurer, Bob Hoke, to conduct the meeting. Bob began the meeting at 12:18 pm. He first thanked Roger for the excellent morning session.

Next were the Officers' reports. No word or no report had been received from Carol. Vice-Chairman Roger Bartholemew reported that when deadline for papers for the 1997 session had arrived and that he had virtually no papers. He proceeded to run up his phone bill to obtain papers. He asked that people send in papers for the 1998 sessions, and he asked that they send in these papers before the session deadline, so that he would not have to run up his phone bill a second time.

Secretary George Dasher reported that he neither received nor sent out any correspondence within the past year, that no one had complained about the 1996 meeting minutes published in *The Compass and Tape* (C&T), and that he was passing around a sign-in sheet.

Treasurer Bob Hoke said that the Section had \$3007 at present, and that a bunch of this money was committed to the already-paid-for issues of the C&T. He also suggested that the Section financial year be changed to the calendar year, instead of from Convention to Convention—a time which can vary by as much as two months each year. He asked if there were any questions. Hearing none, he asked if anyone was opposed to this idea. There was no opposition, and the "motion" was considered passed.

Editor Pat Kambesis said that one issue of *Compass & Tape* had just been printed, mailed, and received, that a second issue was in the works, and that she was working on the third issue. She asked that people send her articles. Bob Hoke said that the last issue looked good, and Hazel Medville requested that some of the Convention papers be published in future issues.

George Dasher gave a report on the 1997 Cartographic Sa-

lon. He said that 34 maps had been entered, that four maps were display only, and that ten green ribbons, two blue ribbons, and two medals had been awarded. He gave an overview of the planned strategy for the Cartographic Salon. This was that he would continue to coordinate the Salon, but that there would be a new Salon Chairman and a new Salon Vice-Chairman each year. The Vice-Chairman would then become the Chairman for the following year's Salon. George had in hand a list of the people who had volunteered to chair a Salon; however, none of these people were present. Don Coons had already volunteered to chair the 1998 Salon, and he said that he would handle locating a 1999 Chairman.

Bob Hoke said that a list of all those persons owing the Section dues will be printed in the next *Compass & Tape*, and that—if these people did not then pay they would be hassled by postcard.

Pat Kambesis said that she intended to put more maps in the *Compass & Tape*, but that this would cost a little more money. Bob said that the Section has the money and should spend it.

Bob asked if there was any Old Business. There was none. Bob next asked if there was any New Business, and he again asked about changing the financial year. George Dasher said that this had already been done.

Arnie Weisbrot then brought up the subject of map labeling and folding standards. He had given a talk on this subject at the morning session, and he had prepared a written motion which read:

"A Proposal for Standardized Sizes of Maps—

I move that the Survey and Cartography Section of the National Speleological Society adopt the following standard for use on all cave maps:

1. Adopt these parts of American Society of Mechanical Engineers Standards Y14.1 and Y14.1M:

- a. Para 4 - Drawing Sheet Sizes
- b. Para 6.1 - Title Block Location
- c. Para 11.1 - Margin Drawing Number Block

2. Title Block shall contain: Cartographer Name and Address, Cave Name, Location Description, Survey Date and Map Date.

3. Margin Drawing Number Block shall contain Cave Name and Location Description.

I further move that the Survey and Cartography Section of the National Speleological Society award bonus points at the Cartography Salon for maps that meet this standard."

Bob Hoke seconded Arnie's motion. George Dasher asked if these auxiliary labels would go on to the map outside of the border. Arnie said yes, and that the labels would in no way

affect what was inside the border. There was some discussion, and it was noted that the standard page size seemed to be more of concern than the auxiliary labels. Pat Kambesis made the comment that the Section should not fly this through, and that Arnie should write an article and solicit more input. She then made a motion to table Arnie's motion. This was seconded by Hubert Crowell.

George Dasher said that there is no NSS map standards and no SACS map standards, so this motion would be precedent setting. He also said that the Cart Salon standards were formulated by a committee and—if the labeling and sheet size options were to be made a requirement for the Cart Salon—then that committee should be reopened to formulate a decision. The motion to table was then unanimously tabled.

Bob Hoke mentioned the subject of lava tube map symbols, which had been discussed at the 1996 meeting. Hazel Medville asked that the Section take no action at this time.

Bob then brought up the subject of the section purchasing a LCD Plate. Roger Bartholomew said that the plate supplied by the Convention had been inadequate, and that he had been prepared to drive to Saint Louis and rent an adequate plate with his own money. Roger also said that these plates—which are used to project computer screens onto a large screen—are manufactured in two varieties. One kind fits on an overhead projector; the other is a total system which stands-alone. Also, Roger said that many of the total systems can be used with a VCR. Aaron Addison had provided the LCD used during the morning session. His company was located nearby.

Bob Hoke said that the Section might be able to share the costs with another section, and he said that a high-resolution, high-intensity view graph could cost as high as \$2500 to \$3000. Another possibility was a scenario where the Section pays pay half, the Convention pays half, and the Section gets guaranteed use. This unit would then be an NSS resource.

There was a lot of debate. Hazel Medville commented that, because of the high cost of the equipment, it would not be possible to ship it around the country.

Hubert Crowell said that the section should not purchase any equipment before contacting him, as he works for a company that supplies this equipment and he might be able to arrange a donation. Fred Wefer said that it was a good idea to get a projector that could interface with a VCR.

Don Coons said that he had recently priced this equipment, that a plate unit would cost between \$2500 and \$5000, and that a total unit would cost between \$5000 and \$8000. He also said this technology was on the way out and would soon be replaced by a more expensive technology. He said that the Section should thus move quickly if they wanted to purchase a cheaper system. Aaron Addison said that the unit in the room was NSS owned and was a low resolution unit.

George Dasher asked if there was truly a need for this equipment, and he asked if it could be supplied by the each Convention.

Bob Hoke said that a high school might have such equipment, but a location like an elementary school would not. He

said that each convention supplying the unit was problematic and that it would cost \$500 to rent a unit for at least two days. Roger Bartholomew added: If a good rental place could be found. Bob also said that the Section might receive co-funding with the Photo Salon. There was more discussion.

Bob Hoke then formed a committee of himself, Roger Bartholomew, Hubert Cromwell, and Fred Wefer. He said that the committee would look into the options and make a recommendation prior to the 1998 Convention. The consensus of the group seemed to be that the Section could spend up to one-third of its assets. All but one seemed to be in favor of this idea. None were opposed, and one abstained.

Hazel Medville remarked that the unit used in the morning session had not been adequate. Aaron Addison said that the room's low ceiling had made for a poor projection. Roger Bartholomew added that the unit needed an extension cord. Bob Hoke remarked that the NSS had actually bought several extension cords for convention use, but that often-times the Convention committee does not locate these until repacking the equipment after the convention. He again said that the newly-formed committee would look into the options.

Kirk MacGregor said that using Convention-owned equipment would side step the issue of someone dropping our equipment.

Hubert Crowell then brought up the issue of the convention survey contest offering prizes. He said that he would like the Section members' thoughts on this and he said that the contest was only offering certificates at present. Pat Kambesis said that prizes would be nice. Hubert said that 16 people had participated in the 1997 contest.

Bob Hoke asked if the contest should be more for more than one day. Arnie Weisbrot said that a donation from the vendors might be nice; Roger Bartholomew suggested a \$50 gift certificate. Hubert said that no decision was needed at present. Bob said a \$10 gift certificate would be good; Pat Kambesis suggested \$20 or \$25.

Pat then made a motion that the Section award a \$20 gift certificate to the winner of the convention survey contest. Arnie Weisbrot seconded this motion. All but one person was in favor of the motion. No one was opposed and one person abstained.

George Dasher asked about the USGS inclusion of cave locations in their GIS system. Hazel Medville said that the USGS had dropped the locations from their system.

Bob Hoke called for elections. He asked if anyone knew if Carol Vesely was willing to continue as the Chair. He then said that Roger was willing to continue as Vice-Chair, George as secretary, himself as treasurer, and Pat as Editor. Hazel Medville said that the Section's meeting was taking twice as long as the Geo2 meeting, that there was no objections to the current officers, and that they should remain the Section's officers. Bob asked if there were any objections to this and no one spoke up.

Bob then asked if there was any other business or if there were any announcements. There was none. He adjourned the meeting at 1:01 pm.

## **1997 CARTOGRAPHIC SALON**

*by George Dasher*

The 1997 Cartographic Salon was staged at the Sullivan Elementary School in Sullivan, Missouri. A total of 34 maps were entered, four of which were Display Only. Maps entered were of caves in the United States and Costa Rica. The U.S. states included Missouri, Kansas, West Virginia, Tennessee, Alabama, Texas, Hawaii, California, Pennsylvania and Alaska.

The following people served as judges for the Salon:

Mick Sutton, Cave Research Foundation - Mammoth Cave and Missouri

Rod Horrocks, Timpanogas Grotto, Cave Specialist: Great Basin National Park and Timpanogas Cave National Monument

Dick Graham: Friars Hole Cave System, Droop Mountain Cave Club

Gary Storrick: West Virginia Speleological Survey, Southern Pocahontas County (West Virginia), Friars Hole Cave System, Overholts Blowing Cave System

After the maps were judged and awards made, a map critique was held on Friday morning of the convention week so that the entrants and judges could discuss judging criteria and talk about specific maps

Following are the Cartography Salon awards as presented at the convention.

### **GREEN RIBBON HONORABLE MENTION**

Eagle's Roost Cave  
Prince of Wales Island, Alaska

Kevin and Carlene Allred

The Cataracts of Miramar  
Puntarenas Province, Coasta Rica

Bert Ashbrook

Ben's Cave and Nearby Caves along Carr Branch,  
Greenbrier County, West Virginia

Bert Ashbrook

Daniel Boone Caverns  
Scott County, Virginia

Bill Balfour

Bolling Cave  
Scott County, Virginia

Bill Balfour

Roaring Creek Cave  
Greenbrier County, West Virginia

Bill Balfour

Skyline Caverns  
Front Royal, Virginia

Bill Balfour

Coffin Cave  
Lee County, Virginia

Bill Balfour

Fort-Peebles Cave  
Franklin County, Tennessee

Brent Aulenbach

Cave Location Map of Harbridge Run Hollow  
Derry Township, Westmoreland County, Pennsylvania

Walt Hamm

#### **BLUE RIBBONS MERIT AWARD**

Hickey Pot  
Warren County, Tennessee

Pat Kambesis

Wayback Cave  
White County, Tennessee

Pat Kambesis

#### **MEDAL WINNERS**

Cave Creek Caverns  
Park County, Colorado

Hazel Barton

Kazumura Cave Atla  
Island of Hawaii

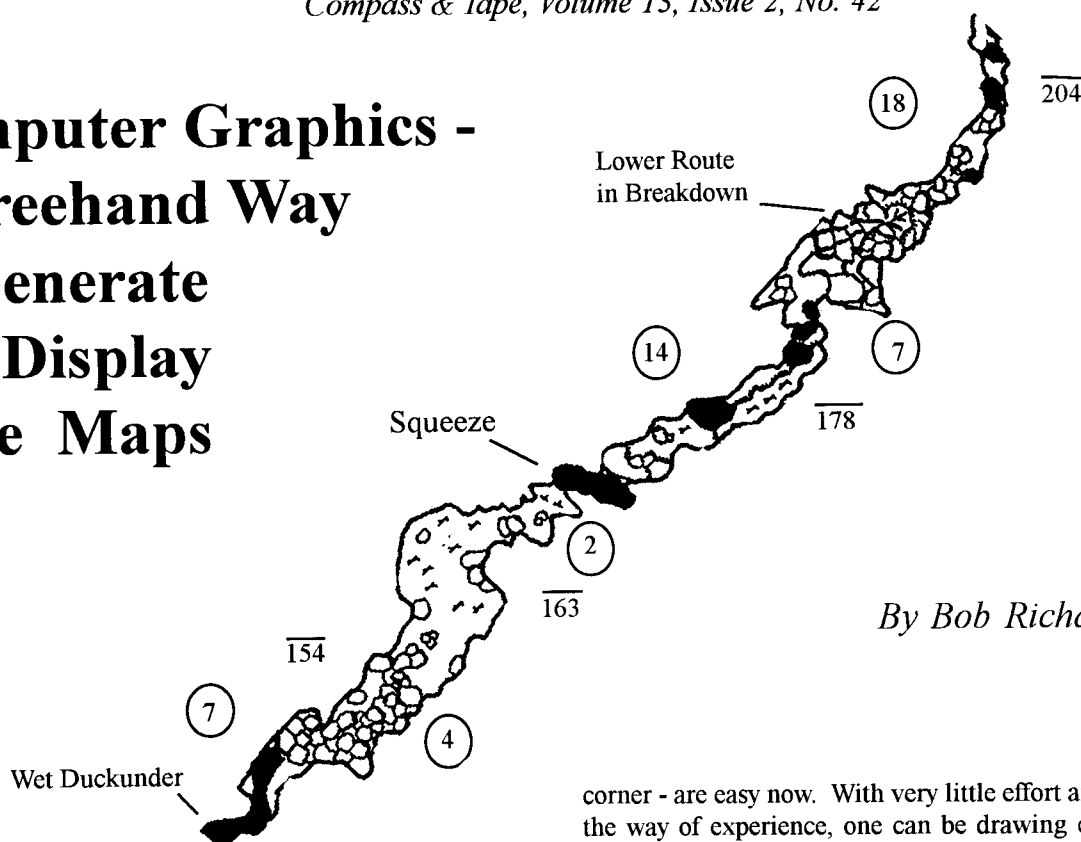
Kevin and Carlene Allred &  
Bob Richards

#### **About the Cartographic Salon:**

All cartographers are encouraged to enter maps at the 1998 Cartographic Salon. For more information about categories, judging criteria and deadlines for map submissions please contact Don Coons, 1998 Convention Salon Coordinator. (cornycaver@aol.com)



# Computer Graphics - A Freehand Way to Generate and Display Cave Maps



*By Bob Richards*

## Introduction

In the not-too-distant past, the art of cave cartography did not involve computers at all. Former tools of the trade included pen, ink, straight edge, compass and many equally low-tech devices. All of those tools proved to be effective, but the process was extremely labor-intensive and required finely honed, specialized skills. As home computer hardware and software becomes cheaper and easier to use, graphics software is replacing some of the manual cartography methods used by cavers in the past. The use of FreeHand software is one such package available to cave cartographers.

## Graphics Software

MacroMedia's FreeHand is one of four popular illustration software programs available to cavers today - Illustrator, Canvas and CorelDraw being the other three. All four drawing programs are fairly robust, each boasting many more features than the original Illustrator which was first used in the home just ten years ago. In this second decade of Postscript drawing programs, all of these software programs continue to add features and improvements as home PC's become more powerful.

Regardless of how powerful an illustration package is, it won't be useful if you can't draw with it. FreeHand enables you to draw high quality line art and technical drawings. Techniques that were extremely difficult ten years ago - like getting two thick pen lines to meet and form a perfectly sharp or smooth

corner - are easy now. With very little effort and not much in the way of experience, one can be drawing cave maps that would have been time consuming and possibly frustrating - were you to approach the task using traditional drafting tools.

At my workplace, we started making the switch from hand drafted maps to the computer nine years ago. I started with AutoCad, still the most popular CAD program but also a very expensive (\$3000) program. My first computer generated cave map was made using AutoCad back in 1991. However, AutoCad is not an illustration drawing program. My department has evolved from a drafting department to a graphics presentation shop. Although we started with PC's, we switched to Macs because we have far fewer problems with hardware and software configurations. Although the Macintosh marketshare has dwindled, it's still the preferred platform among computer graphics illustrators.

We started experimenting with CorelDraw but because it had a drawing size limit of only 30 inches we did not continue using it. We also used Illustrator and Canvas software before switching to FreeHand software four years ago. My staff found FreeHand easier to use and learn. FreeHand also has a larger drawing pasteboard, as large as 220 by 220 inches, a requirement in my business which provides geological maps, montages and graphics at a large scale.

All four of these graphics software packages will get you where you want to go today. FreeHand just does it with a lot fewer keystrokes. All of these graphics programs can be purchased for around \$400 each. If willing to shop around, one can get a competitive upgrade version for half that price or an earlier version for less than \$100. All four are available in both Mac or Windows PC format. I recommend the latest version of FreeHand software, a combination of groundbreaking innovations and improvements derived from picking the best features

of competing programs. In my opinion, FreeHand offers the best collection of drawing features on the market today.

### **Computer Hardware**

The computer processor and memory influences how fast you can manipulate images. The computer you buy should be expandable - and should allow for upgrading its capabilities. Most new computers today come standard with a four gig (billion byte) hard drive and CD reader for loading and using the graphics software.

On the Macintosh platform, the Power Macintosh G3 series is currently the best investment. Mac has perfected the plug and play which Windows (PC) has been trying to imitate and catch up with ever since. The new G3 series have PCI slots for upgrading its processor when faster chips are developed. The processor chip that runs these computers and enables them to process data at lightening speed is the G3.

In the PC windows world, any computer using the Pentium chip is recommended. Higher end models are now using the new MMX-Pentium II chip which is nearly as fast as the Macintosh computers. Just remember that you will want to add hardware, like external hard drive and scanner as time goes on. Your computer should have enough SCSI (pronounced skuzzy) parts, or plug receptacles, in the back to accept the new additions to your system. If you are still undecided between Macintosh and the Windows PC world, keep in mind that most service bureaus doing scanning, printing and film output are still oriented to Mac.

RAM stands for random access memory, and it is measured in megabytes. This is a component you buy for the computer to make it process information faster. All new computers come standard with 32 meg of RAM and it is up to you to buy more. I feel the minimum amount of RAM needed to work on graphics (your cave maps) is 64 meg. I started with 32 meg but soon found out that graphics files were memory hogs. I was still able to accomplish everything I needed to do. The processing time was slow but it got the job done. If you can afford to buy more RAM it will be the single best investment you can make to speed up your computer.

RAM prices have dropped dramatically so bumping a computer from 32 to 64 meg costs less than \$100. Sixty-four megabytes of RAM will significantly decrease processing time, and 96 meg and above will make your machine really fly. I now have 96 meg on my Power Macintosh and it is incredibly fast.

The monitor is one of the most important decisions you will make with respect to price versus features. A 20-inch monitor lets you keep several windows and images on screen with amazing clarity but is very expensive (\$1500 & up). The next-best choice, and one that will save you a \$1000 is a 17-inch color monitor. At home I use a 17-inch monitor and I'm able to do everything the larger one can do; it's just that my digital images ap-

pear somewhat smaller to work on. A 15-inch monitor is, in my opinion, too close in price to the 17-inch to be considered seriously. If you are going to invest in computer equipment for graphic manipulation, you would be disappointed in a 15-inch monitor.

The last crucial part of your system is a means of storing and transporting your digital graphics files. The hard drive in your computer eventually gets filled up, and you will want to store all the scans, photos and cave maps. You will need some means of bringing that digital file to your service bureau for outputting your cave map by transferring it from your hard drive in your computer to a portable drive. There are several choices. My preference is the new SyQuest SyJet or Iomega's Jaz drive (\$300). These portable drives plug into a SCSI port on a computer. With a cartridge holding more than one gigabyte inserted into the drive, your graphics can be copied onto it and taken to a service bureau for outputting to a large color plotter. Cartridges cost about \$80 but give you unlimited storage capability. A cheaper alternative is Iomega's Zip drive (\$150) which is very popular and still gives you a method of storing and transporting digital files.

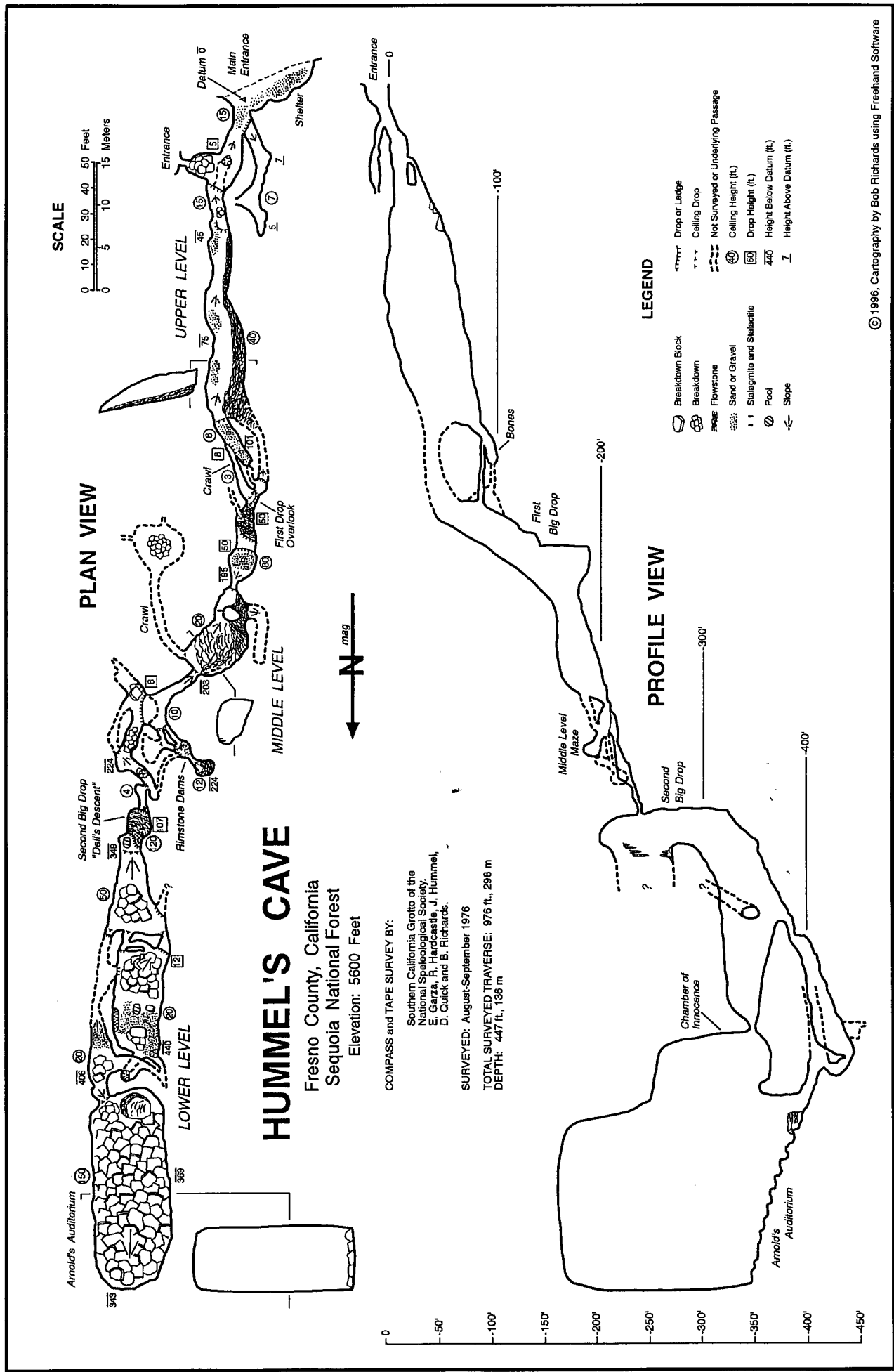
Cartridges hold 100 megabytes at a cost of only \$15 per cartridge. Service bureaus can take your digital file and output your maps to a printer or plotter. The local Kinko's or QuickCopy shops can image your page-size or 11 by 17 prints on a color copier for a few dollars. Former blueprint-engineering and photolab shops have gone digital by adding large color ink-jet plotters to handle printing of larger maps. These plotters can handle maps up to 60-inches wide and any length. Pricing is based by the total square footage of paper used on your map. Price can vary (\$4-8 per sq. ft.), so shop around.

I realize not everyone can afford to play cave cartographer with a computer. But as hardware and software continue to come down in price more cave maps will be done digitally. One can get started with a new computer system for less than \$2000. That price range gives you a system that is twice as fast for half the price of what I paid less than two years ago. If you already own a computer you can get started by getting FreeHand software with very little cost to your computer system.

### **Setting Up Your Cave Map**

I begin my cave map like I used to do when I was drafting everything with pen and ink. The traverse line comes from the raw survey data that is reduced with some trigonometry. Today there are a few good programs available to the cave cartog-

**If you are still undecided between Macintosh and the Windows PC world, keep in mind that most service bureaus doing scanning, printing and film output are still oriented to Mac.**



rapher to make this part of the job easier. CavePlot, TopoRobot on the Mac and Compass, On Station, or WALLS software programs on the PC side are popular today with cavers. Output a hard copy of this corrected line plot so you can make a pencil draft using the sketches made from the survey book.

If one has sketched to scale and kept good detailed sketches, it will be much easier to transfer the field work to your rough draft. I scan the rough draft into the computer, using a page size flat bed scanner and bring it into FreeHand. Scanners have come down drastically in price this past year to make it affordable to have one at home. Color scanners used to cost more than \$1000 but can now be purchased for less than \$100. This allows me to scan maps, lineart and color photographs which can then be added to the final cave map.

Since I'm limited to a page size scanner, I reduce my image to fit that dimension. A cave map or system may require several page size scans that can be joined later and merged into one file on your computer. Each page is scanned, imported into FreeHand, given a file name and sent to a background layer to be used as my tracing template for my final drawing.

To reduce file size and speed up drafting time I scan in as line art black and white at 150 dpi (dots per inch). The reason for a low dpi is because this layer will be deleted when I complete my drawing. For my actual drawing, I set the printer resolution to 300 dpi. This is the maximum resolution that most ink-jet printers and color xerox can handle. Scans create a raster image (dots) which use lots of memory on the computer. FreeHand is a vector drawing application (define lines and shapes) as opposed to raster and will generate a much smaller file. Vector applications produce graphics that are clean and smooth regardless of the level of screen magnification. In contrast, a raster bitmap image becomes increasingly grainy as you zoom in to see individual pixels. There is no need to keep this rough scan layer when you are done drafting your map.

### Digitally Drafting in FreeHand

The fun really begins with the use of FreeHand software and its many tools and palettes (windows) that float on top of the pasteboard. Drawing with a mouse may take a little getting use to if you have been drawing with a pen. If the mouse does not feel comfortable to you, you can upgrade to an electronic pen and tablet. Another option is a track ball; I use a Kensington TurboMouse model that I find is easier and quicker for me to move around on the screen and with which to draw. I can also program four keys on the TurboMouse for the functions that I use most often such as "save".

FreeHand's tool palette floats on top of the pasteboard as seen in Figure 1. I usually have several of these palettes open to allow me to access needed tools for drafting my map. These

can be open and placed anywhere on screen so that my preliminary sketch of the cave can be viewed along with the digital tools.

The tools palette (upper left of figure 1) is one window I always keep open. The arrow (black) box that is highlighted on the tools palette shows that it is now the active tool and allows me to point, click on an object to select, and drag or move objects by using the arrow on the screen.

The Pen tool (sharp like the head of a pen) is found on the tools palette, and allows me to use the pen to create lines or shapes one point at a time. Click to add the line in progress or drag to add an arc. This pen tool is how I draft my cave passage. Because the pen tool is more precise, you can specify both the location of points and curvature of connecting segments.

To designate the line type and thickness, use the Inspector palette (lower right of Figure 1). This palette performs several key tasks by allowing you to set up size, layout and printer resolution. The last icon, top row of this palette gives access to onscreen scales, guides and page layout on which your pasteboard can be greater than 18 feet long, for outputting that large cave system.

The use of Layers in FreeHand can be useful. Layers can be locked, removed, displayed or not displayed. Figure 1 shows a zoomed in portion of the scan of the rough

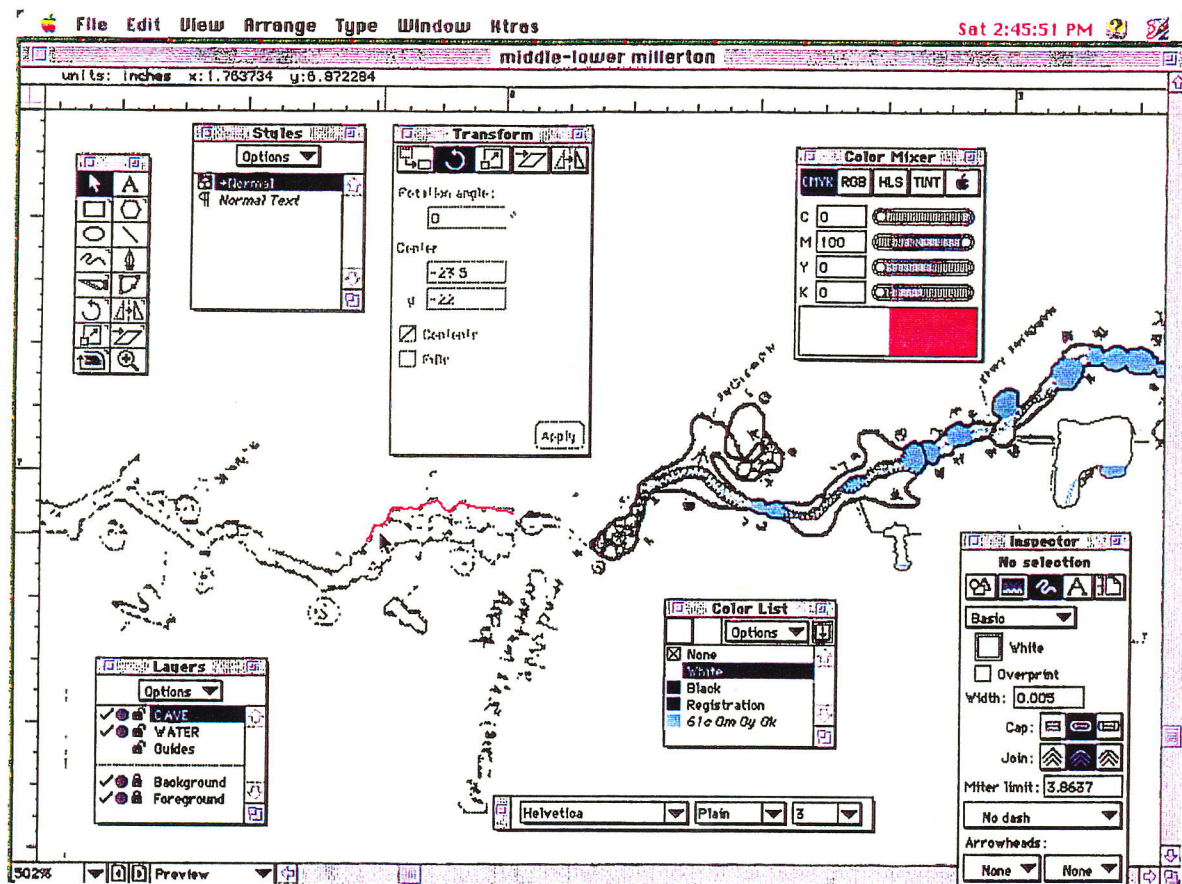
draft. The scan is residing on the Background layer and is locked. I will not put any new data on that layer because it will be deleted when my drawing is done. Anything put on the layer named Background will give the linework a halftone gray look. This allows me to see my current cave layer more easily. Adding a temporary bright color (red line on fig. 1) makes the tracing over the scan easier. This line work can be changed back to black when the scanned image is no longer needed.

When drawing a cave map by hand or computer, the use of line weight is an important drafting technique. I try to limit myself to just a couple line thicknesses. The walls of the cave are always at least twice as thick as my floor detail as seen in figure 2. I like to draw floor detail as I go. Sometimes I will copy and save symbols to save time but for the most part I draw as I go. This gives my maps a more hand drafted look and not so much a computer look. Besides, no two breakdown blocks are alike in a cave so why draw and copy the same breakdown block over and over again. With the freehand line tool, I can draw as quickly as I would have with a rapidograph pen.

One of FreeHand's most useful features is the one for finding and replacing graphics. This versatile tool lets you instantly change color, stroke widths, scale, fonts, and path shapes. You can, for example, instantly double the stroke weight of every 1.5-point path, so your cave map will reproduce better on an old copy machine or at a smaller scale.

**If one has sketched to scale and kept good detailed sketches, it will be much easier to transfer the field work to your rough draft.**





**Figure 1.** Screen with several floating palettes (windows) opened for accessing the needed tools for drafting over the rough sketch of the cave. Note that when the scan is put on the background layer it screens the line work to make tracing over the scan much easier, especially when using a color (red) line as seen in this example.

### Finishing Touches

Computer generated maps have the advantage of easily adding color to a cave map. For an aesthetically pleasing map, both the use of color and the cave layout have to be balanced. Proper use of color can add visual impact. When I entered my hand-drafted Olaa cave map in the salon a couple years ago I wanted to show off the passage detail more. To do that, I masked out all of the caves floor detail and cross sections by hand. This is done by cutting and pasting a spare copy to use as the mask. These are the steps taken before airbrushing the map. The results are beautiful but very time consuming. Not only that but you are lucky to get 2-3 copies made before the mask is unusable.

FreeHand's blending tool transfers one color shade into another over a series of interpolated steps. This allows me to have that same airbrushed look by using the blend box icon on

the Inspector palette (fig. 2 lower right window) tool. The example shows a brown to white color fade. This is done fairly easily by copying the cave passage wall outlines, sending the copy to the back and then moving it to a separate lower layer called color. I continue copying the cave passage line work by extending the line outward a couple inches (depending on the scale chosen) and by joining the two end points together to complete the color fill. Repeat this step several times as you angle your graduated boxes to fit the flow direction of your cave. Cross sections are given a white fill which sits on a higher layer so they can float above the color layer. On my Millerton Lake Cave System map, the use of color was added quickly and easily.

With a computer generated map, I now have the option of color choices and multiple copies at various scales which I did not have with the old hand air-brushed method. To give this map added visual impact I scanned several photographs that



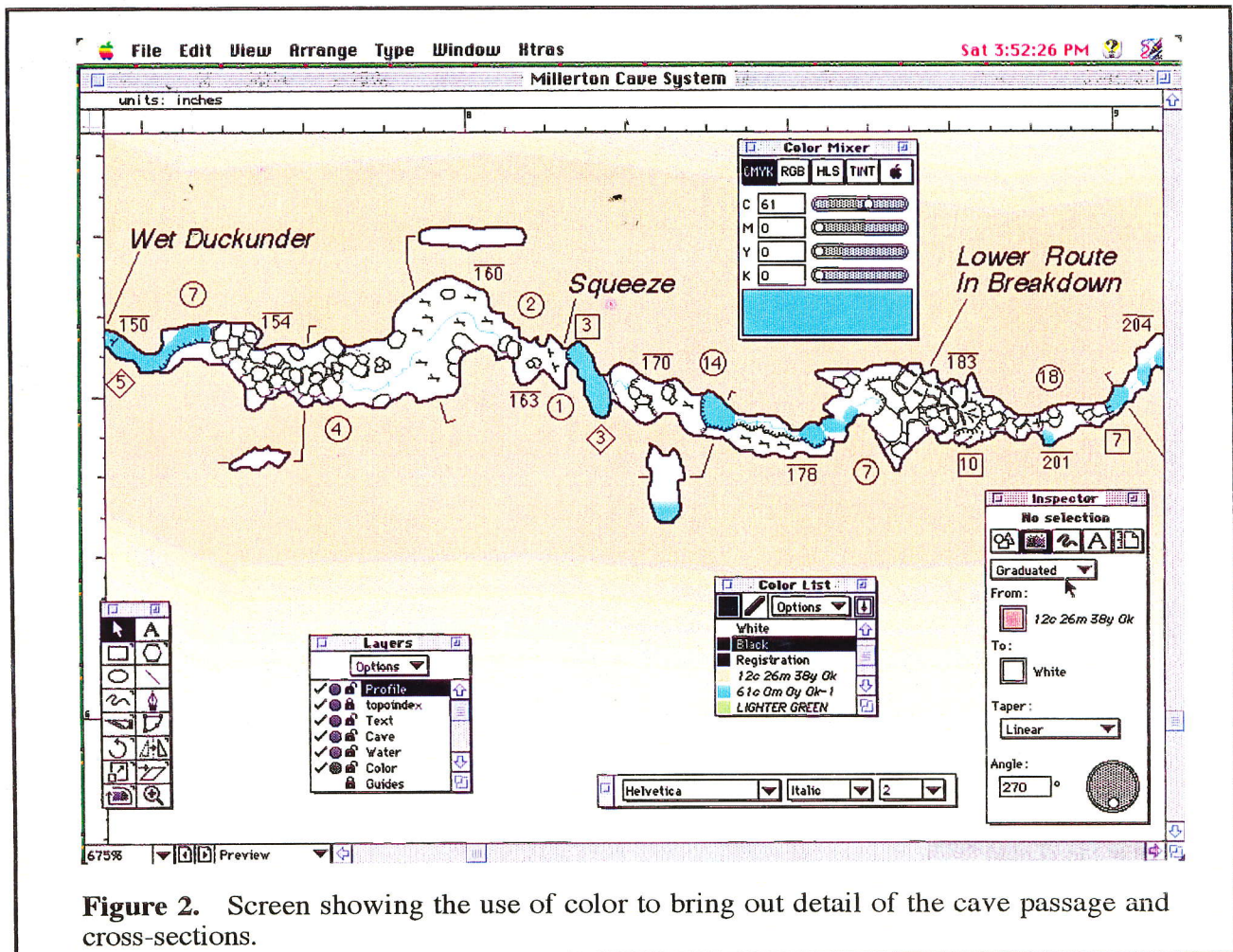
had been taken at various points in the cave. This was done with Photoshop software and placed into my FreeHand drawing to balance out my layout and complete my computer generated map.

### Salon Winning Map

After 15 years of entering cave maps at the NSS cartographic salon with hand drafted pen and ink maps, I set out to improve on that technique using a home PC and FreeHand software. The Millerton Lake Cave System was the first computer generated map that I entered. Although others before me had ribbon

winning CAD generated maps, Millerton Cave was the first computer generated map to win the medal. This is only the beginning as more cavers start using FreeHand and other illustration programs. The computer generated maps will be the preferred choice and method to draw and display cave maps. FreeHand gives you several different ways to do what you need to do, so you can choose the method that feels best to you. Try working with your ideas, in your own way, rather than forcing yourself to work the way the program does.

All of the above, of course, is just my opinion. But I hope I have given you an insight on possible hardware and software, along with some understanding of how to enter, setup and execute a successful computer generated map.



**Figure 2.** Screen showing the use of color to bring out detail of the cave passage and cross-sections.

# On Surveying Underwater Caves

by Jim Coke

Perhaps one of the more intriguing facets of underground surveying is exposed through a breed of caves that happen to be engulfed by water rather than air. Imagine two neutral-buoyant explorers suspended in the midst of a liquid cavescape. Neither lofty passages, black pits, nor unsteady slopes of boulders can escape their appraisal from a position far above the floor. Nearby lays a nylon guideline that was knotted in 10-foot intervals hours before the dive. It blazes a path through borehole tunnel that continues beyond sight and now beyond the final tie-off.

To the explorers, an impulsive urge to attach another fresh reel of line is tremendous. But air reserves command the team to retreat to the distant exit while surveying their new discovery. With the first station, depth and azimuth recorded, the lead diver starts to tow the dumb end of the tape to the next station. There's no time to dally about with the cave's dimensions; this will have to wait for another dive. Right now, priority lays in collecting accurate transit line and tie-in data. As the second diver watches the yellow tape roll off the spool, she prepares for the lead diver's "on station" signal. With two quick tugs and a stretch of the tape the first segment is complete. Now only a dozen stations remain as they waltz the stretched tape through the next segment.

A cave's exploration is never complete without an honest attempt to document the character and configuration of its known passages. For underwater cartographers, this venture might require minutes or years to conclude. This wonderfully fluid environment creates a ruthless climate for air-breathers. But how accurate is this underwater survey? Is the precision of their underwater instruments and techniques adequate to form a reliable basis for a cartographic rendition of this natural wonder?

Crisis navigation, zero visibility, equipment failures and team confusion can invite circumstances where an inexperienced caver might fail to have the last breath that's needed to surface at an exit. Consequently, most underwater surveyors are well drilled in preventing or managing these predicaments. The true challenge for these mappers evolves as their team begins to push a survey further and further into the cave. Both large and small loops start to close, bringing a sort of personality to a part of a greater watershed.

Ultimately the survey exceeds the range of a normal caving kit. Now the logistical problems become more complicated as additional life support equipment is needed to follow a hopeful explosion of leads. As the survey grows more distant from an entrance, it matched by an increasing amount of time and air that is used in commuting back and forth from the "end" of the line. Unless additional entrances are discovered along the way, the air that is earmarked for exploring and mapping quickly dwindles to near useless proportions.

Do massive decompression liabilities and extreme depths begin to exercise their command over passage detail and accuracy? At what point does the cartographer decide to use the most expedient means for data collection when prudence adds "it's indescribable taste to the flavor of exploration? These and other factors are just as important to underwater cartography as Koh-i-Noor and mylar. Each shapes the final draft of a map in the eye and heart of the cartographer.

Realistically, it is not easy to uncover the subtle distinctions of an underwater cave map. At best, one should assume that a map reflects a delicate balance between a surveyor's repertoire of mapping techniques, how they chose to manage their time and air reserves in the cave, and to what degree they felt committed to invest in the detail and accuracy of their map.

Underwater cave maps have taken an evolutionary path similar to that of dry cave maps. Long ago they began as fundamental portrayals, and eventually matured into a definitive form of art that utilizes a wide spectrum of media to display the final draft. The example provided in this article is a more traditional presentation of an underwater map.

Cenote Mayan Blue is the central section of a very large underwater cave in Quintana Roo Mexico. In roughly three years over 350 survey dives were completed, not including those aborted due to rather stimulating misadventures. This equates to nearly 1050 underwater hours spent in collecting polar coordinates.

**Unless additional entrances are discovered along the way, the air that is earmarked for exploring and mapping quickly dwindles to near useless proportions**

A laptop computer was used to manage the basic survey line data through SMAPS 4.4, which generated rectangular coordinates. The actual cave and its properties though, were all drawn by hand on vellum. Given the final draft, it appears to be analogous to a dry cave survey in style and presentation, aside from a smattering of uncommon map symbols. But the techniques that were used to build this map are variations on a dry cave surveying theme; one that was designed to be used within an abundance of breathable air. A discuss on the oddities of underwater surveying is important before dissecting this map.

### Compasses

Apart from any silly mistakes or blunders, the accuracy of a survey depends largely on the instruments used to collect the raw information in a cave. Unfortunately it is all too easy to introduce errors in this sort of surveying due to the crude nature of underwater instruments. Many subaquatic compasses are constructed for the most basic navigation. Their compass cards are poorly marked and are rarely calibrated in less than 10-degree increments. Fortunately Suunto produces a more refined side-reading compass which is marked in 5-degree intervals. It is used much like a Suunto KB-14. With a bit of practice, it is possible to distinguish degree estimates on its more spacious compass card.

Silva models are also used successfully but catching the azimuth is a bit of a juggling match. The straightedge on the compass body is aligned perfectly to the tape or guideline as the compass needle is leveled. However, the straightedge must not touch the distance standard or a "sighting" error occurs as the distance standard is pushed out of position. By turning the bezel to bring the lower arrow silhouette into exact alignment with the compass needle, the azimuth is finally recorded from the outside scale on the bezel. Each Silvatic model has its own character and scale on the bezel which lends to various modifications in collecting the azimuth. These models also fluctuate in their north arrow dampening and machined and corrosion resistant calibration marks.

### Depth Gauge

An important instrument for underwater surveying is the depth gauge. It replaces the angular function of the inclinometer in adjusting the length between survey stations. By noting the change in depth from one survey station to the next, the hypotenuse (measured shot length) and one side (change

in depth) of a right triangle is established. A quick exercise in Pythagorean geometry supplies the true length of the shot. Should you have deep pockets, it is best to avoid using the more generic depth gauges. The simple mechanism that rotates their depth indicator hand cannot be relied on to yield consistent depths as the surveyor moves up and down in the water column.

The more dependable gauge by far is computerized with a professed accuracy of plus or minus one foot in depth. However these machines also have their shortcomings when used for precise work. As they are calibrated in one foot intervals, their displayed depths on station could conceivably extend over a range of 23.99 inches. In experimenting with one machine (no two are alike). I found this error to average within a 6 to 12 inch range. Should a traverse line include a series of long shots at a near constant depth, the generated error is usually negligible. However a sequence of short (25 feet or less) and steeply ascending and/or descending shots can play havoc with a survey. One possible solution might be to average the depth display on two computers whose range of error is known. Yet this can become overly complicated. In any case its critical to record the water level (zero datum) at the beginning of a project. Should the water table fluctuate over seasonal flooding and dry periods, then the variance can be added or subtracted to the depths recorded on any future survey dives.

Until a more accurate compass and depth gauge is modified for underwater survey use, azimuth and depth estimates will continue to plague the standard of underwater surveys. Not that this suggests a wholesale inaccuracy with these surveys; one needs to be very familiar with their instruments and willing to resurvey (hopefully not too often) until the numbers crunch to the degree of accuracy that is desired. It should be obvious that incorporating the very same compass and depth gauges on a survey project eliminates a giant source of headaches!

### Measuring Distances

But what of the length between the survey shots, and ultimately of the cave? There are two methods that are currently accepted in measuring the distance between underwater survey stations. Both have been suitably adapted to the Continuous Guideline axiom in underwater cave exploration. This states that at any point during a cave's exploration, a continuous guideline is always maintained to the cave's exit. As exploration time is rather precious, the cave or tunnel is explored first with a guideline installed to trace the exploration path. This guideline is often repositioned during exploration to yield the longest possible survey shot, or to avoid delicate areas. Once this line has been surveyed, it is seldom repositioned as its series of survey stations becomes the backbone for tying in offshoot tunnels and measuring the cave's dimensions and features. A quantity of air is always reserved for the survey back, on top of the customary reserves held for the exit swim. It is these reserves that determine when exploration stops and



the survey of the new passage is initiated as the team exits the cave.

The first distance standard employs a fiberglass tape. It is used in the same traditional approach as in dry caving, although voice signals such as "on station" etc. are replaced by a predetermined set of coded tugs on the tape. The survey team normally consists of two members; one diver records the azimuth between stations while swimming the dumb end of the tape to the next station while the second records the exact distance between stations when the tape is in position. Both members record each of the station depths along with their assigned data. This may sound redundant, but it is extremely difficult to "compare notes" underwater as verbal communications are impossible. Thus when both sets of incomplete survey data are combined at the surface, matching the station data together becomes a simple task. This method prevents giant blunders while also serving as a comparison of station depths.

The second measuring procedure is known as a Knotted Line Survey (KLS). It relies on counting intervals and their portions (to the nearest foot) between spaced knots on a guideline. The survey "team" in this routine consists of only one person. The KLS concept was first suggested by John Zumrick in the early 1960's as a unique alternative to taping survey shots. As new guideline is loaded onto an empty reel, an overhand knot is tied into the line every 10 feet. By laying this prepared guideline through an unexplored cave or tunnel, these intervals can be counted quickly and easily between the survey stations. The guideline is normally wrapped around a floor projection where the tunnel changes directions (a survey station), there is always a portion of a knotted interval to estimate before and after each station. This technique was adopted immediately by most American cave divers due to its advantages over the taped survey.

The primary advantage of KLS is the speed of which a transit line can be surveyed. When diving at great distances from the cave's exit or at extreme depths, heavy decompression obligations can make a slower technique very uninviting. KLS also holds the distinct advantage of being quite compatible to surveying while driving an underwater scooter. Today this is particularly important as technology has allowed explorers to push deeper and further into more isolated sections of caves that were impossible to visit just a few years ago. Another advantage is that the survey can be accomplished in zero visibility conditions while the team members remain close together and in contact with the guideline. Finally, KLS is an easy technique for beginning surveyors to learn and execute underwater.

Yet KLS is not without its shortcomings. Considering the problems mentioned with other underwater instruments, this technique can further erode the accuracy of a survey. Its greatest fault is that it requires a surveyor to estimate a distance measurement not once, but twice. The first instance occurs when the line is knotted before it is spun onto the reel. Even though the knots be spaced accurately, an un-

known factor is immediately introduced as the line is knotted. This concerns the tension of the line as it is being knotted versus its future tension when it is installed underwater. To misjudge the tension during either phase will undermine the most fastidious efforts to tie accurately knotted intervals.

The second estimation occurs during each survey segment; each portion of a knotted interval is estimated only to the nearest foot - given that a surveyor can easily estimate a two to nine foot span. In theory, it's possible to generate a plus or minus two foot error in each survey segment. To confirm this state of affairs, I decided to tape over 150 "one-hundred-foot sections" of guideline in various underwater caves around Quintana Roo. Each of these caves had been previously surveyed with the KLS technique. Given a wide range of results, the average of the final tally indicated that a 100-foot KLS survey segment is one to five feet longer than its taped counterpart. To be extremely conservative, I concluded that a KLS survey can boost a cave's length by as much as 10%. As a quick note, you might be curious as to which method of measuring distances is in the vogue these days. KLS has it hands down. Even within the most easily surveyed portions of a cave, a taped survey is never the method of choice.

### **Bookkeeping**

Most underwater surveyors can choose between two "bookkeeping" systems in recording their raw data. Both are nearly identical in nature and quite dependable, unless the two systems are inadvertently mixed together when compiling raw data for a cave.

During a normal survey dive, data is recorded on underwater slates that have been permanently engraved in a four or five column grid pattern. Each row in the grid column represents a survey station while the first three columns are used to record station depth, azimuth and distance entries. The remaining columns are used to outline only the most basic station and passage appearances, if they are used at all. Quite simply, there is rarely time or a need to collect acceptable data on both the tunnel's trend and its structure.

When drawing a complete map most cartographers prefer to postpone their drawing of a passage until all of the passage surveys in a region of a cave are proven to be accurate. After the dive, the line data is converted such that it leads into the cave, and then is transferred to a notebook or software program that accepts a depth entry rather than an inclination entry.

**When diving at great distances from the cave's exit or at extreme depths, heavy decompression obligations can make a slower technique very uninviting**

Both the SMAPS 4.4 and CAPS programs provide this default, and are the most popular programs at this time. Finally the data is converted to rectangular coordinates and a simple line plot of the cave is constructed from zero datum (the water level directly above the main entrance) to the furthest surveyed point(s).

### Accuracy

The majority of underwater caves in Quintana Roo contain a labyrinth of loop passages; those tunnels that branch off from a passage to later rejoin the same passage at a point further into the cave. Either short or very long, they have become a convenient standard by which we judge the accuracy of our line surveys. By no means is this the best means to determine a survey's accuracy, yet it is the most reasonable method for this type of cave. Ideally a loop survey always "starts" at a known station on a survey line, to end exactly at a more distant station on that line. The closure error between the two surveys at this final station determines the survey accuracy of both lines.

What constitutes an acceptable or unacceptable amount of loop error in underwater surveying, exactly? This is not an easy question. Using the best survey tools will obviously reduce errors in a loop, but it won't preclude inaccurate work and resurvey dives. In fact it was essential to resurvey 9 loops (18 lines) of the 36 loops in Mayan Blue to reach the final accuracy that I expected. A few of these loops were "easy" to resurvey, while others were far more difficult due to their depth and distance from the entrance.

Interestingly enough, azimuth discrepancies were the sole culprit in each "bad" closure. As I mentioned before, this nebulous concept of accuracy is a large hurdle for cartographers to leap as they start to pencil their survey into a hard copy map. What if a survey loop combines KS at extreme depths, and the loop closure error is over 5%? What is considered an acceptable error for a 2500 foot loop that begins 3500 feet from the nearest entrance?

Most cavers would jump at the opportunity to explore these passages, but the underwater surveyor is forced to strike a balance between an accurate map and an elevated risk to decompression sickness and other calamities. Good underwater surveying requires a lot of time, and it is rooted in a survey team that's having great fun. Clearly there are no easy answers to be had. The mapping team ultimately makes their decision as to which errors to correct, and those they are willing to live with so that they can continue to map in grand style.

### Data Recording and Use

Organizing raw data into a line plot is a simple task if only one or two teams are surveying a cave. Mayan Blue is in this category as very few cavers were involved in its entire survey. But what if many teams are surveying an underwater cave?

These teams may generate one or two thousand feet of raw data per day; woe to the poor data processor who must decipher, organize, and keep up with this torrent of information.

In years past, each survey team would invariably use a slightly different means of passing their data along to be assimilated into a growing map. Where their new data tied into an existing passage may have been crystal clear to those surveyors. It was usually as clear as mud to the survey organizer. Having some experience with this, Harve Thorn and I created a data form that would hopefully alleviate this problem and also serve as a hard copy for raw data information (Figure 1). Although this form requires a little extra effort from the surveying team, it attempts to clarify a number of questions that might arise over the survey data. It not only organizes and asks the most obvious questions about the raw data; it provides a visual means for a person who is not acquainted with the cave to interpret the position and area that the raw information holds in the cave. This is especially true in the case of offshoot and loop lines.

As an example, let's say that one group originally surveyed a main trunk passage using a depth computer, tape and side-reading compass to get the "best" results. Later on a second group discovers an obscure lead in this passage that opens up a totally new area of the cave. For whatever reason they elect to use KLS techniques to survey this area. To add this new data to the original survey, they must tie into a recognized trunk station and collect 5 bits of information about this survey station for the data organizer. The first is the depth of the station where they began their new exploration. From this station they record the azimuth that the trunk line takes leading further into the cave. Then a second azimuth (a backsight) is sighted on the line leading towards the exit. As they measure the distance of this "exiting" segment, they finally record the depth of the next station. With these 5 points of data it is easy to place the new offshoot line on the map, no matter how either of the tunnels were surveyed or whether the data processor is familiar with the cave.

This form became fairly popular for Q. Roo cavers as it simplified a rather mundane task of adding data to a computer, while providing a team with a hard copy of their work for future reference. With maps being generated at a faster pace, spotting errors and planning the next day's explorations were made

**Most cavers would jump at the opportunity to explore these passages, but the underwater surveyor is forced to strike a balance between an accurate map and an elevated risk to decompression sickness and other calamities**

# CENOTE MAYAN BLUE

## TULUM, QUINTANA ROO

### MEXICO

20° 11' 38" N LATITUDE  
87° 24' 50" W LONGITUDE

AN UNDERWATER CAVE PLAN OF THE  
MAYAN BLUE SYSTEM AND XEBALBA  
SECTIONS OF SISTER NAAMAL  
SURVEYED  
JANUARY 1990 TO DECEMBER 1992

BY  
JAMES G. COKE IV  
LOUIE COMLIN  
THOMAS M. YOUNG  
DRAFTED BY  
JAMES G. COKE IV

Plan Length: 24,852 FEET (8184 METERS)  
Plan Depth: 91 FEET (27.7 METERS)

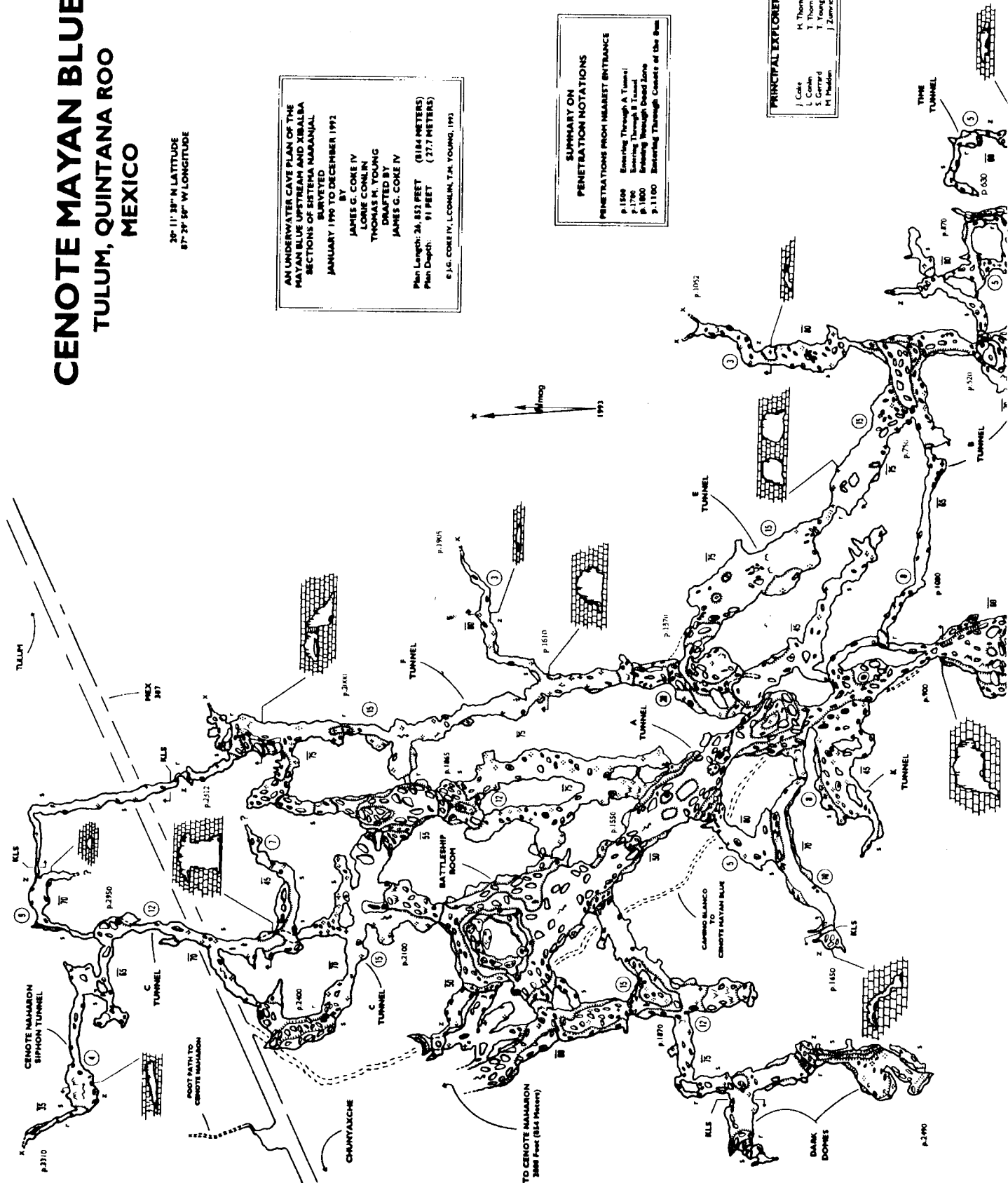
© J.G. COKE IV, L.COMLIN, T.M. YOUNG, 1993

#### SUMMARY ON PENETRATIONS FROM NEAREST ENTRANCE

p.1500 Emerging Through A Tunnel  
p.1790 Emerging Through B Tunnel  
p.1800 Emerging Through Dead Zone  
p.1100 Emerging Through Coasts of the Sea

#### PRINCIPAL EXPLORERS

J. Coke  
L. Comlin  
S. Corrad  
M. Hedden  
H. Thorne  
T. Thorne  
T. Young  
J. Zuercher



- UNMOUNTED PASSAGE
- UNMOUNTED PASSAGE
- UNDERLAYING PASSAGE
- BOULDER
- FLOOR-TO-CEILING COLUMNS (LARGE, TAPERING)
- FLOOR RELIEF (MATCHING TO LOWER LEVEL)
- SLOPE
- CLUSTERED SPELOTHAPHS
- NATURAL LIGHT LIMIT
- DIRECTION OF CURRENT
- 1 SALT
- 2 EXPECT ZERO VISIBILITY
- 3 DEPTH OF FLOOR (IN FEET)
- 4 FLOOR-TO-CEILING HEIGHT (IN FEET)
- 5 PNEUMATIC LIGHTING (TOWARD VIEW)
- 6 PNEUMATIC LIGHTING (AWAY FROM VIEW)
- 7 UNMOUNTED LINE SURVEY BEYOND ARROW
- 8 MINOR RESTRICTION (DIVERSE PASS IN SINGLE FILE)
- 9 MAJOR RESTRICTION (BACK-MOUNT GEAR CANNOT PASS)

Figure 1 is a map of the study area, showing a network of roads and a dashed rectangular box labeled "AREA DISPLAYED". A scale bar indicates 200 METERS. A north arrow is also present.

In the present geological era, the underwater limestone cave is completely flooded by fresh and salt water. The cave system is located in the Mexican Caribbean, it is within the drainage pattern followed by the Cozumel River, towards the south of the island. The cave system is formed by a series of chambers and passages. A limestone is encountered at a depth of 66 feet (17 meters) below the surface. The cave conditions include warm colored all floors with chertstone colored walls and ceilings. Only trained individuals using proper equipment and expert techniques should enter this fragile cave system.

Friction underwater instruments were used to confirm all azimuths and depths of the cave. A thermopne type was used to measure all distances except where needed as (PCL5). A Kusted Line Survey was also reported by and the KLS symbol appearing on the map plan. All distances have been corrected for the effect of refraction.

Penetrations depths and ceiling heights are noted in feet. The cross section and profile information is enlarged by twice the plan scale unless scaled otherwise. This survey depicts the major features of the cave passages.



Cave \_\_\_\_\_ Date \_\_\_\_\_ Area \_\_\_\_\_

Team \_\_\_\_\_ Survey IN OUT Line Name \_\_\_\_\_

Please sketch tie-in area

(circle one)  
Reported  
by

Tie-in's Need  
2 dpths  
2 azms  
1 dist

\_\_\_\_\_ azm dist \_\_\_\_\_  
in sta ▲ dpth \_\_\_\_\_  
tie-in sta  
+++++ ▼ dpth \_\_\_\_\_  
out sta ▼ dpth \_\_\_\_\_  
\_\_\_\_\_ azm dist \_\_\_\_\_

fm	to	dpth	azm	dist	comments	fm	to	dpth	azm	dist	comments
0	1					13	14				
1	2					14	15				
2	3					15	16				
3	4					16	17				
4	5					17	18				
5	6					18	19				
6	7					19	20				
7	8					20	21				
8	9					21	22				
9	10					22	23				
10	11					23	24				
11	12					24	25				
12	13					25	26				
DPTH is depth of "fm sta" AZM is from "fm sta" to "to sta" DIST is from "fm sta" to "to sta" RECORD DEPTH OF FIRST AND LAST STA						26	27				
						27	28				
						28	29				

ASSIMILATED SURVEY DATA ← FOR QRSS SURVEY RECORDS USE

Data Into Cave

Survey Data Prefix \_\_\_\_\_ Tie-in Station Name \_\_\_\_\_

1st Raw Data Station # \_\_\_\_\_ Tie-in Sta Prefix/# \_\_\_\_\_

Raw Data Survey Grade \_\_\_\_\_ Recorded by \_\_\_\_\_

Figure 1: Data Form

easier. These “instant” maps were also great moral boosters.

I have tried to address how most survey data is collected in order to build a line map of an underwater cave. Given an underwater cave in Quintana Roo with a total length of 15000 feet (an average size for these caves) and it’s “normal” amount of offshoot and loop tunnels, a reasonably accurate line map for this cave could be constructed in about 60 exploration dives (or nearly 100 hours of dive time excluding decompression). Usually this type of map is the final fate of most underwater maps. With the bulk of the cave’s exploration complete, it takes a committed team to fill in the blanks of the actual details of the cave.

### **Sketching and Passage Detail**

The diving required to pencil cave walls and features into a map, or to present the cave’s true personality, will more than triple the number of dives that were required to explore the cave. Returning to the Mayan Blue map, should you spot the various cave entrances you may notice that there is a bit more passage detail in these areas rather than in the more remote areas of the cave. Simply put, it is much easier to spend a longer amount of time in these areas to draw the cave’s details.

The drawing method I prefer to use in these areas is fairly simple. I prepare a stacked set of five underwater slates with a selection of survey segments drawn to scale on each side of the slate. The segments and slates are arranged to lead deeper into the cave. Such details as station depths and the position of offshoot lines can also be included on the segment lines. Once in the water it becomes a matter of stretching a tape to the side-walls from each survey station and noting boulders and stals on the slate in their proper scale. Taking back azimuths to the station assures their proper position.

After the dive, the passage minutiae on the slates are immediately transferred to a vellum master map of the cave. This master copy contains all of the cave’s survey lines (drawn to rectangular coordinates) while the grid pattern on the vellum provides the scale. Although very time consuming, the first 1500 feet of a cave (from an entrance) can usually be drawn by this method as long as the cave’s depth does not become too excessive. Should large rooms be included in the map, then multiple dives may be needed to sketch this chamber. If the depth of the cave is a potential hazard, the less of the cave is drawn “at one setting”. Most underwater mappers use a variation of this theme as it is an efficient way to draw the particulars of a cave.

However, this technique has a highly disturbing idiosyncrasy. The line survey of the tunnel being drawn must be known to be accurately surveyed. If a resurvey of that line is needed, its passage details can’t be reconstructed without fudging. This is why most underwater cartographers prefer to survey first and draw later. The problem itself surfaces; underwater cartographers have yet to discover a viable equivalent to the dry caver’s survey book. Once the in-cave drawings are trans-

ferred from the slates to a master map, the slates are cleansed in preparation for the next sketching dive and the in-cave drawings are lost forever. Although a good Xerox machine may produce a readable copy of these drawings, I never had much success with either the machines or the “archive-ability” of those copies in Mexico. We have also experimented with small sheets of acetate and marking pencils, suitable for underwater use, with little success. Indeed, unless a small fortune is spent on preserving and filing each slate, in-cave drawings eventually become graphite down the drain.

### **The Final Map**

Can you imagine the importance that the master vellum copy gains after 6 month’s worth of drawing? During infrequent trips to the United States I would duplicate the master copy. But in between those trips, I must confess, I had a few noteworthy moments of panic over these original drawings. Nearly sleeping with my map tube in a hotel room in Coba during Hurricane Gilbert was bad enough, yet how I ever misplaced that tube years later (temporarily) in the Cozumel airport.....!

The ultimate challenge in drawing these caves starts when the cave grows out of the range of a normal caving kit. By this I am implying that stage bottles (carrying one or more extra tanks aside from the double tanks on your back) and possibly underwater scooters are needed to reach the work area. After an hour’s commute, time and air become valuable commodities, so the team’s efficiency needs to be at a high level at these distances.

One approach we used with some success was to restrict the exploration of main trunk passages through air rules. As it is fairly simple to determine the total volume of air required to travel to a chosen area and then return to the entrance, one can determine how much air (subtracting air reserves for safety) is available for exploration. In dividing this volume by three, we would allot one third of our air to be used in exploration. With this volume exhausted the remaining two thirds would provide ample time for surveying and drawing. When a section of the main passage is complete, any subsequent dives would investigate offshoot tunnels before the main passage was extended. The primary advantage of this technique was that a portion of the cave was completely surveyed and drawn while none of the offshoot passages were overlooked.

This demands a high level of concentration from the team. Each diver needs to be very conscious of their air rules and body heat loss, to stay focused on the survey, and to be able to shrug off the haze that can sometimes settle in after so much concentration. A further disadvantage is presented if the new survey is part of a yet undiscovered loop. Hours of effort can quickly be undone should the loop not close to the desired accuracy. So if we even suspected that a loop might be in the making, it was time to revert to another strategy.

Our new strategy for extended cave survey emphasized a

more traditional means of exploration. After a few air calculations, the team would push a part of the cave that might close a possible loop, while reserving enough air in their exit to get excellent (we hoped) survey data. As exploration continued and loops were closed, solo dives would be initiated to draw regions of the cave that were judged accurate while checking for omitted leads.

Due to the geological nature of Mayan Blue, this mode of surveying became the more expedient means in creating the complete map of Mayan Blue. The time that was actually spent in drawing during these dives depended on the distance the sketcher was from the exit. As this area of the entire cave's boundaries are fairly defined, unlike the region south of this map (still being explored and drawn), most areas of Maya are not too distant for very productive drawing sessions.

The actual production of this map to a mylar "presentation grade" copy was quite similar to most drafting methods. The real question that remained was how to inject utility to the map so that a diverse set of users would find it worthwhile.

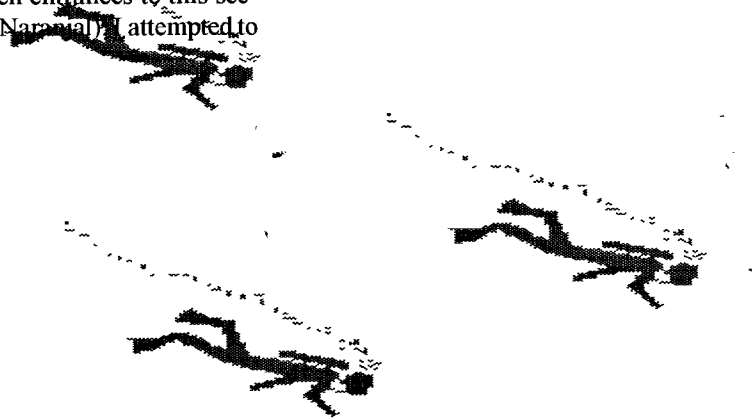
A map is only as useful for those that find it useful. With this in mind, I incorporated a set of odd symbols to show environmental features and hazards. Many cave divers plan their excursions using a map. With these symbols (including visibility warnings, restrictions, delicate areas, etc.) they have a better idea as to what to expect during their caving. These cavers also utilize penetration distances from an entrance in planning their dive. As there are seven entrances to this section of Mayan Blue (a part of Systema Naranjal), I attempted to

highlight penetration notes using distinct fonts from different entrances. Although I would have preferred to use metric values in depths and penetration, I decided that English measurements would be more useful for the majority of underwater cavers that use this map. Most of the underwater instrumentation today is still in English Standards.

This section of Systema Naranjal (the Mayan Blue Cave) required a few years to survey and draw. During this time the survey discovered major extensions in all sections of the cave, which eventually quadrupled it's known length. In opening the main siphon area of this important watercourse, the entire cave became known as Sistema Naranjal. Sistema Naranjal is currently surveyed at over 18450 meters, and it is still going. It is currently the third largest underwater cave in the world.

### Acknowledgments

There are many people who deserve special mention in the creation of this portion of the Naranjal map. Excursiones Akumal, Dick Blanchard and Gonzalo Arcila displayed endless patience with me during those many years of surveying. Lorie Conlin, Harve and Toni Thorn, and Tom Young put up with a ton of my under and above water antics. And then there is Pat Kambesis who has been so supportive of my cartographic efforts over the years. I am very pleased to display this map publicly for the first time in *Compass & Tape* under her editorship.



# Notes for cave surveyors on the Earth's magnetic field, and orienting cave surveys to True North using the USGS GEOMAG program

by Ira D. Sasowsky

## Introduction

Though the Earth's magnetic field is something that cave surveyors rarely consider, it is this unique feature of our planet that allows us to construct detailed and accurate maps of caves. The magnetic field shifts through time, requiring special considerations for both the completion of long-duration surveys and the archival quality of maps. This East or West shift of the Magnetic North Pole (with respect to the True North Pole) is called declination. As Bert Ashbrook pointed out in *Compass & Tape No. 41*, there is "No excuse for not knowing magnetic declination".

It is recommended that all surveying be done with compass declinations set to zero. Then, during the data reduction stage of the mapping project, a correction for local magnetic declination should be made by using up-to-date declination data (not the data given on the bottom of USGS topo sheets) to correct the survey to True North. A convenient way to get this declination data is now available free, on the Internet.

## Surveying in the subsurface using magnetic compasses

It is the magnetic field of the Earth which causes the needle in a compass to pivot, allowing us to measure angles with respect to some reference (magnetic North). When combined with a tape measure, and an inclinometer to measure angles with respect to another reference (horizontal), we can construct highly accurate maps of extensive caves. The presence of this magnetic field is critical to the cave surveyor. Without it, our maps would be much more difficult to make, and much less accurate.

Although the magnetic field is also used by "surface" surveyors, it is much less important, because as well as having surficial landmarks to close surveys, the sun and moon are usually available to provide orientation to True North (the rotational axis of the Earth). The only alternative in the subsurface

(other than using magnetic compasses) is the method of accumulating angles, where at each station the angle between the preceding and following station is measured. This procedure is tedious, and prone to severe accumulated errors.

## Earth's Magnetic Field

It is useful to understand some features of the magnetic field, to make better use of it while surveying. The magnetic field is a vector; it has both orientation (the direction in which the compass needle points) and magnitude (how strongly the needle is "pushed" by the magnetic field). Cave surveyors are not concerned with the magnitude, nor are they concerned with the vertical component of the direction - we only care about the horizontal component of direction (N, S, E, W) - what our compass reads. An exception regarding the vertical component is if one is surveying in the Southern hemisphere - compass needles must be properly balanced for use in either the Northern or Southern hemisphere, and a "Northern" compass may not work in the southern hemisphere.

## True North vs. Magnetic North

When we look on the legend of a USGS topographic sheet, we see that the map is oriented to True (Geographic) North, shown by a star. But 2 other "Norths" are also shown, along with their declinations from True North, at the bottom of the page. These are the Universal Transverse Mercator (UTM) Grid North (GN) and Magnetic North (MN).

The **True (or Geographic) North Pole** is defined by the spinning axis of the Earth. It is located at 90° North latitude, and remains in a constant position when considered on human timescales. This is the preferred North to reference maps to.

**UTM North** is used for certain cartographic operations. It is constant over broad areas, but not worldwide.

The **Magnetic North Pole**, which we are interested in, does not exactly match the position of the True Pole; neither does it match UTM North. The rela-

**The magnetic field shifts through time,  
requiring special considerations for both  
the completion of long-duration surveys  
and the archival quality of maps.**



tionship between the True and Magnetic poles and equators is shown diagrammatically in Figure 1. The bottom of the topo sheet gives a declination, or angular difference between True and North Poles. However, this data is only valid for that location, on the date the map was made.

Figure 1 shows that the magnetic north pole is not exactly at the Geographic (True) North Pole (which is defined by the rotational axis of the Earth). In 1994 it was in Canada, on the Noice Peninsula, southwest Ellef Ringnes Island, at 78.3° N, 104.0° W. It

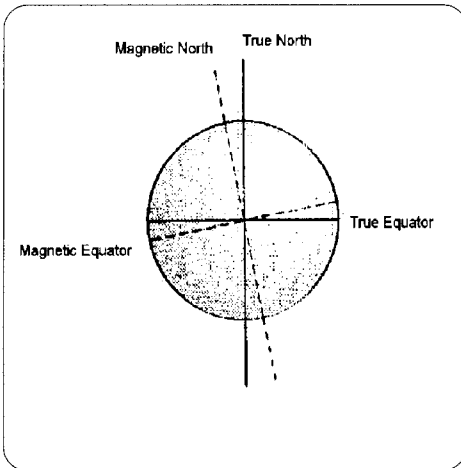


Figure 1. Diagram showing general relation between True and Magnetic poles and equators.

moves about 15 km per year. Likewise the magnetic South Pole and the magnetic equator do not match their "True" counterparts exactly.

In actuality, the field is even more spatially variable than our simple drawing shows, and it varies through time. Figure 2 shows the 1995 values of magnetic declination.

Note how irregular the pattern is. Also, this field changes noticeably every year. This means that a declination taken from a USGS map made in 1970 will be incorrect for converting 1997 magnetic compass readings to True North readings. For these reasons it is important that all cave surveys be referenced to True North using up-to-date declination data. This produces maps that are correctly oriented, and whose orientation does not vary through time.

In a cave survey made during a single year, the error introduced by ignoring magnetic declination will only affect the orientation of the cave map with regard to topography. In multi-year surveys, however, the serious problem of actual mis-orientation of different segments of the survey will occur (because magnetic north has been drifting during the period of the survey).

#### How to get and use current declination data - USGS GEOMAG Program

I find the most convenient way is via the Internet. The U.S. Geological Survey has produced a program (GEOMAG) which will calculate, based upon the latest spherical harmonic models of the Earth's field, the declination at any point in the world.

This is available via the following methods.

#### 1. Using a WWW browser (such as Netscape, Mosaic, etc.)

Go to this URL:

<http://www.ngdc.noaa.gov/cgi-bin/seg/gmag/flsdsnth1.pl>

The following input data will be interactively requested by the program:

**Altitude of cave** To nearest 100 feet is fine

**Latitude of cave; Longitude of cave**

To nearest 5 minutes is fine - estimate from corners of 7-1/2 minute topo sheet if unknown.

**Date of survey**

If all of survey is within one year, just use the "average" date. If not, use multiple runs of the program to calculate all of the varying declinations that you need. After you have submitted the electronic form, results will be immediately transmitted back, along with a detailed explanation. Most of the results can be ignored, use only the value given for "D". Save a copy of the results for future reference regarding your survey.

If you do not have access to a WWW browser, the declination may be calculated also as follows:

#### 2. Using Telnet from an Internet-connected computer

• If possible, please avoid using GEOMAG via Telnet or Dial-up between 9 a.m. and 4 p.m., mountain time, Monday through Friday. Use the telnet command: "telnet neis.cr.usgs.gov". When the prompt: "Username" appears, type: "QED" and press Return.

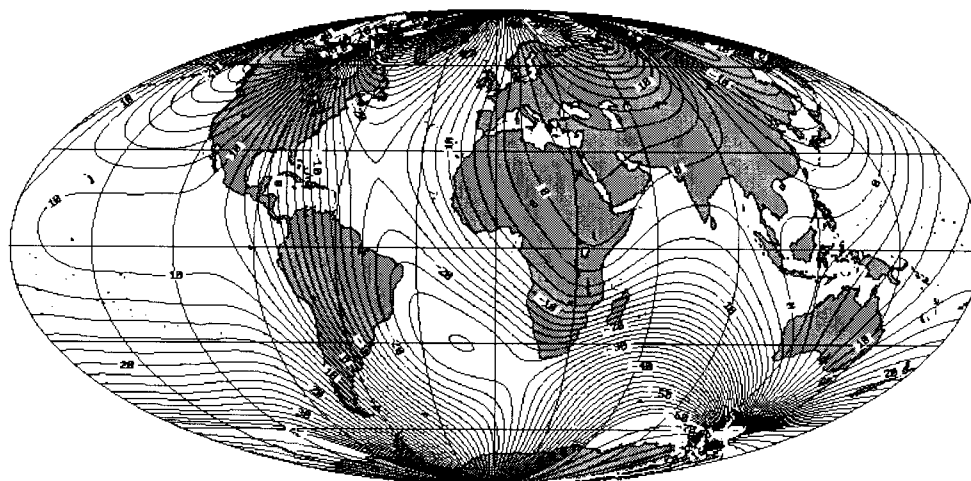
Upon access, the Main Menu will appear:

Q	Quick Epicenter Determinations (QED)
L	Earthquake Lists (EQLIST)
M	Geomagnetic Field Values (GEOMAG)
X	log out

Type M to select GEOMAG. General help will be offered at the start. Specific help can be obtained at any time by typing a question mark (?).

When finished, Press "Cntrl-Z" to exit GEOMAG. When the main menu reappears either select another option or type "X" to log out. The GLDSV1> prompt will reappear. Type "LO" to disconnect.

**Figure 2**  
**Magnetic Field of the Earth - 1995**  
**Declination Chart**



### 3. Using Dial-up (modem) connection from a computer

Set your modem to even parity, 7 data bits, 1 stop bit. Dial one of the following (toll-free outside Colorado only):

Phone Number

**Baud Rates** 800-358-2663  
14,400 303-273-8672  
1200 303-273-8673  
300 303-273-8678  
300

Upon carrier-signal detection, press Return once or twice. The following two prompts will appear. Type the responses underlined (followed by pressing RETURN):

GLDSV1> cneis [RETURN]  
Username: QED [RETURN]

Follow directions regarding the Main Menu from 2. above.

### 4. Via US Mail, email, or phone

You can email John Quinn at [quinn@gldfs.cr.usgs.gov](mailto:quinn@gldfs.cr.usgs.gov), or write or call the National Geomagnetic Information Center for more information.

National Geomagnetic Information Center  
U.S. Geological Survey  
Box 25046 MS 968  
Denver Federal Center  
Denver, Colorado 80225-0046 USA  
TEL: +1 303 273-8475, FAX: +1 303-273-8450

### So where does the magnetic field “come from”?

The actual source of the main magnetic field is still a matter of some debate. The most accepted theory among geologists is that the main magnetic field is generated by a process called a “self-exciting dynamo” due to spinning of the Earth’s solid nickel inner core and liquid outer core. This generates a field (called the main field) which may approximately be thought of as a “bar magnet” in the center of the earth. Although this is the major source for the Earth’s magnetic field, other, more minor components of magnetism are added also, explaining the complexity of the field as seen in Figure 2.

### Recommended sources of additional information on Earth magnetism

<http://www.geomag.cr.usgs.gov/geomag/> - The USGS Geomagnetism Home Page. Note: This URL does **not** have a period after “WWW”.

<http://www.ngdc.noaa.gov/seg/potfld/geomag.html> - The National Geophysical Data Center Geomagnetic Data Homepage

*Paleomagnetism: Magnetic domains to geologic terranes.* 1992, by Robert F. Butler, Blackwell Scientific Publications, 319 pages.

### Acknowledgments

Much of this document is modified from materials presented on the WWW pages noted above. I thank John M. Quinn of the USGS for help with GEOMAG.

# Mapping Equipment for Wet Caves

by Philip L. Moss, 15977LF

For many years, cavers have been struggling with fogging instruments and soggy paper. There is little need to do that anymore with availability of "inherently" waterproof instruments and waterproof paper.

## Instruments

Suunto has "inherently" waterproof (prismatic) compasses and clinometers. The Silva 80 compass is inherently waterproof and floats. Brunton has two factory-waterproofed compasses with built-in clinometers.

I have been using a Silva 80 compass for about 5 years. Most of the caving that I do is wetsuit and crawling in considerable mud and gravel. I have had no problems with the Silva 80. The factory internal lighting fails very quickly, but I don't see that as a problem as the compass collects light very effectively. The compass collects light through the bottom, instead of the top of the compass. If I am in chin-deep water I don't even have to shine a light under the compass, the light bouncing off the water is enough to read the compass easily. The Silva 80 has proven to be quite durable.

I have only used the Suunto Prismatic Twin a little. Since the 1997 NSS Convention, it went on its first \*real\* mapping trip; about 600 feet of water and belly-crawl. One of the glass lenses delaminated from the prism and got water between the lens and the prism making it impossible to read. Both of the liquid-filled dials got mud in them! I don't know how. I am sorry that I recommended the Suunto Prismatic compasses at the NSS Convention.

I have fairly limited experience with my high-impact plastic, waterproof Brunton. So far it has not had any problems, but it is not inherently waterproof. It does have air-filled voids. All I can say is so far, so good. It does have improvements over the older Bruntons; it is damped, it has green liquid in the levels making it easier to read in low-light conditions, the plastic seems to be more durable than pot metal, and it is waterproof.



## Paper

Rite-in-the-Rain (tm) paper or equivalent is what most cavers have used for mapping in wet caves. Avery Tear-Proof Paper For Copiers (tm) is much better. It is indestructible (in cave terms) and you can create your own template for data. The Avery paper never gets soggy, vigorous erasures can be made when wet, and a pencil will not puncture it. Unfortunately, the Avery Tear-Proof paper (tm) is no longer produced. You may be able to acquire it as old stock from office supply shops. Avery is making something called Rip-Proof (tm) Reinforced Sheets, which I have not seen yet.

Nalgene makes something they call PolyPaper and it is quite durable under wet conditions. It is preprinted with a grid. the biggest drawback that I have encountered with it is it does not take or hold pencil marks well once it is wet. While the paper is durable, the notes are not. If someone comes up with a more permanent marking system for this paper than pencil, I would very much like to know about it.

Equipped with the wonders of modern technology, a wet caver can quit worrying about fogged compasses and limp, ragged paper and focus on mapping.

## Cartographers Corner

by Pat Kambesis

### Cross Sections & Elevation

Cross Sections are an important element of a cave map because they depict the shape and dimensions of the cave passage (at the leader lines). Depending on how much detail the cartographer has and ultimately uses, cross sections can also show lithologic and structural relationships and the floor sediment/wall rock interface.

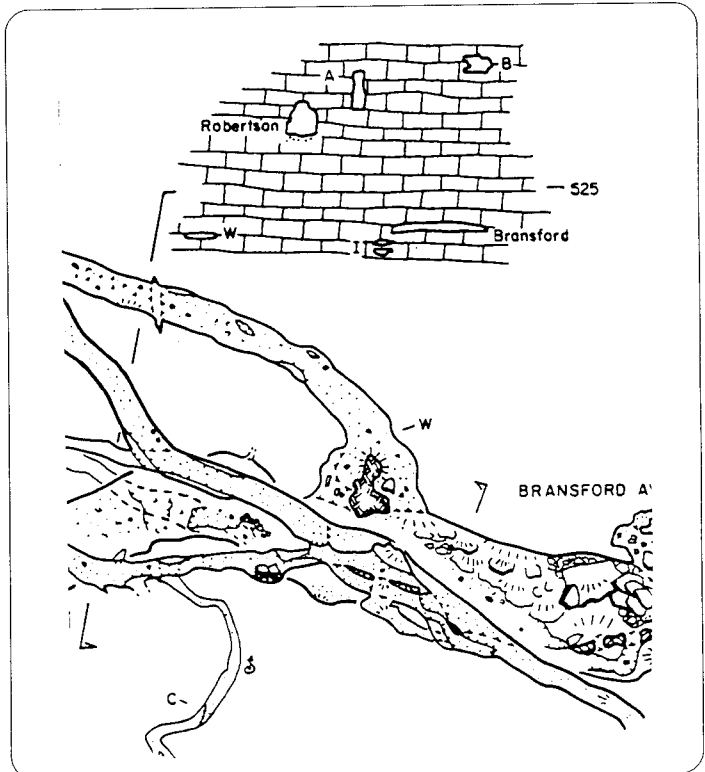
However, one set of data that is not commonly shown with cross sections is that of elevation. To get that information, the map user has to locate a reference to vertical control on the map. For horizontal caves the information is often not included or is very sparse. For vertical caves, the map user has to use the profile as a reference point in determining the elevation of the cross section. In either case, the user has to do some cross-referencing of information, maybe a bit of measuring, and probably some creative projecting to get the elevation information.

One of my objectives as a cartographer is present enough graphic information on a map such that the map user doesn't have to spend a lot of time cross-referencing and projecting to get the information they need. A fast and easy solution for the elevation reference with respect to cross sections is to just include it next to the cross section. However, I'm always looking for more creative and graphically interesting modes of presenting information on maps. The following four examples meet that criteria.

Figure 1 is a small segment of a preliminary version of one of the Mammoth Cave (KY), map sheets, drafted by Mick Sutton. Note that Mick has not only included an elevation reference with the cross section, but has also depicted the vertical and horizontal relationship between cross sections in a fairly complex segment of cave passage. At a glance, the user gets a sense of passage relationships and elevation information.

The next example (figure 2) is a map Fisher's Fissure, Texas (please note map is from 1961 - DE is the cartographer initials but I don't know who that is). The cross sections are referenced in the plan by letter and then shown next to the depth scale. This is a simple and elegant method of showing cross sections and depth information in a visually clear and concise manner.

The next example is a portion of the map of Gruta del Café, Mexico, (Figure 3, drawn by Urs Widmer and Thomas Bitterli). The cartographers have referenced the cross sections on the plan view but actually draw them in with the profile. A vertical



**Figure 1: Section of Mammoth Cave sheet by Mick Sutton.**

scale bar would have been a nice addition to the map but the vertical extent (-48 meters) and scale is noted in the title block.

The map of Palace Cave, Texas (located on the back cover of this issue) is the final example. The cartographer, John Brooks, uses a dashed line to depict 0 datum and that dashed datum line is shown in all of the cross sections and on the profile.

These are just a few examples of the how use of graphical elements makes information easier to find and visualize on cave maps.

### Acknowledgements

Section of Kentucky Avenue map, Mammoth Cave, KY. Cartographer: Mick Sutton. From NSS Bulletin, 51-115, 1990

Gruta Del Cafe, Mexico. Cartographers: Urs Widmer, Thomas Bitterli, From Proyecto Cerro Rabon (Bitterli, Jeannin, Meyers, Rouiller, ) page 40., 1990

Fisher's Fisher, Texas, Cartographer: DE. From the Caves and Karst of Texas, 1994 Convention Guidebook, p. 290

Palace Cave, Texas, Cartographer: John Brooks. From the Caves and Karst of Texas, 1994 Convention Guidebook, p. 226

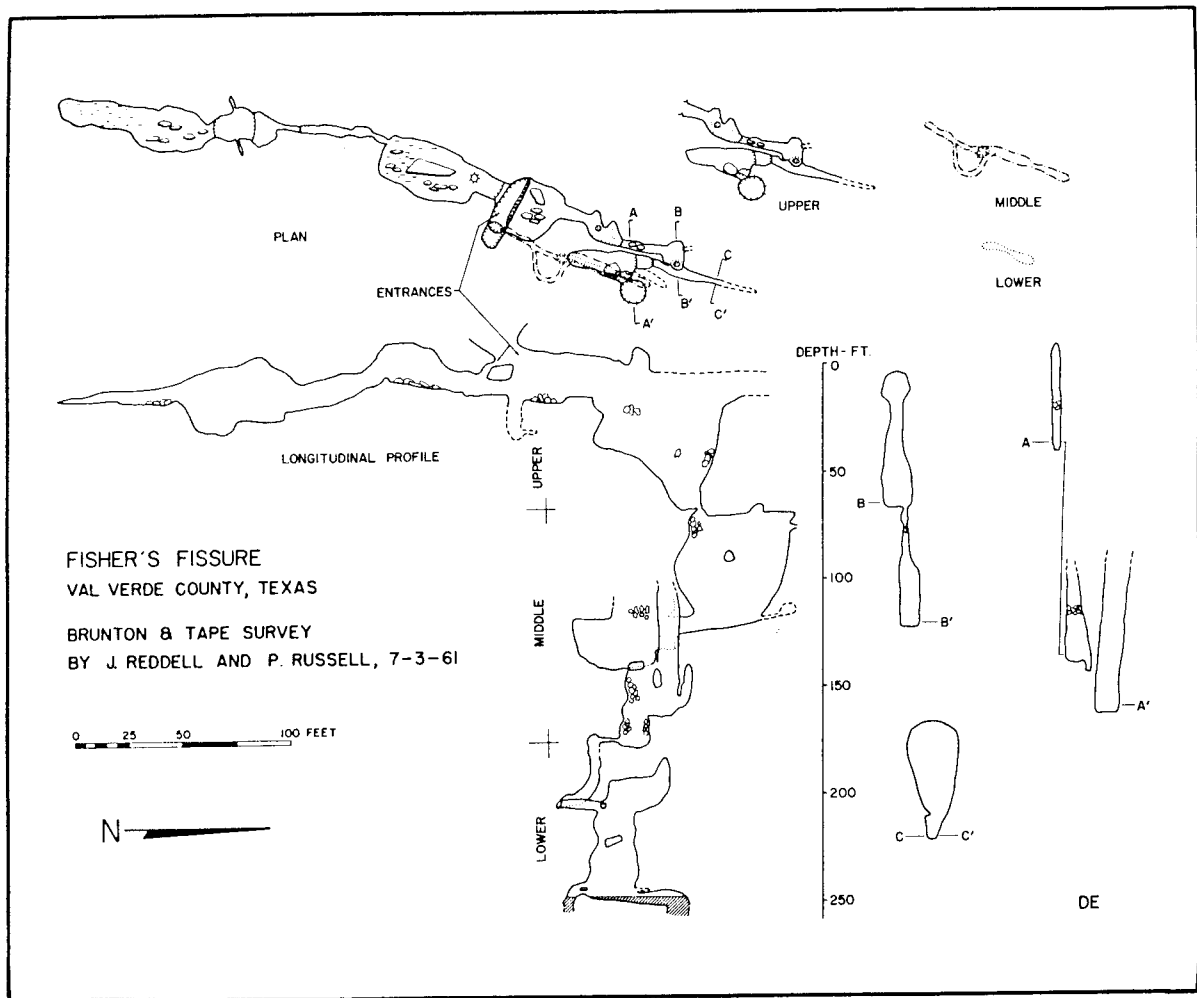


Figure 2. Fisher's Fissure by DE, 1961

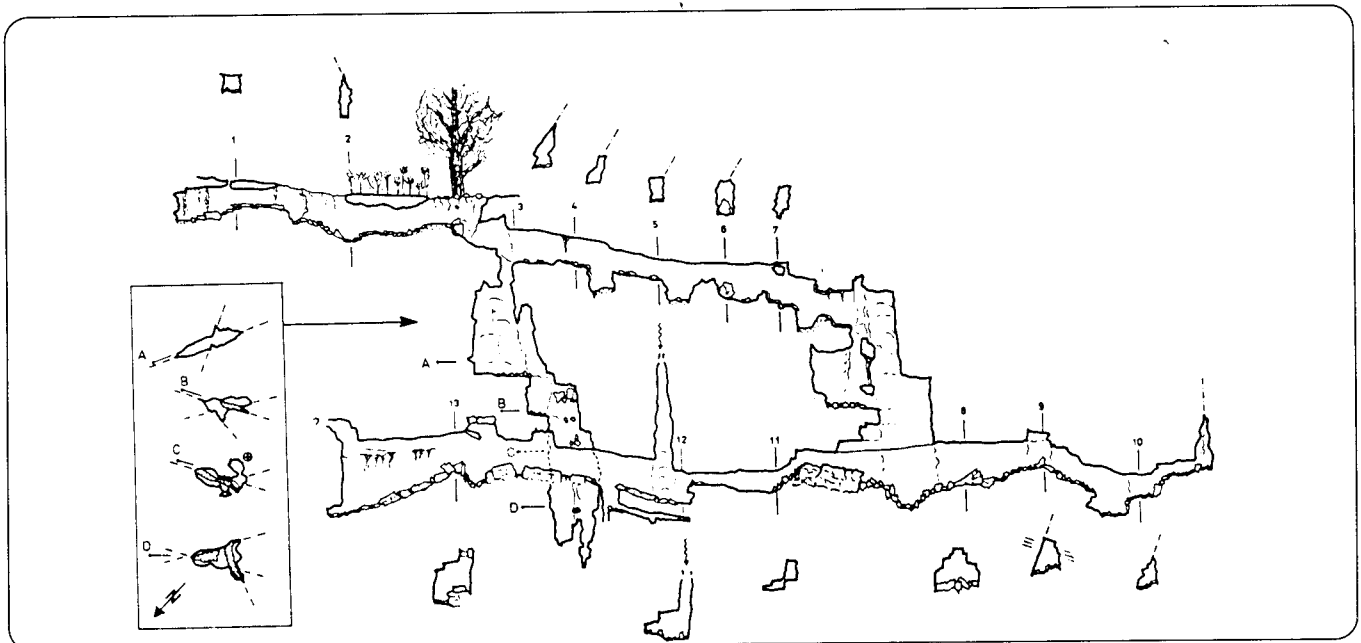
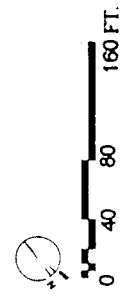
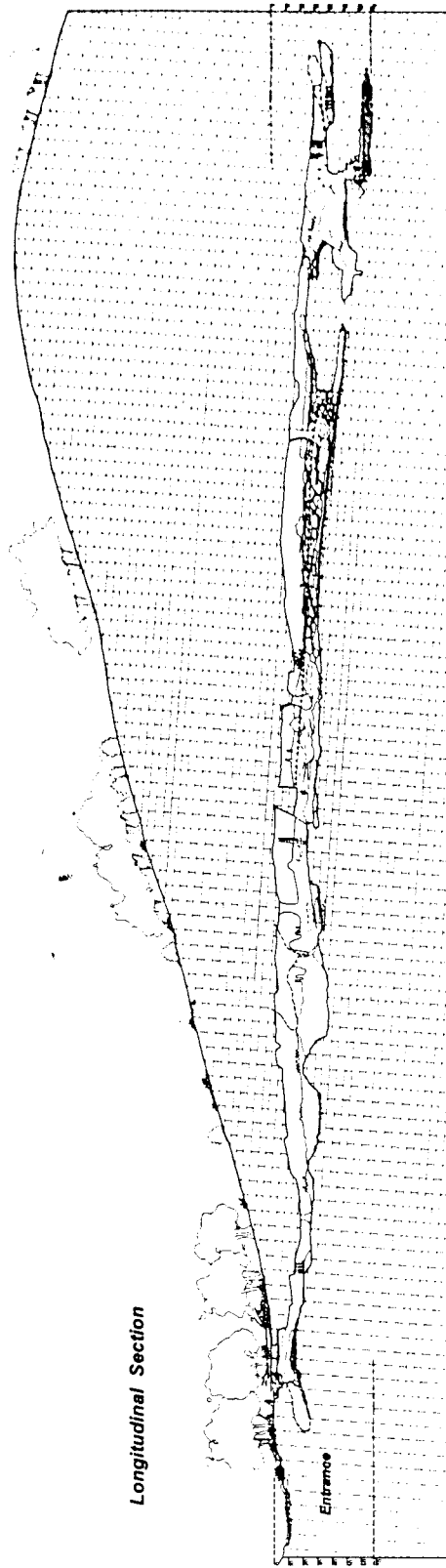
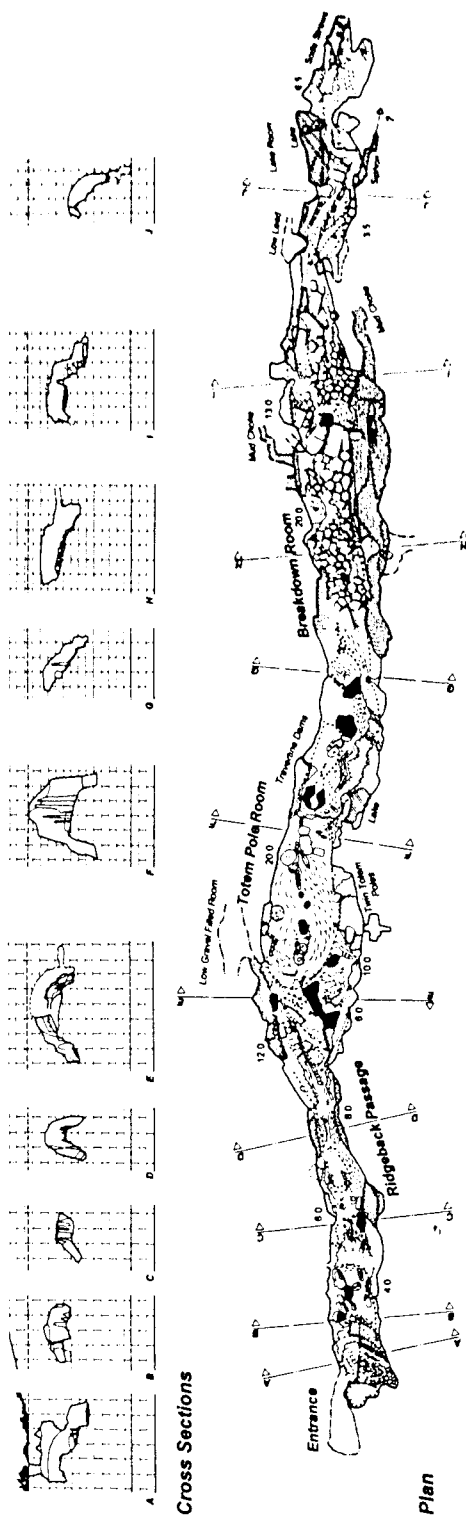


Figure 3: Gruta del Café, Mexico, by Bitterli & Widmer





Survey and Tape Survey  
 Dallas/Fort Worth Grotto  
 Blaine Grotto  
 John P. Brooks, Brian Burton  
 Alan Cobb, Andy Grubbs  
 Jerry Jordan, Sheila Knight  
 July 4-5, 1985

**Palace Cave**  
 J. Wells Ranch Cave  
 Kinney County, Texas

Cartography: John P. Brooks  
 Data Reduction: RLB Holbert  
 Standard AAMCS symbols used

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