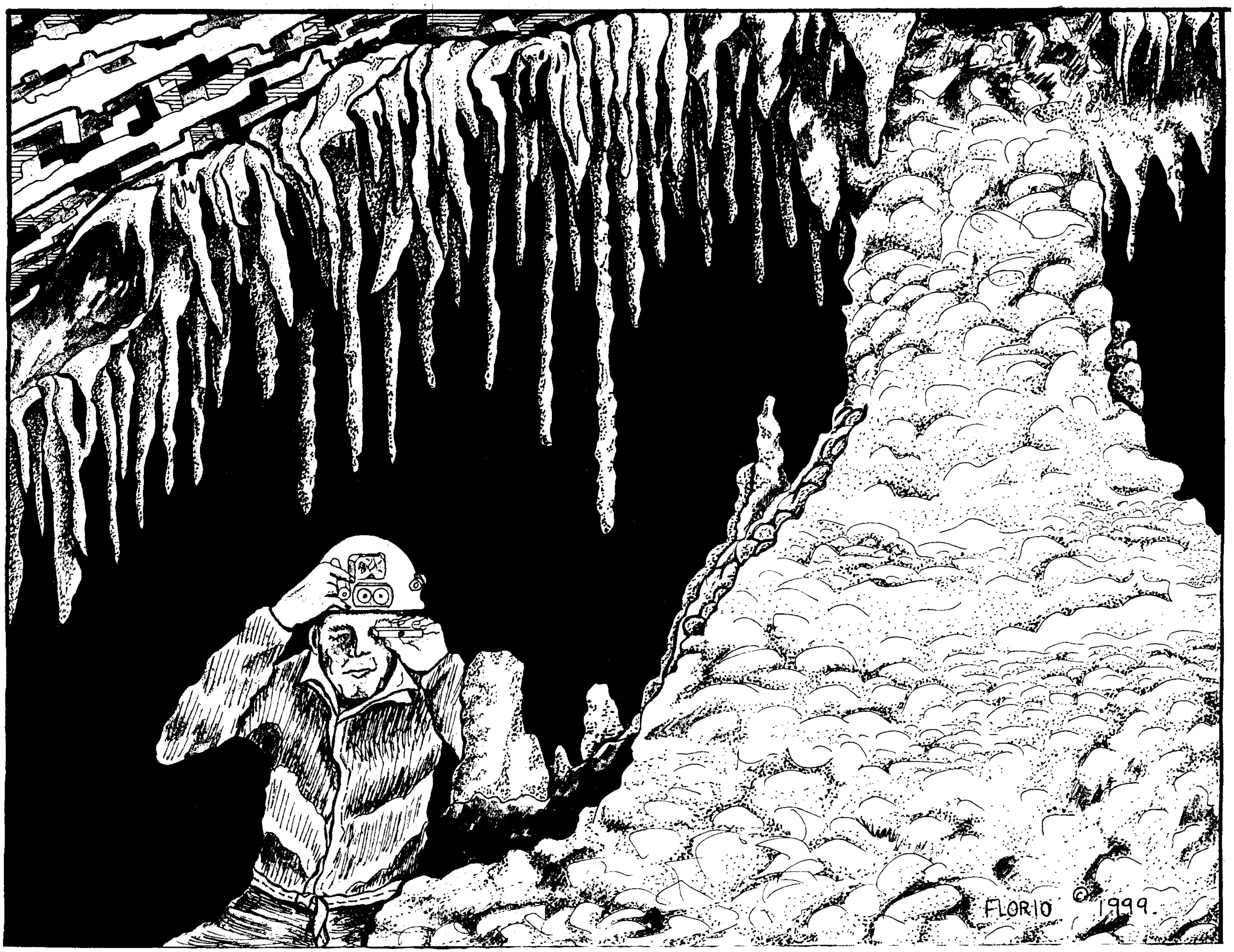
Compass & Tape

Volume 14, Issue 2, Number 46



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: Does 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 3 years ($12.00). Checks should be made payable to *"SACS"* and send to the Treasuer.

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 primaly 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.

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Inside:

Front Cover: Illustration of Tom Oakes, Central Connecticut Grotto, taking a compass bearing in virgin passage in West Virginia. Artwork by Joanna Florio-Jeffreys

Back Cover: Amazing Maze Cave, Texas, Cartographer: Mike Wharton, reprinted from 1994 NSS Convention Guidebook.

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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, grammer, or punctuation, and to edit for clarity, so long as such alternations 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.

SUBMISSIONS

All types of materials related to cave survey and survey data, cartography, and cave documentation in general, 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 is any form. shape or size is also welcome

Send all submission for *Compass & Tape* to:

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2000 NSS Convention, Elkins, West Virginia
Survey and Cartography Section

CALL FOR PAPERS

This is a call for papers for the Survey and Cartography session at the 2000 NSS Convention. The session is informal and provides a good way to tell other cave mappers what you are doing, and to discuss problems related to cave surveying, data management and manipulation, and cartography. Most cave surveyors have either devloped 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 be included 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 presented can be for any level of mapping/cartographic experience. A partial list of potential presentation topics include:

- Cave mapping applications of high-accuracy GPS and digital mapping technology
- How to keep cave mud off your survey instruments
- How to minimize instrument fogging
- 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, critique)
- New tools and toys to aid in mapping or cartography
- Representing complex vertical caves on a 2-dimensional map
- Use of computers to 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 ususal 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 comptuer. 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 so that he can insure that the abstract gets scheduled and into the Convention Program. Please be sure that your abstract includes a summary of your conclusions and results, in addition to a simple statement of what you are going to talk about. Roger's address is 910 Laurel Street, Rome, NY 13440. His phone number is 315-336-6551.

The tentative deadline for receiving abstracts is May 1, 2000 though earlier submission is encouraged. Abstracts can be submitted via email to the SACS Session Chair, Roger Bartholemew (RVictor43@aol.com) or to Bob Hoke (bobhoke@smart.net)

Check the SACS website for updated information on deadlines and scheduling.

1999 NSS Survey & Cartography Section Meeting Minutes

July 15, 1999
NSS Convention, Filer, ID

The annual membership meeting of the NSS Survey and Cartography Section was called to order by Section Chair Carol Veseley at 12:50 pm on Thursday, July 15 1999. There were approximately 27 members present.

Vice Chair's Report: Roger Bartholomew thanked the Survey Session presenters and noted that papers for the 2000 convention are welcome. Carol noted that Roger did an outstanding job in organizing the Survey Session and he received a round of applause from those present.

Secretary's Report: George Dasher was not present, but Bob Hoke read a brief report from him. He said that his secretarial responsibilities had been minimal during the last year. He also noted that his address was incorrect in *Compass & Tape*. (This has since been corrected. -ed.)

Treasurer's Report: Bob Hoke said that the Section is in excellent financial shape, with about $2,800 in available funds. He said that he sends sample issues to anyone whose map appears in the newsletters received by the DC Grotto and suggested that members send the addresses of prospects to him so he can send them a sample issue. Copies of the 1998 financial report were available to be picked up, but there was little apparent interest.

Old Business: none

New Business: Special *Compass & Tape* issue: Scott Schmitz suggested reprinting some of the winning Salon maps, along with their critique sheets, as a special issue of *Compass & Tape*. The maps would have to be reduced for publication, but some sections might be enlarged if they are discussed in the critiques. Bob Hoke noted that a normal issue of *Compass & Tape* costs about $175 to print and mail. He then moved that the Section authorize the expenditure of up to $400 to print and mail the special issue. The motion was seconded and passed. Scott Schmitz agreed to gather the material and prepare the special issue for printing.

Sketching Workshop: Carol Vesely said that she and Pat Kambesis will probably run a map sketching workshop at the 2000 NSS convention. The workshop will include both a classroom session and a field exercise, perhaps in the entrance area of Bowden Cave (which is near the convention site).

Surveying Workshop: Bob Thrun suggested that a basic surveying workshop be held at the 2000 convention, and he volunteered to run it. He may also use the entrance area at Bowden Cave for the class. Both he and Carol Vesely noted that they will need a lot of assistants to help with the workshops.

Computer Drafting Workshop: Hazel Barton suggested that a computer drawing class be held at a future convention. The consensus was that it is a good idea if enough computers and appropriate software can be made available and that it is probably not practical to do it at the 2000 convention, but it would be good in 2001. Someone noted that many software companies allow 30-day demos of their software.

Survey Contest: Roger Bartholomew noted that there was no survey contest this year because

Hubert Crowell was not present to run it. Bob Hoke said that there is always a survey contest at OTR (the site where the 2000 convention will be held) and that it may be possible to convince George Dasher to set one up for the convention. Hoke will discuss the possibility with Dasher, Roger Bartholomew, and Hubert Crowell. The OTR contests do not require anyone to be present to administer the contest so it can be run anytime during the convention.

Cave Naming Conventions: Russ Kennedy said that he is interested in reprinting, and possibly revising, his paper on recommendations for naming caves. He would like to print it in *Compass & Tape* (and other publications) and solicit suggestions for changes.

Map Salon: Steve Reames reported on his experience as a map salon judge. He said that was a lot of work and that he liked the new categories (apprentice, experienced, professional/medal winner). He noted that the contestants will be able to comment on the judge's comments this year for the first time. Bob Richards suggested that the maximum number ribbons allowed should be related to the number of maps entered and not be a fixed number. Rod Horrocks will be run the map salon at the 2000 convention.

Elections: Carol Vesely said that all the current officers are willing to run again, and asked if anyone else was interested in running for any office. There was a sudden silence. Someone moved that the current officers be elected by acclimation. The motion was seconded and quickly passed. The new (and old) officers are: Chair: Carol Vesely; Vice Chair: Roger Bartholomew; Secretary: George Dasher; Treasurer: Bob Hoke.

Bob Hoke
Acting Scribe

SACS Cartographic Salon 2000

This year's Cartographic Salon will be coordinated by Rod Horrocks. **The postmark deadline for mail-in entries is May 15, 2000.** Rod's mailing address is 2201 Wilson Ave, Hot Springs, South Dakota 57741. **Maps can also be hand-delivered to Rod at the Cartographic Salon exhibition area at the NSS Convention by Monday, June 26, 2000.** A self-portrait slide should be included with all entries.

There is no fee for map entries. Please enter copies rather than originals. Maps will be considered to have been donated to the NSS unless otherwise specified upon submission. If you wish your entry returned by mail, please provide cost of postage and map tube or envelope.

Cartographic Salon entries must be representations of caves or karst-related features. There is no restriction on method of presentation and innovative techniques are encouraged.

Judging will occur at convention. At entrants request, maps may be submitted for display only (no judging).

If you have any questions about the upcoming cartrographic salon contact Rod via email at Rod_Horrocks@nps.gov or call 605-745-1158.

NSS
Cartographic
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Judging Criteria for SACS Cartographic Salon

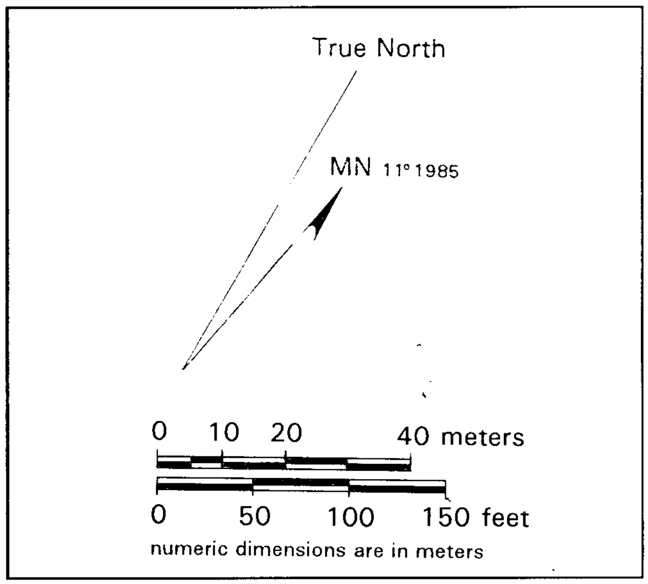
SACS Cartographic
Salon Committee

The SACS Cartographic Salon Committee was comprised of George Dasher, Bob Gulden, Tom Kaye, Doug Roberson, George Veni, and Carol Vesely. The following is an explanation of the Judging criteria for how the NSS' Cartography Salon. The intent is to provide uniform standards by which maps can be fairly judged, and to aid cartographers in developing better cave maps.

Mandatory Requirements

North Arrow: All cave maps must have a north arrow. This arrow should point to true north and, if the cartographer wishes, may include a subordinate magnetic north arrow. A magnetic north arrow by itself, though not preferred is acceptable as long as the date is displayed with it. The north arrow must be long enough to be useable, but it is should not be so ornate that it is distracting. The most optimal north arrow includes a true north arrow, a magnetic north arrow, and the date of the magnetic north.

Bar Scale: All cave maps must have a bar scale, and this bar scale must include the linear units. The cave map may include two bar scales, one for meters and one for feet. Ratio scales, such as 1:600, or written scales, such as 1" = 50', are not desired because, if the map is reduced or expanded, then this scale will be incorrect.

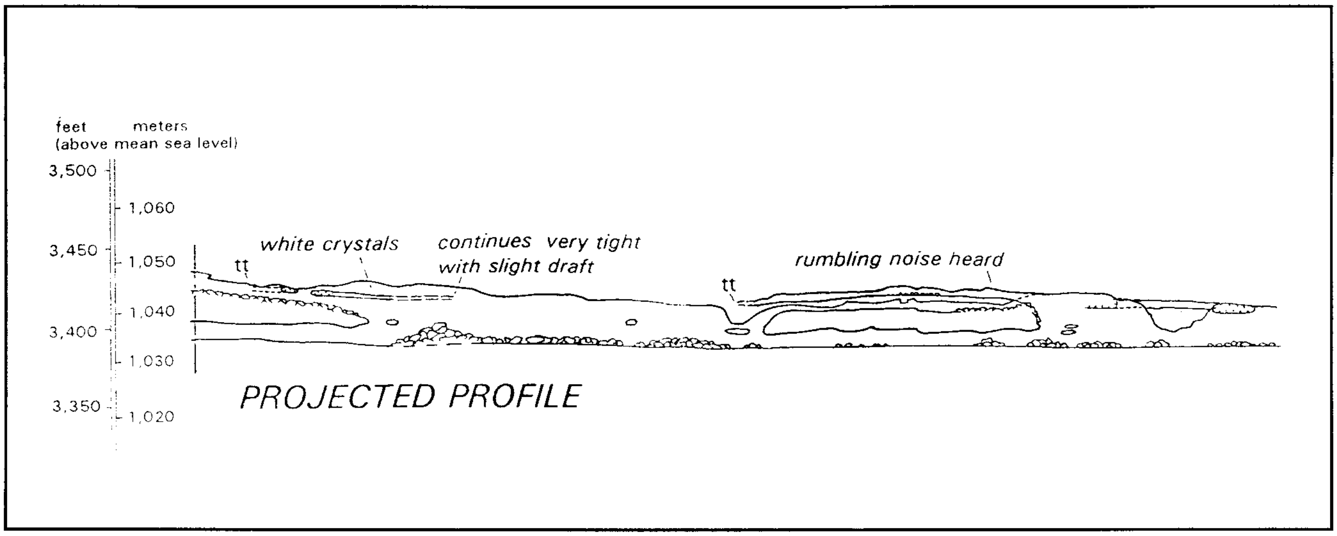


Examples of north arrows and bar scales

Date: All maps must include a date. Features change, both inside and outside of the cave. This date should not be the magnetic or cartographic date. Rather it should be the date of when the cave was surveyed.

Vertical Control: All maps must have some kind of vertical control. Usually, in North America, this is shown as either a profile or as vertical symbols. Both methods can be utilized together. If a profile is used, it should include a vertical bar scale and it should be labeled as to type (e.g., Projected Profile, Expanded Profile, or Idealized Profile). If vertical symbols are used, the map should be prominently noted as to whether the units are in meters or feet. These vertical symbols should include (as needed) cave elevations, pit depths, ceiling heights, and water depths. In addition, a zero datum should be labeled near the cave's main entrance.

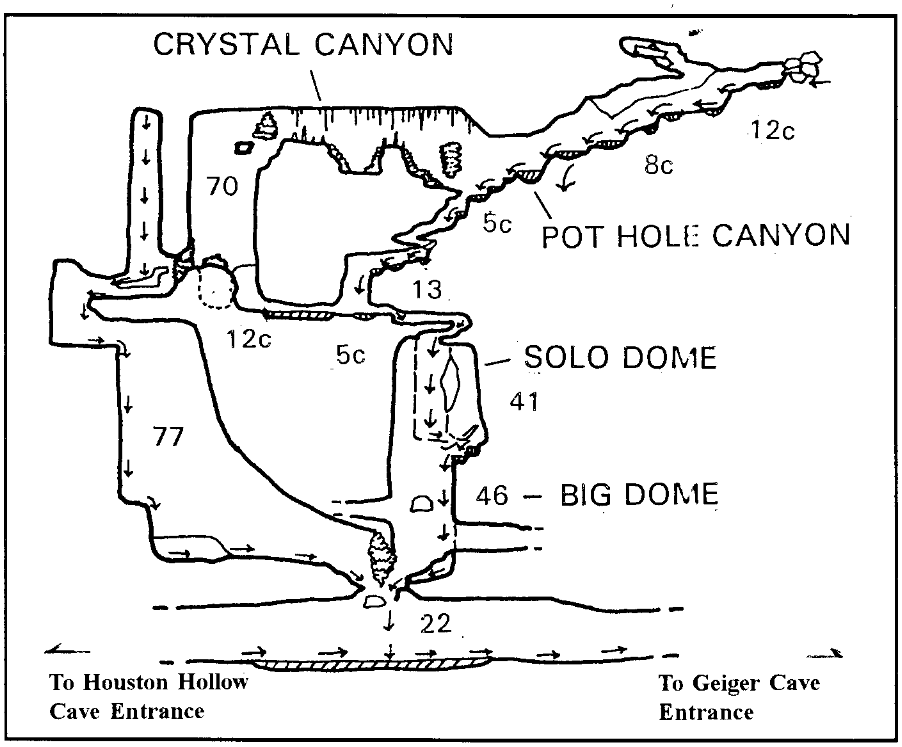
Instead of the two more popular North American methods of showing elevations, the cave map can



Vertical control, from Kazumura Cave Atlas, Medal-1997, Cartographers: Carlene Allred & Bob Richards

utilize contours, either drawn inside or outside the cave passage, or it can use a large quantity of cross-sections and show the vertical on each cross-section.

Obvious Entrance or Connection with the Rest of the Cave: All cave maps must have an entrance or a connection with the rest of the cave. If this entrance or connection is not obvious on the map, then it should be marked and made obvious. If the map is of a section of the cave, then the connection of that section with the rest of the cave should be made obvious or marked. If the map is a quadrangle that connects to other quadrangles, then the places where a cave passage "runs off" the edge of the quadrangle are considered as the obvious connection and do not have to be further marked.

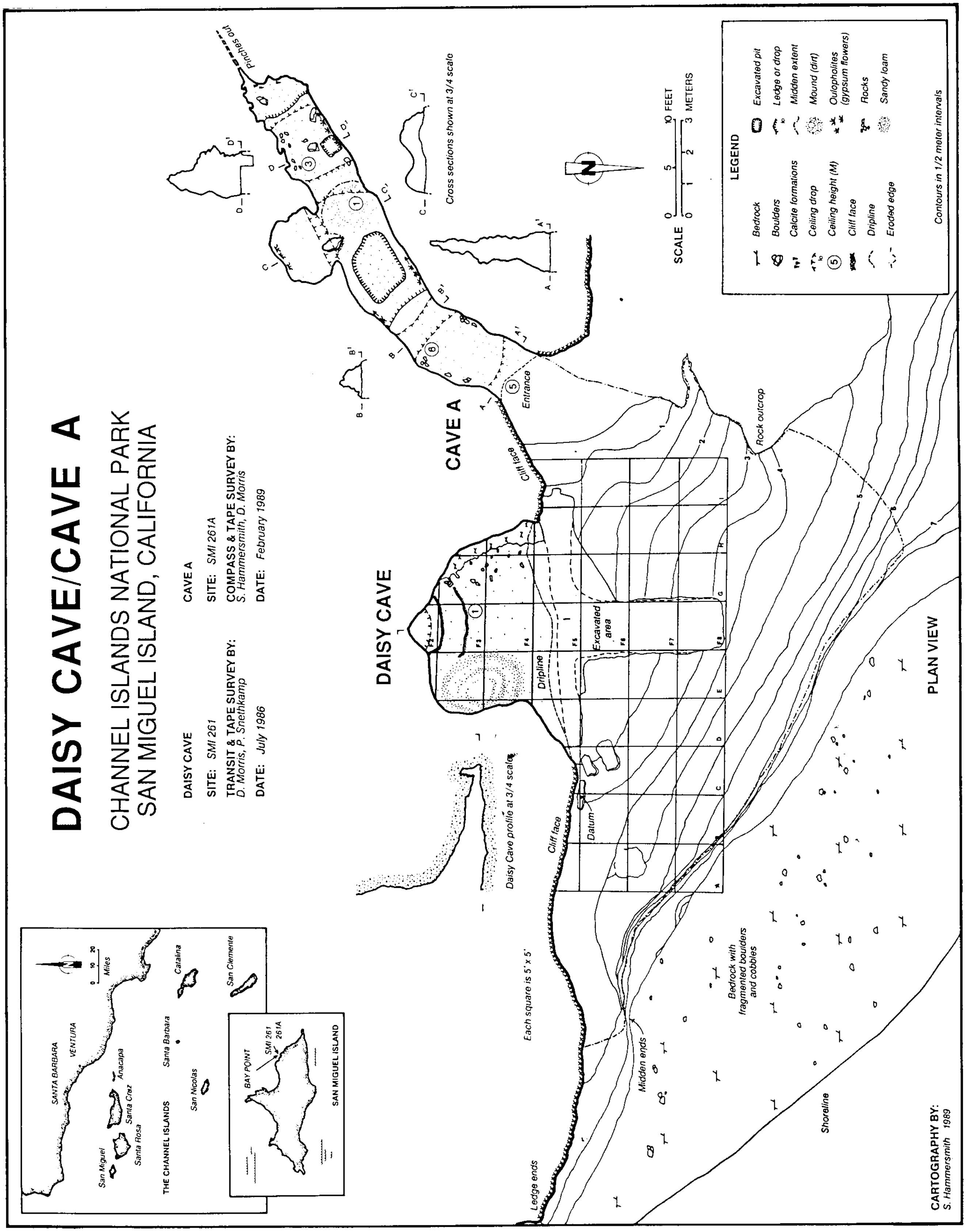


Partial profile of a section of Geiger Cave, AL showing connection to rest of cave. Cartographer: James H. Smith

Cartographer or Survey Group: All cave maps must include the cartographer or the survey group's name. Thus, if someone is interested in the cave—be they either a geologist, biologist, rescue expert, or another exploratory group—they can contact the cartographer or the original survey group. Simply put, the cave map is a scientific document, and it should have an author and a date.

Quality Factors

Balance and Layout: Does the cave map appear well balanced to the eye? Are some areas of the map blank while other areas are crowded? Did



This example contains all of the mandatory elements of a salon map. In addition, site details, legend, cross sections and area location insets visually convey a great deal of information about this archeologic site. Cartographer: Susan Hammersmith Morris

the cartographer make good use of white space?

Drafting Technical Quality: How technically correct is the drafting? Are the line widths consistent? Do the lines end and blend well, without blobs of ink? Are the symbols drawn well? Are the symbols correct? Are the outside walls of the cave obvious? Is there a True North Arrow? Is the magnetic north arrow out-of-date relative to when the cave was surveyed?

Detail Thoroughness: Is there too little detail? Is there too much detail? Does it extend into every passage? Is it consistent throughout the entire map? Is the detail easy to understand or is it confusing? Are the more mundane floor features shown? Is ceiling detail shown? Are conjectural ceilings or walls shown? Does the detail match the legend or the list of symbols utilized? Would a caver be able to use the map to navigate through the cave?

Vertical Control: How well is the vertical explained? Has the cartographer adequately dimentioned ceiling heights, pit depths, cave elevations, and water depths. Are there too few symbols to fully comprehend the vertical nature of the cave? Horizontal caves are no exceptions! Is the Profile View large enough and well centered enough to be understood? Is a vertical scale included with the Profile View? Does the Profile View include the entire cave? How well does the Profile View match the Plan View?

All cave maps which use vertical symbols and all maps of caves with more than one entrance should contain a zero datum. This datum should be a precise, labeled point and should be included on any profiles. Leader Lines to each vertical symbol's exact location in the passage may or may not be utilized.

Lettering: Is the lettering even and consistent? Is it too small or too big? Is it all evenly spaced, both horizontally and vertically? Is the lettering easy to read?

Visual Impact: Does the cartographic presentation make the map the cave seem interesting or boring? Overall, how 'good' does the map look?

Additional Factors

Still other items can be used to enhance the cave map. These include, but are not limited to:

Site details, such as geology, surface and cultural features;

Complex representations, such as multi-level caves or cave passages;

Imaginative innovations, which enhance the understanding up the cave. The use, or lack of use, or poor usage of these features should be considered when the judges assign point values in the various categories.

Cultural Location: This should be included on the vast majority of all cave maps. A few maps, however, because of the sensitive location of the cave, do not include the cultural location. Abbreviations should not be used in the cultural location.

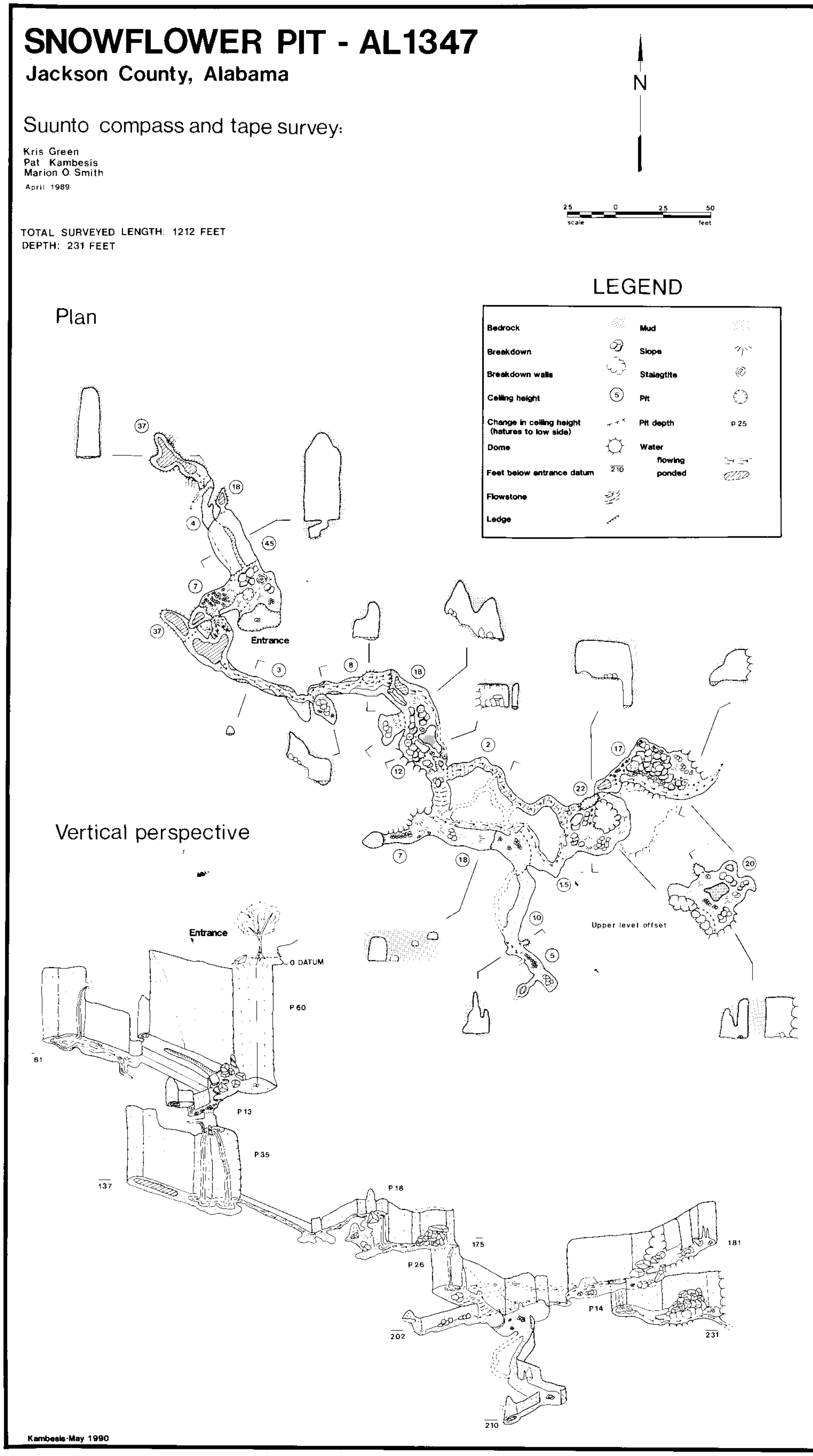
Precise Geographic Locations: This is a controversial issue. Some cartographers include them, others do not. It should be remembered, however, that the sole difference between sport and science is good documentation. If the cartographer has not allowed for the map user to generally locate the cave in the field, then the cave has not been documented in a way that allows the map user to fully utilize the map. What this means is that some sort of location should be provided (at the very least, county and state).

It is possible, rather than putting a precise geographic location on the map, to place a state speleological survey pointer (e.g., a county cave number) on the map. This informs the map user that a state speleological survey exists. Most state cave surveys are willing to provide locational information if the requestor can demonstrate a valid need to know.

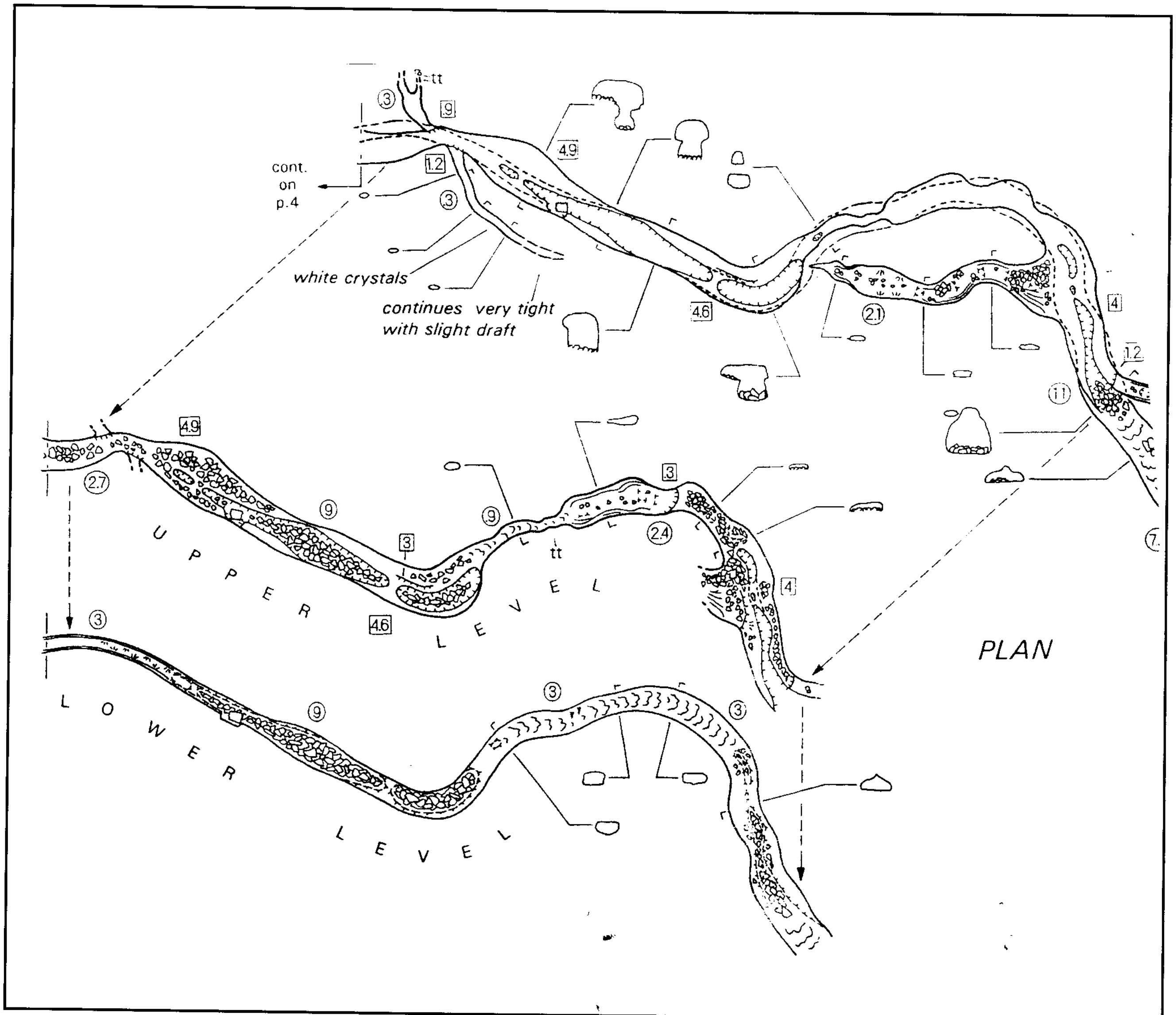
If a precise geographic location is placed on that cave map, and if latitudes and longitudes are used, then which latitude and longitude should be stated on the cave map (e.g., are they north, south, west, or east?)

If UTM coordinates are used, then the UTM zone should be stated on the cave map. If state plane coordinates are used, then which state plane coordinate system should be stated. Elevations are always above some datum, such as mean sea level, or one of the North American datums (e.g., the 1927 North American or 1983 North American), and these should be noted on the cave map. Abbreviations are not recommended in labeling the Precise Geographic Location.

Cross-Sections: These are extremely important as they illustrate the shape of the passage (perpendicular to the survey line) and can often be used to show relationships of the various cave passages to each other. When at all possible, cross-sections should be included on the cave map. Detail inside the cross-sections should be shown and this detail should match the detail on the Plan and Profile Views. Cross-sections should only be omitted in the most complex, crowded maze caves, and only then after much soul-searching. Maps without cross-sections usually do not score well in the Cartographic Salons.



Innovative presentation of profile. Medal-1990, Cartographer: Pat Kambesis



An elegant presentation of of multi-level passages. From Kazumura Cave Atlas, 1997 Medal Winnter. Cartographers: Carlene Allred and Bob Richards

Cross-sections can either be drawn next to the cave passage or away from the passage and then flagged with letters or numbers. Cross-section lines should be arrowed to show the direction of view, they should show the horizontal and vertical relationships of adjacent passages. They should be consistent and should not be confused with passage lines or detail. They should not be squeezed in too close to the cave passage, nor should they be placed too far from that passage.

Type of Survey: This is very important. While most North American cave surveyors choose not to use survey grades, the map should be noted as to its type (e.g., Topofil, Brunton and pace, or Suunto and fiberglass tape). In addition, loop closure accuracy may also be included.

Legend: As many cave map users are not cavers, it is often a very good idea to include a legend with the cave map. All non-standard cave symbols should be explained or formatted into a legend. If there is no legend, then it is good idea to note what set of cave symbols were used.

Length and Depth of the Cave: Most cave maps include the length and depth of the cave. Linear units must be included. The length of caves can be measured by one of two methods, surveyed or horizontal length. If no method of measure is noted on the map, it is then assumed that the length is the surveyed length, which is the preferred method. The depth of the cave is the difference between the elevations of the highest and lowest station or point in the cave. These may or may not be at an entrance.

Passage endings: Passages should be shown as they end. Those passages which became too small for human passage, or are too high, or otherwise beyond the abilities or time of the surveyors, should be should shown as continuing. Passages which ended in the cave should be shown by the cartographer as endings, with no passage continuing. The words "Too Tight" or "Too Small" may or may not be used at the passage endings.

Personnel: It is always a nice touch to say who helped map the cave. Credit may be given to the project leaders, the people who reduced the data, and the cartographers. A thank you can also be given to the landowner or the appropriate government agency.

Miscellaneous

Survey stations should not be shown on the final map, unless the map will be used for future geological, biological, or paleontological work.

State or province speleological survey code numbers can be displayed on the map. These may be placed in the title block, or they may be displayed in an unobtrusive manner elsewhere on the map. The code number should not be designated in such a way that the map user must have an "inside" knowledge of the Survey to understand the code. If no cultural or geographic location is given on the map, then the state or province speleological survey code number must be displayed in a prominent and obvious location on the cave map, as this code is now the only method by which the user can locate the cave in the field.

Unobtrusive notes on the geology, biology, history, or whatever can be included on the map if the cartographer so wishes.

An unobtrusive artistic drawing of the cave entrance or some feature in or around the cave can be included if the cartographer so wishes. These can enhance the map a great deal.

Borders: All maps should include a border. Some maps include double borders. Maps have won awards in the past without borders; however, this is the rare exception, not the rule.

Copyrights are common on many cave maps.

1999 NSS Convention Cartographic Salon Entries and Winners

by Hazel Barton
1999 Cartographic Salon Coordinator

This year 31 maps were accepted for display, representing 11 US States and three countries, including; Indonesia, Mexico and China.

APPRENTICE CATEGORY

1. Ponderosa Cavern, Quintana Roo, Mexico
   Gary Walten

2. James Cave, Lee County, Virginia
   Jim West and Kenneth Storey

3. Pruitt's Pit Cave, Rockcastle County, Kentucky
   Jim West and Kenneth Storey

4. Achilles Heel, Heceta Island, Alaska
   Connie LaPerriere

5. Ayers-West Cave, Hancock County, Tennessee
   Jim West and Kenneth Storey

6. Gear Grabber Grotto, Fayette County, PA
   Alex Boughamer

7. No Bufferin, Heceta Island, Alaska
   Connie LaPerriere

8. Bray Ice Cave, Siskiyou County, California
   Bighorn Broeckel

Honorable Mention

1. Papoose Cave, Idaho County, Idaho
   Pete Crecelius

2. Hellsinky, Heceta Island, Alaska
   Connie LaPerriere

3. Las Grutas De Cuesta Chica, Tabasco, Mexico
   Abigail Wines

Merit Award

1. Goa Hatu Saka, Seram, Indonesia
   Chris Andrews

2. Eiswert Cave #2, Lycoming County, PA
   Jim 'Crash' Kennedy

EXPERIENCED

1. Down Draft Cave, Skamania County, WA
   Garry Petrie

2. Badger Cave, Guizhou Province, China
   Peter Bosted

3. Lilburn Cave, Tulare County, California
   Peter Bosted

4. Coyote Cave, Wind Cave Ntl. Park, SD
   Joel Despain

5. Parson's Cave and Franklin's Pit,
   Wise County, VA
   Bill Balfour

6. Dynamite Cave, Skamania County, California
   Garry Petrie

7. Caves of Basket Bay and Kook Creek, Chichagof Island, Alaska
   Carlene Allred

8. La Cueva De Los Ecos, San Luis Potosi, Mexico
   John Ganter

Honorable Mention

1. New Cave, Skamania County, Washington
   Garry Petrie

2. Lime Creek Cave, Eagle County, Colorado
   Paul Burger

Merit Award

1. Narrows Cave, Williams Canyon, Colorado
   Paul Burger

MASTER/PROFESSIONAL

1. Wind Cave, Wind Cave National. Park, SD
   Mike Hanson

2. Hurricane Crawl Cave, Sequoia and Kings Canyon National Parks, California
   Joel Despain

3. Links Cave and Missing Link Cave Giles County, Virginia
   Mike Futrell

Honorable Mention

1. Sexton Cave Section, Kazumura Cave, Hawai
   Carlene Allred and Bob Richards

Merit Award

1. Cueva De Villa Luz, Tabasco, Mexico
   Bob Richards

MEDAL

From the 'experienced' category:

Arabica Cave, Heceta Island, Alaska
Carlene Allred and David Love.

Carlene has now won 2 medals and moves up to the Master/Professional division.

HOW COMMON ARE BLUNDERS IN CAVE SURVEY DATA?

By Larry Fish

One of the most important problems facing cave surveyors is blunders. Blunders are fundamental errors in the surveying process and, unlike random errors, they can have drastic effects on the accuracy of a survey. For this reason, it would be very useful to know how common blunders are in cave survey data. Not only does this question have implication about the accuracy of our maps, but it also has implications for the design of cave survey software.

Background: Types of Survey Errors

There are three kinds of survey errors: random errors, systematic errors and blunders. Random errors are generally small errors that occur during the process of surveying. They result from the fact that it is impossible to get absolutely perfect measurements each time you read a compass, inclinometer or tape measure. They are predictable, their effects are generally small and they can be dealt with using standard statistical techniques.

Systematic errors occur when there is a constant, fixed error being applied to the data. For example, they could be caused by a bent compass needle, a stretched tape or a distortion of the earth's magnetic field. In some cases, they can be corrected by simply subtracting a constant from the data.

Blunders are fundamental errors in the surveying process. Blunders are usually caused by human error. They are mistakes in the processing of taking, reading, transcribing or recording survey data. Some typical blunders would be: reading the wrong end of the compass needle, transposing digits written in the survey book, or tying a survey into the wrong station. The thing that makes blunders so important is that they can produce very large and unpredictable errors.

Testing Caves for Blunders:

The COMPASS survey software has a feature that calculates the percentage of loops in a cave that are blundered. The feature is designed give you an overall sense of the quality of the surveys in a cave.

The process of finding blunders begins with an estimate of the typical errors that would be found in surveying instruments. The values are specified as standard deviations of the instruments. For example, the standard deviation for a typical survey compass might be 2 degrees.

The program then walks around each loop, projecting the expected errors through each shot and mathematically combining the result. This gives you a predicted error level for the whole loop if all the errors are random. Thus, any loop who's errors exceed the prediction are probably blundered. COMPASS lists the percentage of loops that exceed two standard deviations from the prediction. Because of the way the statistics work, any loop error greater than two standard deviations over the prediction has a 95.4% chance of being blundered.

Over the years, people have sent me a large number of survey files from caves around the world. I currently have more than 250 data sets from a wide

Blunders are fundamental errors in the surveying process and, unlike random errors, they can have drastic effects on the accuracy of a survey.

Table 1

Cave Name	Number Loops	Percent. Blund.	Location	Length	
Alexander's	17	65%	?	2.0 miles	3.2 km.
Fixin'	7	57%	Colorado	1.5 miles	2.4 km.
Groaning	70	49%	Colorado	9.1 miles	14.6 km.
Lechuguilla	1142	32%	New Mexico	100.5 miles	160.6 km.
Cheve	36	30%	Mexico	16.0 miles	25.7 km.
Blue	46	28%	Eastern US	28.0 miles	45.0 km.
Wind	900	25%	South Dakota	71.0 miles	114.2 km.
St.Augustin	20	25%	Mexico	10.0 miles	16.0 km.
Kazamura	83	19%	Hawaii	38.5 miles	61.9 km.
Carlsbad	813	16%	New Mexico	22.1 miles	35.5 km.
Lilburn	238	14%	California	16.4 miles	26.3 km.
Fulford	14	14%	Colorado	1.0 miles	1.6 km.
Cave of the Winds	17	13%	Colorado	2.0 miles	3.2 km.
Fairy	29	12%	Colorado	1.5 miles	2.4 km.
Spider	149	11%	New Mexico	3.5 miles	5.6 km.
Roppel	333	2%	Kentucky	69.1 miles	111.2 km.
Average	230	26%		24.7 mile	39.7 km

variety of caves. To determine how common blunders are, I tested the survey data from a range of representative caves.

Table 1 illustrates the percentage of blundered loops in 16 caves from the U.S. and Mexico. I have lots of smaller caver, but I chose caves that had enough loops to give meaningful results. The chart represents the percentage of loops in each cave that has at least one blunder. For the test, I set the predicted instrument standard deviations at two degrees for compass and inclinometer and 0.1 foot (3 cm.) for the length measurement.

The data here represents a wide variety of caves, survey styles and surveying eras. For example, Groaning and Fixin' are tight, crawly maze caves with difficult surveying conditions. Their entrances are at about 10,000 feet (3048 m.) of elevation and the year round temperature is 39 degrees (4 C.). It is not surprising that the blunder level is high in these caves. Lechuguilla is a less challenging cave, but the chaos of large expeditions and the rapid pace of discovery produced lots mis-tie errors. Finally, the Wind Cave data actually has surveys dating back to 1934.

The majority of the caves were surveyed by cavers from the United States using U.S. style surveying techniques. It would be interesting to know if surveyors from other countries, using different techniques would get different results.

As you see from the chart, there are a surprisingly large number of blundered loops. In fact the average cave in the list has 60 blunders. In many ways this is not surprising given the difficult environment and the large number of measurements that make up a cave survey.

Table 2

Comp/Inc STD	Tape STD	Lech % Blnd.	Wind % Blnd.	Lilburn % Blnd.	Roppel % Blnd.
0.5	0.025 ft.	79.5	75.4	68.5	68.5
1.0	0.050 ft.	56.1	52.9	39.5	25.5
1.5	0.075 ft.	40.5	36.4	22.3	7.5
2.0	0.100 ft.	32.0	25.8	14.7	2.4
2.5	0.125 ft.	26.0	19.6	12.2	0.3
3.0	0.150 ft.	21.2	16.1	10.5	0.0
3.5	0.175 ft.	17.3	13.8	9.7	0.0
4.0	0.200 ft.	14.1	11.8	8.8	0.0
4.5	0.225 ft.	12.6	10.2	8.8	0.0
5.0	0.250 ft.	11.4	9.2	8.4	0.0
5.5	0.275 ft.	10.2	8.2	7.6	0.0
6.0	0.300 ft.	9.2	7.7	7.6	0.0
6.5	0.325 ft.	8.3	7.1	7.6	0.0
7.0	0.350 ft.	8.0	6.4	7.6	0.0
7.5	0.375 ft.	7.4	5.9	7.6	0.0
8.0	0.400 ft.	7.0	5.4	7.1	0.0
8.5	0.425 ft.	6.6	5.2	7.1	0.0
9.0	0.450 ft.	6.4	4.9	7.1	0.0
9.5	0.475 ft.	6.2	4.3	7.1	0.0
10.0	0.500 ft.	5.8	4.1	7.1	0.0
10.5	0.525 ft.	5.7	3.9	7.1	0.0
11.0	0.550 ft.	5.5	3.8	7.1	0.0
11.5	0.575 ft.	5.5	3.8	6.7	0.0
12.0	0.600 ft.	5.1	3.6	6.7	0.0
12.5	0.625 ft.	4.9	3.1	6.7	0.0
13.0	0.650 ft.	4.7	2.9	6.7	0.0
13.5	0.675 ft.	4.6	2.9	6.3	0.0
14.0	0.700 ft.	4.5	2.9	6.3	0.0
14.5	0.725 ft.	4.3	2.8	6.3	0.0

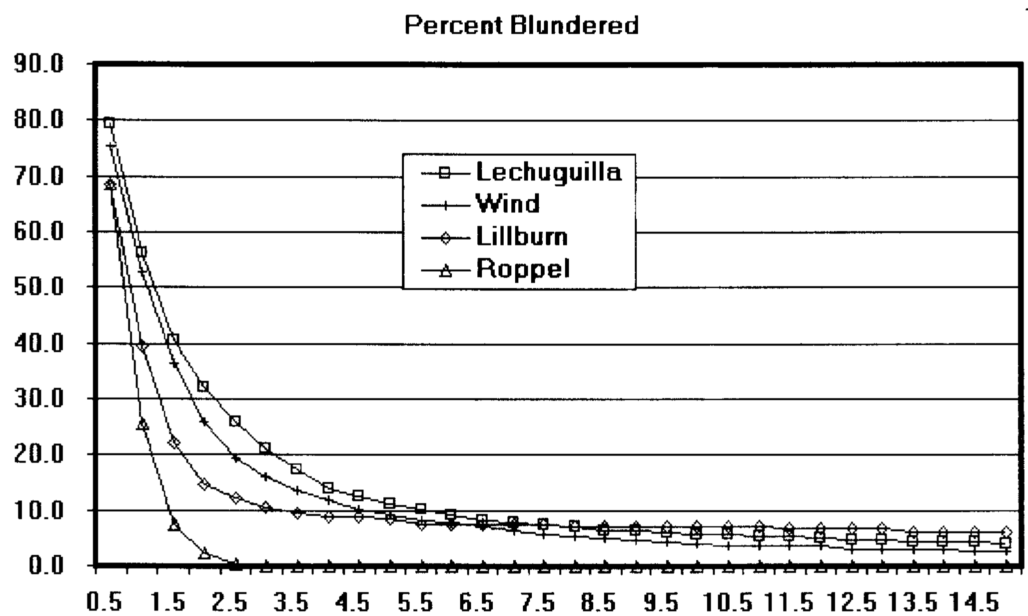
Estimating Instrument Errors

While I was working on this project, Olly Betts suggested an experiment that might show us something about instrument errors. He suggested that we gradually increase the projected instrument errors and see what happened to the percentage of blunders. The result was very interesting.

I started with 0.5 degrees STD for compass and inclinometer and 0.25 foot for tape. I then tested the percentage of blunders and increased the values by 0.5 degrees and 0.025 foot for tape. I did this for four caves representing a range of survey quality. Table 2 lists the results.

I have also included a graph, shown below, of the results that is much easier to understand. As you can see, as the standard deviations for the instruments increase, the percentage of blundered loops drops rapidly and then flattens dramatically. The best cave flattens out at about 2.5 degrees of standard deviation and the lower quality caves around 7 degrees.

I think it is easy to understand what is happening here. As the standard deviations increase, large numbers of the better quality loops are eliminated from



the group of blunders and so the percentage goes down rapidly. At some point, all we have left are loops with severe blunders that have not eliminated by the higher standard deviations. Clearly, the loops below the inflection point are blundered. You would never expect to have random errors of 10 or 15 degrees in a compass or inclinometer. Likewise, the loops at the very top of the curve must be blunder free.

You would never expect to have random errors of 10 or 15 degrees in a compass or inclinometer.

Obviously, the sudden flattening of the curve represents the point at which we shift from unblundered loops (with high instrument standard deviations) to blundered loops. Thus, this point represents the maximum standard deviation for the instruments.

By looking at the graph and calculating the first and second derivatives, it is easy to estimate the point where each line goes flat. Here is list of my estimates:

Lechuguilla -	.5 Degrees	0.375 ft.	11.4 cm.
Wind	- 5.5 Degrees	0.275 ft.	8.2 cm.
Lillburn	- 5.0 Degrees	0.250 ft.	7.6 cm.
Roppel	- 3.0 Degrees	0.150 ft.	4.5 cm.

The values may seem surprisingly large, but they are similar to other experimental values. For example, the March 1998 issue of *Compass Points* has an article describing the analysis of compass errors in an outdoor test-course. In spite of a relatively simple course and the use of experienced surveyors, some of the compass errors were in the range of 6 degrees.

Measuring instrument error this way has two advantages over the traditional survey course method of determining instrument errors. First, the values are based on the combined effects of thousands of measurements, with hundreds of different instruments, done by hundreds of surveyors, each using different survey techniques. Second, it enables us to look at the performance of instruments and surveyors in widely varying survey environments.

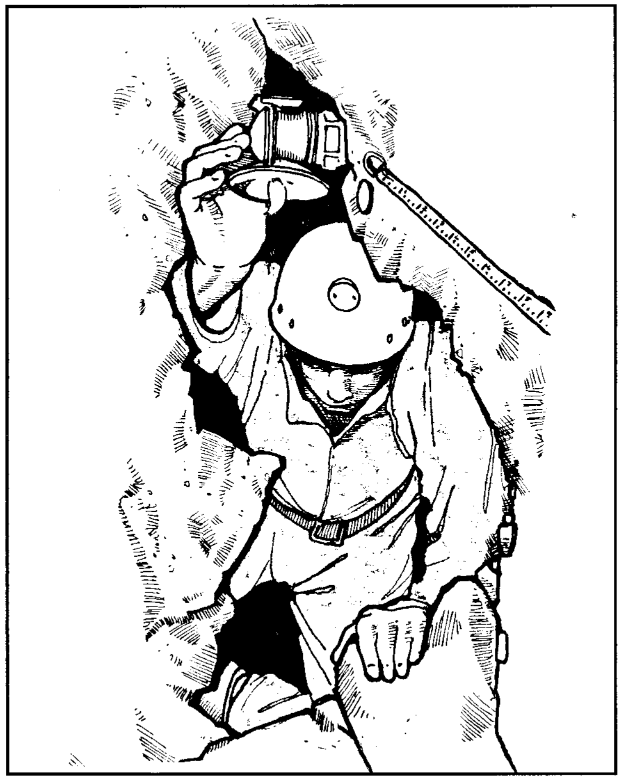
One disadvantage of this technique, is that it gives you a composite error value that doesn't tell you anything about the individual instruments. It could be, for example, that the actual tape errors are much smaller and compass errors much larger than given here. Perhaps, a more complicated test would give separate values for the individual instruments.

Conclusion:

In conclusion, it appears that blunders are a common problem in cave surveying, particularly for certain classes of caves. Also, examining real-world data is a very valuable technique for estimating the general quality of survey data and survey instruments. One advantage of the technique is that it tests the composite performance of many different instruments and many different surveyors.

Intermediate Cave Surveying Tips & Techniques

by Bob Hoke



The following is an assortment of suggested in-cave techniques that will help a survey team do a fast, accurate survey. The tips only cover the setting of stations, reading the data, and recording it in the survey book. The art of sketching is beyond the scope of this paper (and of the author).

We assume that the reader has been on at least one survey trip and has a general idea of how a survey operates and how to use a Suunto compass and clinometer. Bruntons appear to be a dying breed and are not covered here.

This paper was originally written as a handout for a cave surveying class to be offered in West Virginia in 1996, but the class never materialized. The paper was presented at the 1997 NSS Convention in Sullivan, Missouri, and some minor revisions were made following the presentation. It is intended only as a guide and is not a tutorial in cave surveying.

Any reader interested in more detail should read On Station, by George Dasher. If any of the hints presented here are contrary to the conventions used on your project or in your part of the country, then feel free to choose whichever technique works best for you.

1. SETTING STATIONS:

- The sketcher determines the length and general placement of stations.
- Properly placed stations have major impact on survey team efficiency.
- Try to put stations on prominent features when ever possible.
- A sure way to get a feature on the map is to put a station on it.
- Avoid stations on flat walls. They are usually hard to shoot from.
- If you want a station on the floor, build a cairn to get it up at least 8 inches.
- Make sure the station is at a reasonable height for instrument person.
- Avoid very long shots. They reduce accuracy and make sketching difficult.

- Make sure the station is easily usable for both fore and back shots.

2. MARKING STATIONS:

- Be discreet in marking unimportant stations. Carbide is distinctive and lasts for years. Lum ber crayon is good for rock (not mud) and lasts 2-3 years (something seems to eat it).
- Rock cairns may be appropriate in some cases (but are subject to disturbance).
- Formations are usable as stations, but don't touch or mark them in any way.
- Flood prone passage may require a small hole in a rock or other trick.
- Leave obvious, bomb-proof stations where tie-ins are likely later (side leads, etc.)

3. READING THE NUMBERS:

- It is more important to avoid blunders than to get super-precise instrument readings. (This is an opinion that may not be widely shared).
- Calibrate your instruments before (and after) each survey trip. Set up a couple of known shots near the cave for references.
- Always do backsights!! The exception would be in short dead-end leads or flyr (or splay) shots.
- Backsights should usually agree within 2 de grees (although some projects go for 1 degree).
- Take readings in a consistent order - usually dis tance, azimuth, inclination, LRCF. This helps reduce the human error in data recording and makes it easier for the sketcher to stay focused on the sketch.
- Use only one eye to read the compass (some folks use two eyes, but this may introduce er rors.
- Verify that your glasses, lamp, flashlight, hel met, etc. are not magnetic. **Warning:** most alkaline batteries contain steel and cause com pass errors.
- Be sure the compass is level. If the reading does not change when you rotate the compass it means you are not level.
- Read the correct compass scale. If your party is recording corrected backsights be sure to read the upper scale if you are shooting a backsight.
- Read the correct clinometer scale (the one clos est to the window). If in doubt, point the incli nometer straight down. The side of the scale which reads -90 is the one you want to read.
- Read the correct direction to get fractional part of tape reading.
- Know where the correct zero point is on the tape.
- Avoid tapes with 1/10 foot and inches on oppo site sides of the tape. You will usually read the wrong side of the tape.

4. RECORDING THE NUMBERS

- Keep the book clean (in your coveralls, in your mouth, whatever).
- Record "+" or "-" for for every inclination shot.
- Repeat readings after you write them in the book (not before).
- Put a decimal point in every recorded number. Include a 0 if there is room (25. or 25.0 instead of 25 because a speck of sand could make 25 look like 2.5).
- The book person should do a sanity check on the readings as they come in.
- Keep the instrument readers honest. (The sketcher should do this too).
- Tell the book person what type of instrument reading you are giving them (corrected/uncor rected foresight/backsight azimuth/inclination).

5. PASSAGE DIMENSIONS:

- Whoever records passage dimensions (LRCF) can use a "body length" to estimate distances.
- When estimating passage dimensions, record what the map should show (not a tiny crack that is impassable).
- Passage dimensions should be taken perpen dicular to the next shot.
- At the end of a passage they should be perpen dicular to the last shot, but looking in the direc tion of the shot. (This may vary in your area, but be consistent).

6. MISCELLANEOUS HINTS:

- Keep the instruments dry. They are not water proof despite whatever their owner does to try to seal them.
- High angle compass shots are very difficult. Try to use a vertical shot instead. If you must do a high angle compass shot try to use the tape as a plumb line to shoot at, or stretch the tape between the stations and shoot along it.
- Some people let the tape tail along behind them, others spool it up after each shot. Use which ever method you feel most comfortable.
- Fly stations (or splay) should have "F" (or "P") appended to them -such as a fly (or spaly) shot from XY25 to XY25F.
- Keep station names short and avoid names con taining I, O, and special characters.
- When lighting a station, don't shine your light directly at the instrument reader.
- Try to have only one person talking at a time. It is very easy to miss or garble numbers when there is lots of background talking.
- Make use of geometry to make shots easier: You can always get far behind a station. Just line up the instrument, your station, and the dis tant station in a line and take your reading.
- You can take a compass reading from as far above or below the station as you wish. Be sure to stay directly above or below your sta tion.
- You can go as far as you wish to the side of the station for a clinometer reading. Be sure to stay at the same height as your station.
- You can move away from your station if the person at the distant station moves the light the same distance and direction from that station. Make sure you communicate an exact distance.

7. COMMON BLUNDERS

- Reading the wrong direction on the tape (up to 1 foot or meter error).
- Not holding compass level (random error).
- Reading wrong compass scale (book or sketch person should catch 180 degree error).
- Reading the wrong clinometer scale (typically 10-15 degree error).
- "Decade inversion" on compass - reading wrong direction (up to 10 degree error).
- "Decade inversion" on clinometer - reading wrong direction (up to 10 degree error).
- Dyslexia in writing the numbers in book (ran dom, potentially nasty error).
- Failure to record inclination sign in book (ran dom, potentially nasty error).
- Battery, glasses, or helmet has steel (5-10 de gree error usually caught by backsight).
- Notes person records fore/back sights back wards (sketch should catch compass error).
- Illegible book - mud, erasures, lousy handwrit ing, etc. (random errors).

Internal Angles Examples

by John Halleck

There seem to have been notable misconceptions in the cave survey community about what is meant by "computing turned angles" from a survey with foresights and backsights. Hopefully this example will clarify what is meant.

Assumptions

There are [initially unknown] magnetic anomalies at every single point. (Not uncommon for a lava tube.) The survey is laid out as follows:

```
  A
 /\
B - D
 \/
  C
```

Example Survey Data

Contrived survey Data:

Shot#:	From	To	Dist	Inc	Back inc.	Fore site	Back site	(Discrepancy)
1	A	B	10	0	0	214	42	(8 degrees)
2	B	C	10	0	0	162	36	(-6 degrees)
3	C	D	10	0	0	36	209	(-7 degrees)
4	D	A	10	0	0	327	15	(7 degrees)
5	D	B	10	0	0	267	102	(15 degrees)

Note that because there are severe magnetic anomalies at all points the foresights and backsights are going to be dramaticly different. This is not wrong... they differ because magnetic north at the various stations is different.

A survey instructor has pointed out that this data looks much different than it would if it came from a real surveyor. In the interest of pushing cave surveyors back toward main line surveying, I'll include a copy of the data as they would expect it to appear.

BS is Back Station (Sometimes written +S)
IS is Instrument Station (Where you are standing)
FS is Forward Station (Sometimes written -S)
SD is Slope Distance

BS	IS	FS	AZIMUTH	VERT ANGLE	SD
	A	B	214	0	10.0
A	B		42	0	
	B	C	162	0	10.0
B	C		336	0	
	C	D	36	0	10.0
C	D		209	0	
	D	A	327	0	10.0
A	D		154	0	
	D	B	267	0	10.0
B	D		102	0	

Rearrangement

In order to do the processing we have to rearrange the data from a shot specific viewpoint (as recorded) to a station specific viewpoint.

One advantage of this is that it groups shots with the same magnetic deviation. All sightings taken from exactly the same point should share exactly the same magnetic north, regardless of what direction that magnetic north may be at that point.

Another advantage is that we can now compute "turned" angles to use in further processing.

Since we are only concerned with computing internal angles in this example, I'll drop the distance and Azimuth information.

Azimuth

from	to	is	
A	B	214	(Foresight of shot from A to B)
A	D	154	(Backsight of shot from D to A)
B	A	42	(Backsight of shot from A to B)
B	C	162	(Foresight of shot from B to C)

B	D	102	(Backsight of shot from D to B)
C	B	336	(Backsight of shot from B to C)
C	D	36	(Foresight of shot from C to D)
D	A	327	(Foresight of shot from D to A)
D	B	267	(Foresight of shot from D to B)
D	C	209	(Backsight of shot from D to C)

The pattern here is listing foresight if the shot was FROM this point, the backsight if the shot was TO this point. We are basically collecting all the measurements made at each specific point, and making a record of them with that specific point.

Note that we have to be careful here about the order of shots, angles, and labels. The angle Internal Angles Example BAD is *not* the same as the angle DAB, as one is the negative of the other. The label BAD, for example, refers to the angle between B and D as measured from A (214-154) and DAB is (154-214).

Now the internal angles in the loops can be computed.

Computation

```
Loop (A, B, D)
ABD = 042-102 =  -60
BDA = 267-327 =  -60
DAB = 154-214 =  -60
(Isn't contrived data
wonderful?)
---------------------
Total = -180 which is -1*180 + 0
```

The internal angles sum to a multiple of 180. This loop has no (angle) blunder.

```
Loop (D, B, C)
DBC = 102-162 =  -60
BCD = 336-036 = +300
CDB = 209-267 =  -58
---------------------
Total = 182 which is 1*180 + 2
```

The internal angles sum to something other then a multiple of 180. This loop contains at least 2 degrees of angle problems. It could be a single blunder of two degrees, or it could have been a +8 degree blunder and a -6 degree mistake canceling to be a two degree problem..

In this specific case, we know that CDB is blundered, but only because of the way this data was contrived. HOWEVER, in general all we know is that there is a problem (or problems) somewhere in this loop.

[Since the paragraph above was written, I've been taken to task because there IS enough information to correctly identify the blundered angle. For example, the book [Wolf and Ghilani, 1997] "Adjustment Computations, Statistics and Least Squares in Surveying and GIS", in the chapter on blunder detection in horizontal surveys, gives a technique for identifying the specific angle at fault.]

Alternate Computation

Some folk prefer positive angles. For example they take -60 degrees as 300 degrees. This makes little difference, and one could have computed something like:

```
Loop (A, B, D)
ABD = Modulo(042-102, 360) =  300
BDA = Modulo(267-327, 360) =  300
DAB = Modulo(154-214, 360) =  300
---------------------------------
Total = 900  Which is 5*180 + 0

Loop (D, B, C)
DBC = Modulo(102-162, 360) = +300
BCD = Modulo(336-036, 360) = +300
CDB = Modulo(209-267, 360) = +298
---------------------------------
Total = 898 Which is 5*180 - 2.
```

Working with Longer loops

An early reviewer of this complained that it wasn't obvious how to do a loop that wasn't a triangle. So... here is an example of the outside loop (A, B, C, D)

```
Loop (A, B, C, D)
ABC = 042-162 = -120
BCD = 336-036 =  300
CDA = 209-327 = -118
```

```
DAB = 154-214 =  -60
---------------------
       Total =    2
```

Since the outer loop also contains the blundered angle, it should come as no surprise that it also miscloses by 2 degrees.

Note that each angle is just the next angle in the loop.

And for the "positive angle" folk:

```
              Loop (A, B, C, D)
ABC = Modulo(042-162, 360) =  240
BCD = Modulo(336-036, 360) =  300
CDA = Modulo(209-327, 360) =  242
DAB = Modulo(154-214, 360) =  300
---------------------------------
       Total = 1082 = 6*180 + 2
```

Direction of loops

It really doesn't matter which direction one goes around loops. As an example, the loop above in the other direction would be:

```
  Loop (D, C, B, A)
DCB = 036-336 = -300
CBA = 162-042 =  120
BAD = 214-154 =   60
ADC = 327-209 =  118
---------------------
        Total =  -2
```

Or alternately for the positive angle folk:

```
               Loop (D, C, B, A)
DCB = Modulo (036-336, 360) =  60
CBA = Modulo (162-042, 360) = 120
BAD = Modulo (214-154, 360) =  60
ADC = Modulo (327-209, 360) = 118
---------------------------------
          Total =  178  = 180 - 2
```

Commentary

We now know that the first loop has no angle problems, and that the second loop does.

Since the first loop has no angle problems, the discrepancy between foresights and backsights in that loop must reflect real underlying differences between magnetic north between the stations.

Simple arithmetic can now show that the difference in magnetic north between A and B is 8 degrees (The discrepancy between fore and back sights in shot AB), between A and D is -7 (The negative of the discrepancy on shot from D to A) and of course between D and B it is consistently 15 (The discrepancy from shot BD). (The difference between magnetic norths is the negative of the shot discrepancy if you are tracing the graph in a direction opposite the original shot.)

If one sets A as the reference, then it is easy to list the differences for the whole of the (unblundered) net. But magnetic north at C can only be estimated, since some shot to C contains a blunder.

A major obvious assumption being made with that technique is that all shots *FROM THE SAME POINT* have the same offset from magnetic north. This is generally true unless the anomaly is being caused by something the caver is carrying.

Clearly, if you went around averaging fore and back sights, no reasonable analysis is possible. For shot AB this would give you a recorded number of:

(azimuth_A + anomaly_A + azimuth_B + anomaly_B) / 2

which hopelessly intermingles the shots and any magnetic anomalies.

Without loops you have no redundant information to check against, so detecting blunders this way is not possible. HOWEVER, in surveys with few magnetic problems, there is sometimes some information to be gained. If one computes the (apparent) magnetic anomalies in a traverse, the assumed magnetic north will be stable but different on the two traverse pieces on each side of the blunder. In most limestone areas this may aid in locating the blunder.

Mapping the Tiny Cave

by George Veni

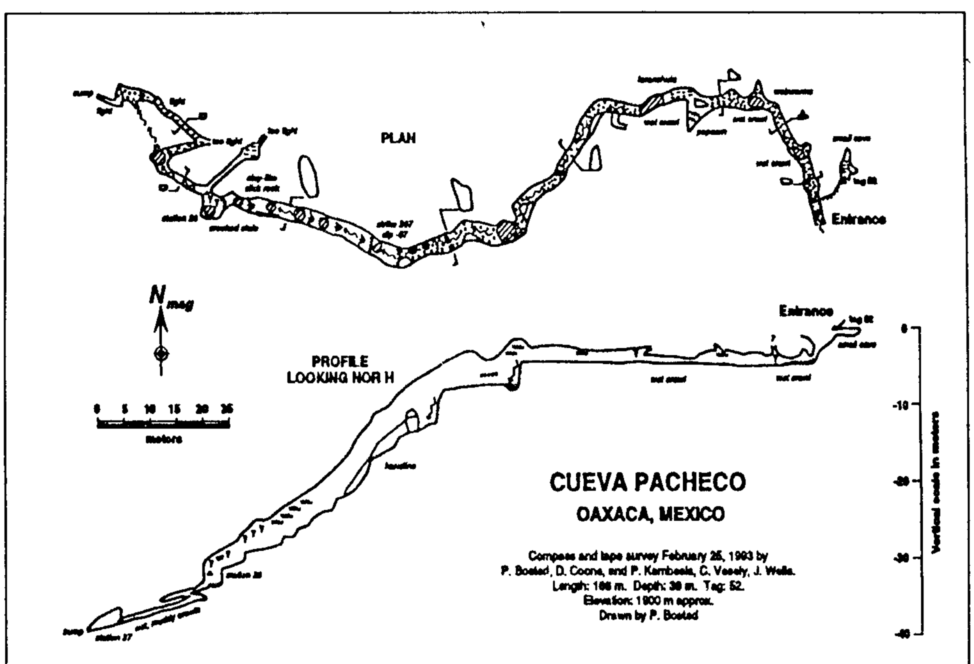
Reprinted from Compass & Tape,
Volume 2, Numer 3, Winter 1985

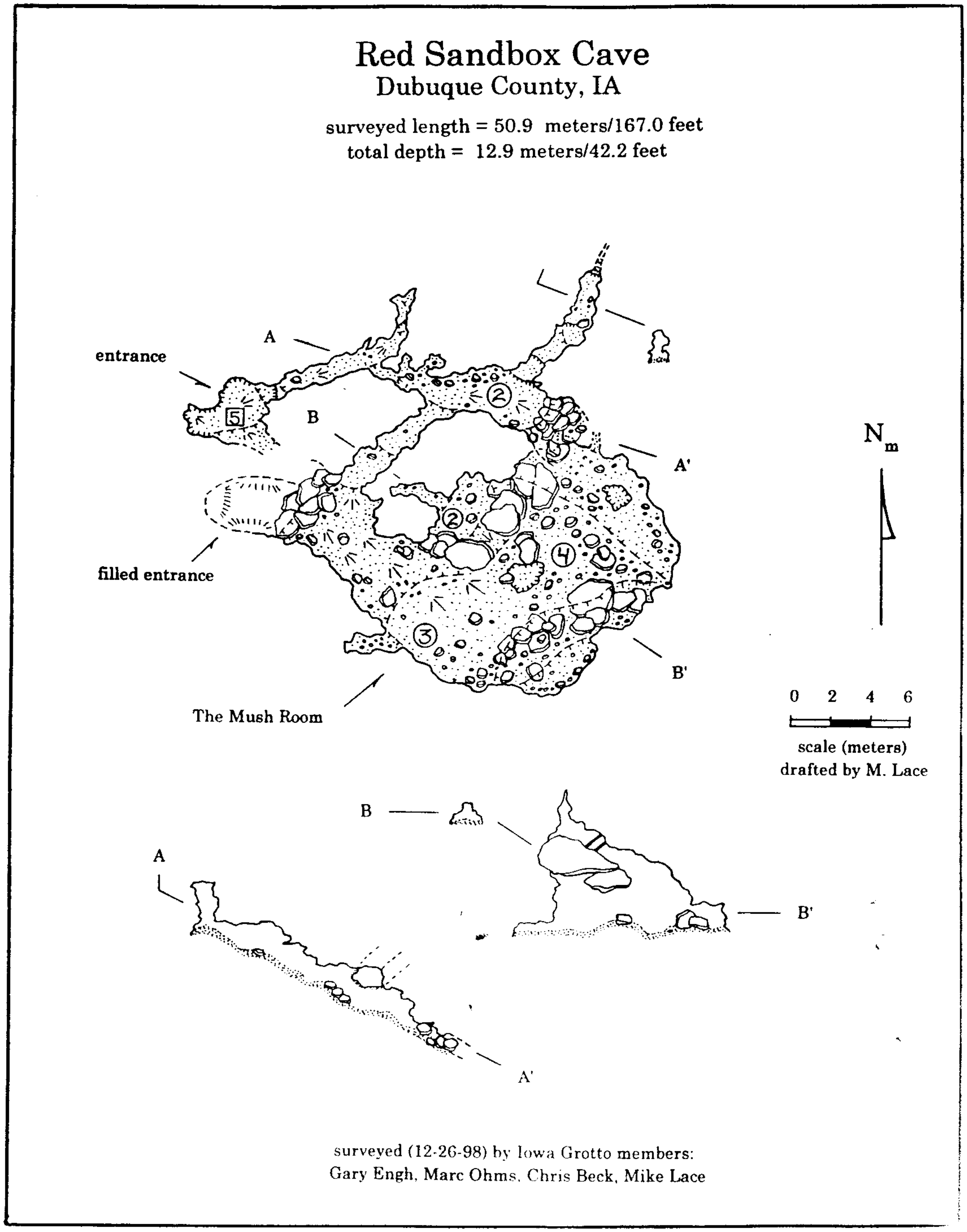
With all that has been written about the techniques, degree of detail, data manipulation, generation of lead lists and cartographic problems of surveying miles-long cave systems, I thought I'd address the issue of surveying the tiny cave.

First, how small is a "tiny cave?" In Texas (where I've done most of my surveying), a cave is defined as being any humanly enterable natural cavity that is 25 feet long or longer, or is 15 feet deep or deeper, with no dimension of the entrance exceeding the cave's length or depth. Tiny caves are therefore, by my definition, any cave which barely meets the above criteria. They are usually less than 50 feet long or deep, but sometimes up to and around 100 feet depending on total cave volume.

How do you survey tiny caves? The same as you survey a larger cave except you travel much lighter. Generally, only a flashlight is needed in addition to the survey gear, and sometimes a light is not needed at all. Packs and extra lights are unnecessary with daylight around the corner - besides, you just end up shoving them ahead of you or dragging them behind, and they usually obstruct the survey's line of sight. Sometimes, a small pry par is useful in pushing a lead, but most times you can find a rock at the dig site suitable for use as a tool. If not, the entrance is not far away.

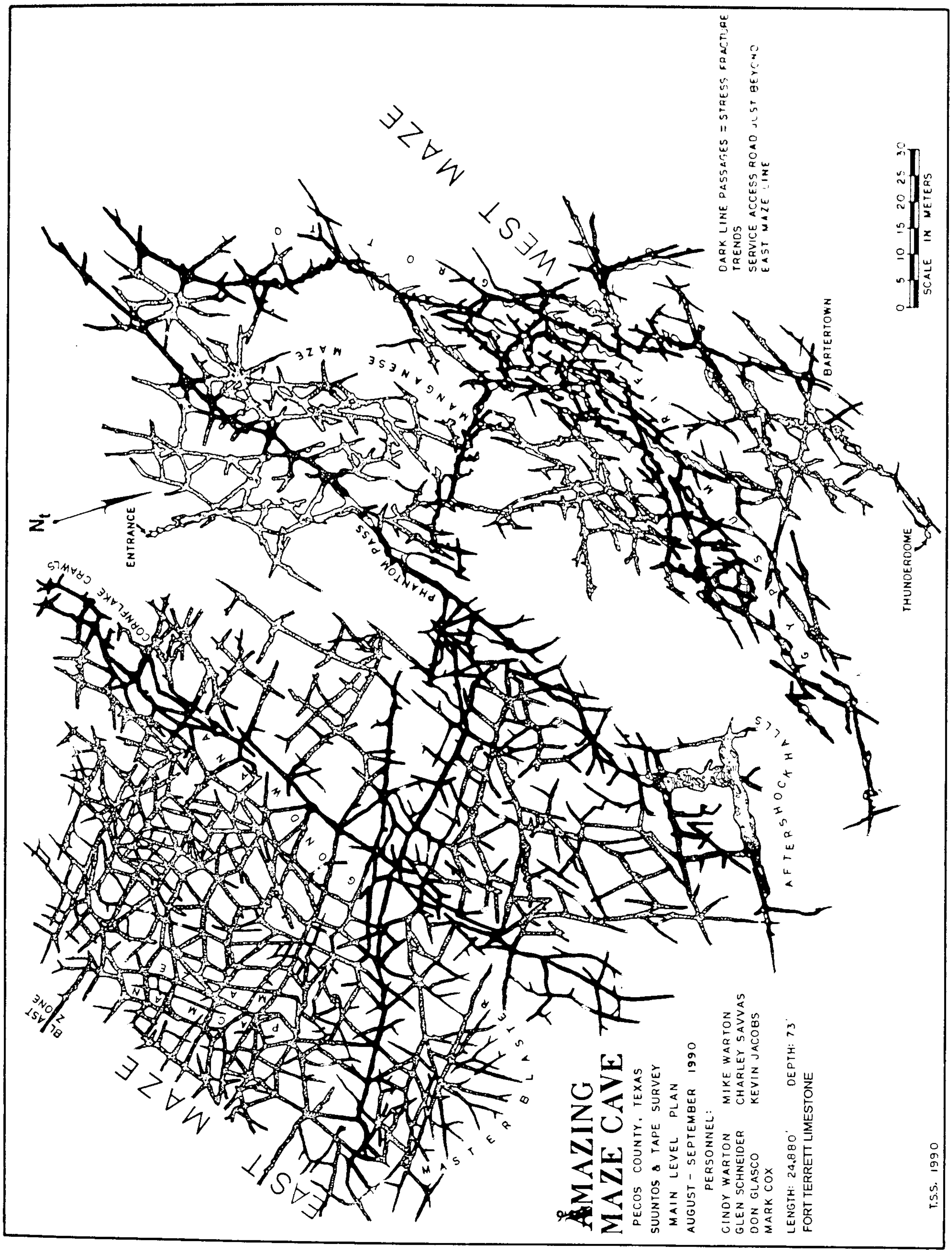
What the tiny cave requires, even more than a large cave, is persistence in pushing all its leads and potential leads. With a big cave there is the momentum of miles of known cave which pushes you to push. In the tiny cave, you have to supply your own drive and momentum. Don't be discouraged by lack of airflow - push on! You might only find 5 feet of new cave (if anything), but it IS a new dis-





covery and thus worth the effort. The surveyor of the tiny cave must learn to appreciate each cave and passage for what it is and not scoff at it, or be disappointed because it doesn't compare to Central Kentucky or Mexico.

Lastly, the most common question is, "Why bother surveying the tiny cave?" "Because it's there." No, that's evading the question. Each surveyor must examine his or her motives for surveying. If one of the answers is to expand the speleological data base of particular a cave or karst region, then the tiny cave survey supports that end. A large cave will provide more information than a small one, yet many tiny caves can sometimes provide more insight into a region than a single large cave. I don't advocate ignoring large caves, but rather to pay more attention to small ones. Surveying tiny caves takes a little more time than just exploring them, and it may provide more critical information in finding that big cave system below.


AMAZING
MAZE CAVE
PECOS COUNTY, TEXAS
SUUNTOS & TAPE SURVEY
MAIN LEVEL PLAN
AUGUST - SEPTEMBER 1990
PERSONNEL:
CINDY WARTON
GLEN SCHNEIDER
DON GLASCO
MARK COX
MIKE WARTON
CHARLEY SAVVAS
KEVIN JACOBS
LENGTH: 24,880'
DEPTH: 73'
FORT TERRETT LIMESTONE
T.S.S. 1990
DARK LINE PASSAGES = STRESS FRACTURE TRENDS
SERVICE ACCESS ROAD JUST BEYOND EAST MAZE LINE
0 5 10 15 20 25 30
SCALE IN METERS
EAST MAZE
WEST MAZE
BLAST ZONE
MASTER BLASTER
CORNFLAKE CRAWLS
ENTRANCE
PHANTOM PASS
MANGANESE MAZE
AFTERSHOCK HALLS
THUNDERDOME
BARTERTOWN