Compass & Tape

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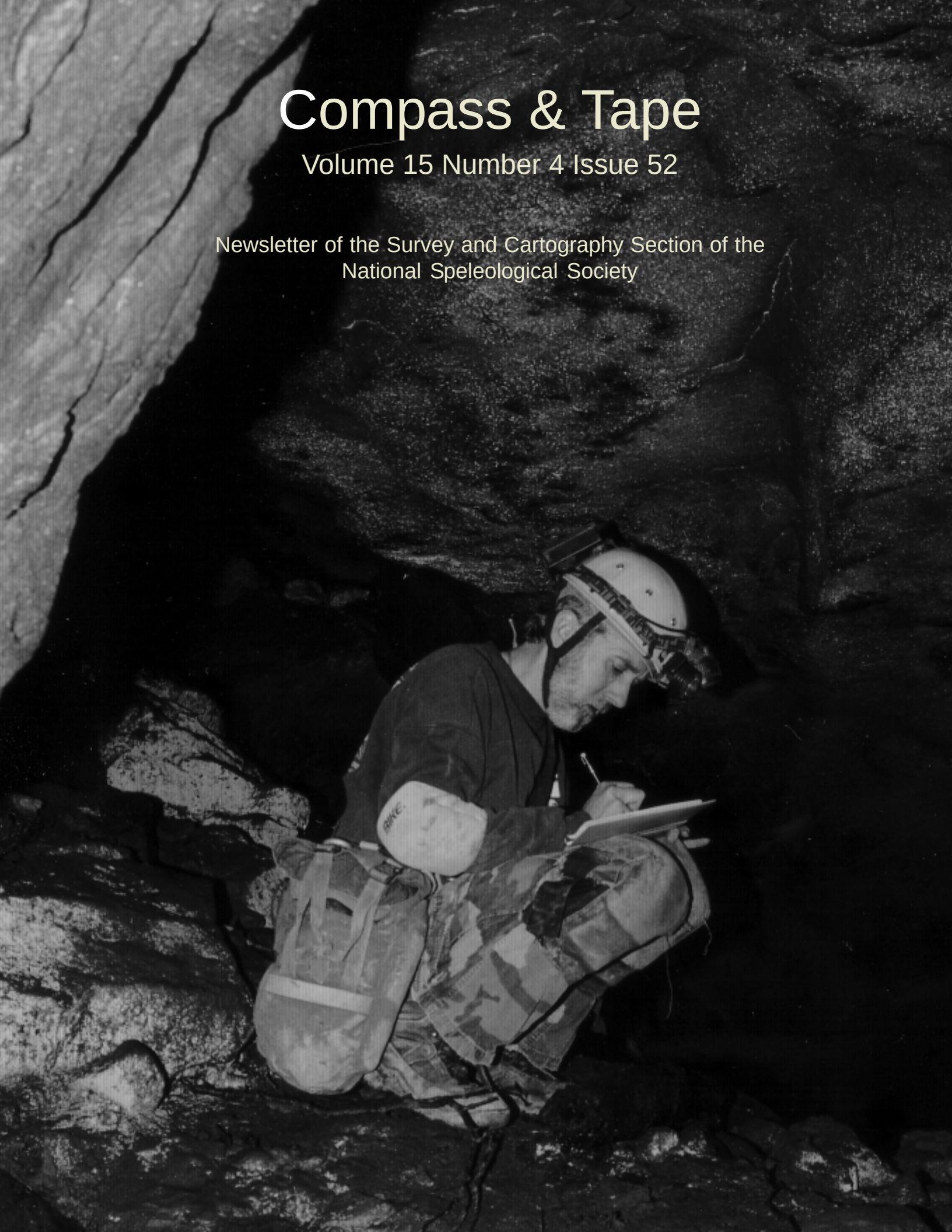
Newsletter of the Survey and Cartography Section of the National Speleological Society



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 sent 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 Treasurer.

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: Mike Lace sketching virgin cave in Arkansas, Photo by Scott Dankof

Back Cover: A section of Tumbling Rock Cave Jackson County, Alabama

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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 as email attachments or on CD's, 3.5 inch diskettes either IBM compatible or Mac format or via email. Typed material is acceptable and 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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2003 NSS Convention, Porterville, California
Survey and Cartography Section

CALL FOR PAPERS

This is a call for papers for the Survey and Cartography session at the 2003 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 31, 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.

MINUTES OF THE 2002 SURVEYING AND CARTOGRAPHY SECTION MEETING

The 2002 meeting of the Surveying and Cartography Section of the National Speleological Society was convened on Friday, June 28th, 2002, in conjunction with the NSS' annual convention. The meeting took place in Room 223 of the Camden High School, in Camden, Maine. Attending were the following 26 members and friends of the Section:

Darrell Adkins, Paul Andrews, Brent Aulenbach, Robin Barber, Roger Bartholomew, George Dasher, Thom Engel, Alicia Flynn, Preston Forsythe, Shari Forsythe, Bill Fromty, Dan Henry, Bob Hoke, Rod Horrocks, Jim Kennedy, Chuck Laon, David Larson, Nancy Pistole, Steve Reames, Bob Robins, Liz Robinson, Henry Schneider, Bob Thrun, Bill Varnadoe, Louise Varnadoe, Carol Vesely

Chairman Carol Vesely called the meeting to order at 1:04 pm. She first welcomed everyone to the meeting, then she said that both the vice-chairman, Roger Bartholomew, and the secretary were not present. She then that Roger had had no submittals for the SACS' Session and that he was doing a good job, that the secretary was in Chile, and that George Dasher was filling in as the secretary.

Bob Hoke then passed out the Treasurer's Report, and said that the Section had $4945.85 and 211 members at present. He also said no newsletters had been printed since November, but that he had the next *Compass & Tape* in hand.

Roger Bartholomew arrived, and he said that he had received no papers by the Convention deadline, and that he had then solicited three talks via the internet. He also said he had sent out postcards to all the Section members, but this had produced no results. He said he now had four talks for the SACS Session. Bob Hoke added that the session deadline this year had been March 1st, and that he felt that this had been far too early.

Steve Reames next gave a report on the Cartographic Salon, and said that there had been 14 entries and eight awards had been given. He said that six of the maps had been "Display only," only one medal had been awarded, and he had only mispronounced one cave name badly the night before at the Awards Ceremony. He also said that Rod Horrocks will be the Salon Chairman next year and that he has everything he needs. Brent Aulenbach won the Cart Salon Medal for his map of Caves of the Snake Well Complex, which is located in Tennessee.

Old Business

Carol said that, last year, they had planned to have a special issue of *Compass & Tape* dedicated to the Cart Salon with both maps and critiques; however, there had been more enthusiasm than follow through and no such issue had been produced.

There was some discussion. Jim Kennedy said that there had been problems with the critiques last year, and that photos of the maps needed to be put on the website using Powerpoint, particularly for archiving; George said that it was good to have a open critique at the Salon, so other people could give their opinions; Bob Hoke said the judging sheets could be added to a website; George asked if it was appropriate to display all the maps on the webpage, and Bob admitted it would be inappropriate to display some of the maps; Thom Engle said that some people might not be able to find the website location; and Roger Bartholomew said that it might be wise to just show sections of the map.

Carol said that the Section has a website, and Bob Hoke said that there is space on that site. George said that the information on that site is really old,

and Brent Aulenbach said the SACS website is now under construction. Steve said he would take care of the website, and several other people made some comments. Jim volunteered to take pictures of the maps and George volunteered to provide a list of the previous years' winners.

Carol then asked if the number of entries is declining, and George said that all the entries for all the salons are down at this convention. Brent said that the breakdown into categories was good, so that the novices didn't have to complete with the experiences cartographers.

George asked about the cartographic salon the Southeastern Region has been hosting, and Brent said that it was made of Mississippi, TAG, North Carolina, and South Carolina, and that it took place at the winter meeting. He said all the maps are on the Southeastern Region website.

Carol asked if this salon was run any different than the NSS salon, and Brent said that the grading was different but that it was modeled on the NSS' salon. Carol asked how many maps were entered, and Brent said that varied year to year. Jim Kennedy said that 12 to 20 maps were usually entered, but that there were fewer cartographers.

Carol then asked if we should have a "pen and ink" category, as it would be good to maintain a link to the traditional technology. Bob Hoke said "Let's experiment and see what happens," and he added that it is sometimes hard to tell the difference many times between the two styles. George said that pen and ink is less inexpensive, and that is a big factor for some people.

Jim Kennedy said that we will have to be careful when differentiating between the two styles, because a lot of the hand-drawn maps use computer-generated text. Nancy Pistole added that if the computer is used to draw any part of the map, then the map should be considered computer drawn. Henry Schneider said that photographic salon considers a photograph "digital" if the data is digitized during any part of the photography process. Bob Hoke said he didn't like the idea of calling a map computer generated if it used only computer-generated text.

New Business:

Carol said it was time to move on, and she said that we will have access to a computer lab at the next convention. Steve Reams volunteered to help with that, and he said that Paul Burger has plans to do two half-day sessions at that convention. He will emphasize not the software programs, but rather the computer cartographic process.

There was additional discursion and Carol said these sessions should be popular. Steve said that they will be hands-on workshops, and there will have to be a sign-up sheet. "And handouts," Carol added. Bob Thrun noted that there are differences in the different cartographic software packages, but Steve said that every company is copying the software from every other company and the feature sets are very similar. In short, he felt the software differences are a non issue.

George said that, several years ago he had—at SACS' direction—put together a questionnaire regarding the different computer data-reduction and drafting programs. No one, he said, completed the questionnaire and returned it.

Carol said that we should bring in Bob Richards or Joel Despain for their input, and Jim Kennedy said we should keep the session program neutral. Carol asked if we should have a beginner and advanced workshop, and Darrell Adkins asked if people could come up with a list of problem areas: "Here's what I'm having trouble doing." Bob Thrun said a good explanation between a CAD [computer-aided drafting] and a drawing program is needed, as well as what each can do. Bob Hoke said that CAD is not as good as the drawing programs, and George Dasher agreed. Steve Reames said that there should also be a discussion of GIS [Geographic Information System] programs, such as Arcview.

George Dasher asked if Steve Reames will be handling this computer session, and Carol Vesley said yes.

Carol then said that she has a friend with a kid who wants to learn cave surveying, and she asked if we should have a kids' workshop. She thought this would be a great idea and a good thing for the next generation. Bob Thrun said that this would have to be a simpler class than the one he had taught in years past. Carol agreed, and said it would have to be more geared to kids. She also said that there was a talk this year in International Exploration where a cave in the Ukraine had been surveyed by kids.

Nancy Pistole asked if Carol will again be running her surveying class at the next convention, and Carol said "Yes and no." She said the sketching workshop planned for next year is a no go, as the closest cave is a commercial cave with severe restrictions. "I would like to do it," she said, "But I need another cave." Thom Engle said it would impossible not to do the course in a cave, and Nancy Pistole added that only a short cave was needed, perhaps only five stations long. George Dasher added you don't need much of a cave, but you do need a cave.

Carol asked if someone would take on teaching the kids' surveying class. Thom Engle asked the age of the kids, and Carol said teenagers. Thom said, "Let me think about it." Liz Robinson asked, "What about at the 2004 Convention?" and Carol said the caves will be further away from that convention site.

Bob Hoke asked about money, and Carol suggested $30. George Dasher suggested $50 and Steve Reams suggested $100. Jim Kennedy seconded the $100 suggestion, and it was quickly voted on with everyone in favor.

Carol asked if there was any new business. There was none.

Carol asked about elections, and she in particular asked if anyone wanted to be the secretary. George said maybe, but he wasn't sure if he could make the 2003 Convention. Robin Barber said she might do it, and Thom Engle made a motion that Robin should be the Secretary. Jim Kennedy again seconded the motion, and Thom Engle made a motion to close the nominations, which Steve Reams seconded. This passed unanimously and Carol adjourned the meeting at 2:06 pm.

Submitted by: George Dasher
Acting Secretary

NSS 2002 Cartographic Salon

Steve Reames, Salon Chairman

A total of twenty maps, by twelve cartographers were entered in this year's Cartographic Salon. There were three judging categories. The Apprentice Category is for those cartographers who either have never entered a map in the NSS Cartographic Salon or have never received a Cartographic Salon Award. The Experienced Category is for cartographers who have won awards at previous Cartography Salons. The Master/Professional Category is for cartographers who either are professional cartographers i.e. they do it for a living, or for cartographers who have won at least two medals in NSS Cartographic Salons. Of the entered maps, seven were entered in the Apprentice Category, five in the experienced category and two in the Master/ Professional Category. An additional six maps were entered for display only.

APPRENTICE CATEGORY
Merit Award (Blue Ribbon)
Majors Cave, by Lee Florea
Horseskull Cave, by Terry Ragon

EXPERIENCED CATEGORY
Best of Show (Medal)
Caves of the Snake Well Complex, by Brent Aulenbach
Merit Award (Blue Ribbon)
Blackberry Branch Cave, by Robin Barber
Honorable Mention (Green Ribbon)
Deliverance Cave by Chris Andrews
Gregorys Cave by Dan Henry
Dingling Hole by Dan Henry

MASTER/PROFESSIONAL CATEGORY
Merit Award (Blue Ribbon)
Mahiehie Cave by Bob Richards

The judges for the 2002 Cartographic Salon were Paul Burger, Jim Kennedy and Nancy Pistole. Next year's Salon Chair will be Rod Horrocks.

Development and Testing of Three Componentsof the Process of Transferring Digital Cave Survey Data

Mike Yocum

Introduction

Determining best management strategies and practices for karst ecosystems requires the integration, analysis, query and display of various types of data from a range of scientific disciplines. Cave Research Foundation's (CRF) GIS Program, in cooperation with Mammoth Cave National Park (MCNP), have been working on developing an information system that would integrate this type of data for the part of the Flint Ridge Mammoth Cave System that is encompassed by the boundary of Mammoth Cave National Park (MCNP). A principal software product used by MCNP staff to perform these tasks is ArcView, a GIS (geographic information systems) product.

A key component in the integration of many of the MCNP's databases is the cave survey data set that has been collected by the Cave Research Foundation (CRF) over a period of some 40 years. The cave survey data set is the framework to which many other data sets, both surface and sub-surface, must be related in order to understand and assess numerous resource management responsibilities incumbent upon MCNP staff.

At the beginning of this project CRF cave survey data did not exist in a format compatible with ArcView, there did not exist metadata[1] describing the transmitted data, nor did MCNP have a procedure for tracking it as it was transferred.

The goals of this project were 1) to develop and test procedures for converting CRF survey data to ArcView format, 2) to determine which data items and manipulations are most significant in maximizing the accuracy of the data in order to provide appropriate metadata, and 3) to develop a framework and procedures for recording the content and status of CRF cave survey data as it is conveyed from CRF to MCNP.

Method

The first stage of the project was to assemble a team of knowledgeable, professionally experienced personnel to review and evaluate the status of original digital data sets, possible transfer procedures, and potential metadata items.

The second stage was creation of a digital database of surface features and surveyed cave passages to be included in the investigation. A study area was chosen in consultation with staff at MCNP's Division of Science and Resources Management and personnel from CRF's Eastern Operations Cartography Program. The area selected was that part of the cave system between the Historic and Violet City entrances of Mammoth Cave.

For surface features, the selected files included geospatial data in four commonly available formats: DEM, DLG, DRG, and DOQQ[2] . In its GIS applications, Park standards for projection, datum and units are UTM, NAD27 and meters. The geospatial data files were obtained in, or converted to, these standards.

Cave survey data files for passages within the study area were obtained from CRF's Eastern Operations Cartography Program. They were available in formats corresponding to software that had been used by CRF personnel: Compass, CML (Cave Map Language), SMAPS and Walls. Each of these programs features some form of ASCII output. Data in these files was in a confidential coordinate system devised by CRF many years earlier at the request of the Park administration in order to protect sensitive locational information.

After survey data in each format had been collected for the study area, it was processed using each of the respective programs. Any data items or processing procedures that were problematic, or were

deemed important for insuring the accuracy of the final data set, were noted.

Only two programs, Walls and Compass, allow conversion to ArcView shapefile format.[3] Walls exports shapefiles directly. Compass plot files can be converted to shapefiles using CaveTools, an ArcView extension. Output from SMAPS and CML cannot be converted to shapefiles without first being converted to either Walls or Compass.

The most complete data set was in SMAPS format. It was imported into both Compass and Walls, where it was converted from the CRF coordinate system to UTM, NAD27 meters, with copies of the data in the original CRF coordinates being retained. Conversion to shapefiles was then performed on all four of these data sets, and the results registered to a DOQQ of the study area.

Using results of the registration, along with insights gained from discussions among project team members, an FGDC-compliant metadata set was constructed. An expanded shapefile format, containing supplementary cave survey attributes requested by MCNP or suggested by team members, was also created.

A framework for tracking transferred data was proposed. CRF's map production at Mammoth Cave has been organized by the Cartography Program into a series of map sheets that cover the extent of the cave, each sheet being assigned to a CRF cartographer. Map production as a whole is charted on a map sheet index that shows all of the maps and their relation to each other and the Mammoth Cave system. The proposed framework for tracking CRF digital data transfers is to assign each station in the delivered station shapefile to the appropriate map sheet.

Discussion

In the context of GIS, the term "legacy data" is applied to data previously collected without reference to use in GIS applications. Often it has been collected over an extended period of time, for many different purposes, and may be stored in a variety of formats. Conversion and integration of legacy data sources into current GIS applications are common tasks for every project that seeks to turn existing feature data into functional GIS information. Typically, legacy systems use different data structures, software architectures, and even different computing environments.[4] GIS is a relatively new field and data transfer technology is often limited. Much of the work may have to be done manually. In either case, whether automated or manual, reconciliation of legacy data is a complex process, and the amount of money spent on it each year runs into many hundreds of millions of dollars. A review of some of the challenges and strategies applicable to importing legacy data is helpful to anyone planning to implement GIS in their work.[5,6,7,8]

Fortunately, conversion of CRF's legacy data did not require the substantial re-engineering that is often the only viable alternative for many federal, state, and municipal agencies. A project team able to contribute its time and professional expertise was adequate for the tasks that needed to be accomplished.

The study area was chosen not only because of its relevance to MCNP projects, but also because CRF survey data for this part of the cave is tied to the Walker benchmarks, which provide a reliable set of control points. In 1935 and 1936, H. D. Walker of the US Geological Survey established a horizontal and vertical control net by running a transit traverse, and subsequent leveling lines along the same route, in Mammoth Cave. In addition to in-cave benchmarks, the net extends to the surface at several entrances. As a result of later surface triangulation conducted in the area, the original Walker data were corrected in 1972 to incorporate a datum shift. The results were published in 1973.[9] Although a few errors have since been discovered in the Hosley publication, the Walker benchmarks represent the most reliable subsurface survey data for Mammoth Cave to date. They are the foundation to which CRF survey data is joined.

One development not anticipated at the start of the project occurred when it was learned that many of CRF's Mammoth Cave cartographers were changing data processing software. Most had used SMAPS for years, and many now were adopting Walls. One

or two began using Compass. It was not within the scope of the project to evaluate or recommend survey data processing software, but simply to examine the output of the software in use and bring to light key issues involved in converting that output to GIS format. As a result of cartographers choosing new software, the final phase of the project focused in more detail on the shapefiles produced by Walls.

Conversion of survey data from its native format to Walls, Compass, CML, SMAPS, or any other software format - and conversion from any one of these formats to any other one of them - raises questions about the conversion process since there is no standard for selection of data fields that will be included in the conversion. Nor, for any given data field, are there standards for how it will be parsed and translated. Each software author has chosen what he believes to be relevant or manageable data, but each differs in his choices. Each author has also chosen what he believes to be the best processing algorithms, but again differ in choices. It thus becomes crucial to know the processing and conversion history of any shapefile since both processing and conversion algorithms may differ from program to program and significantly alter the output.

The raw data-to-GIS shapefile "transformation pathways" are different for Compass and Walls. While both programs permit internal conversion to a projection, datum and units (e.g., UTM NAD27 meters), conversion to shapefile format is performed differently. The output from Compass is a plot file in ASCII format. This file is read by CaveTools, which converts it to a shapefile. Walls creates a shapefile directly without the need for additional manipulation by a conversion utility.

To date, no problems have arisen using the SMAPS-Walls-shapefile route, but an example that appeared in a SMAPS-COMPASS-Cave Tools-shapefile conversion will serve to illustrate the potential for results to be radically affected by the conversion processes. During a transfer of data from the CRF coordinate system, the Historic Entrance of Mammoth Cave (along with the rest of the cave passages in the associated file) was displaced by over 3,000 feet. Larry Fish discovered the causes of the problem, use of two different standards for definition of a foot in Compass, combined with a rounding error in CaveTools. Although these errors have since been corrected in the software, the question is worth examining in some detail because it dramatically demonstrates that seemingly trivial differences can drastically affect final results. Below is part of Fish's explanation.

The problem you are seeing occurs because we are multiplying very large numbers by values in the range of tens of millions of feet for the UTM coordinates. For example, the difference between the conversion constant I am using and the one Bernie is using is:

> 3.28083989501312 - 3.2808 = 0.00003989501312
>
> This is a very small number, but not compared to the large UTM values. If you multiply this very small difference by the large UTM values, the difference is surprisingly large:
>
> 13496183.399 * 0.00003989501312 = 538.43 meters
>
> I ran into a similar problem a few weeks ago because I was using the International Foot (0.3048) in some parts of COMPASS and the "US Survey Foot" (0.304800609601) in other parts of the program. My logic was that the Survey Foot would be more accurate for geographic measurements. However, that 0.000000609601 difference was enough to cause an eight-meter discrepancy in the data.[10]

In an article published in *Compass and Tape*, Fish notes:

> Multiple conversions can make any conversion problems worse. For example, if you convert a UTM coordinate to feet using the US Survey Foot and then convert back using the International Foot, you will cause an error, not just a units discrepancy. This is most likely to happen if you are using differing software packages that support different units. Each transfer can cause increasing errors.[11]

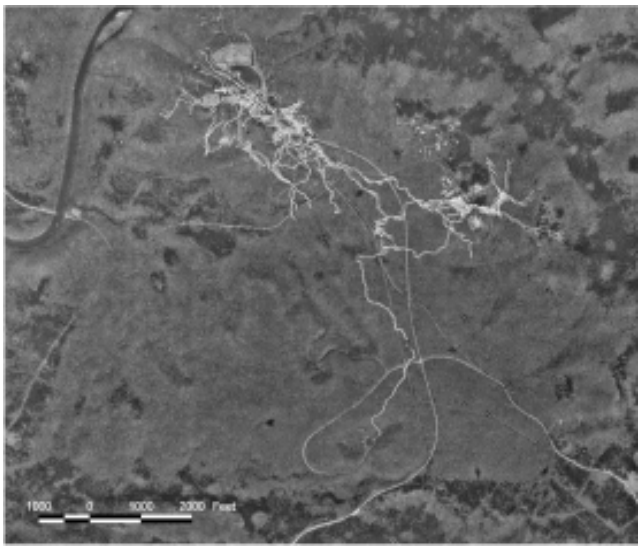


Figure 1:DOQQ of study area

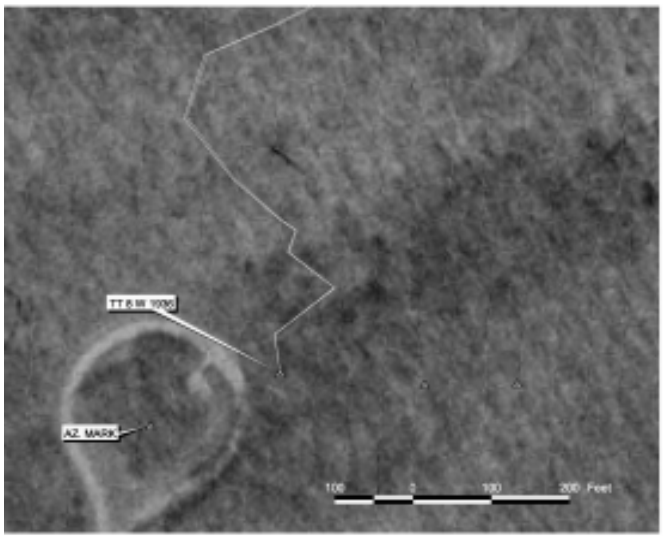


Figure 2 Registration to Violet City Entrance of Mammoth Cave

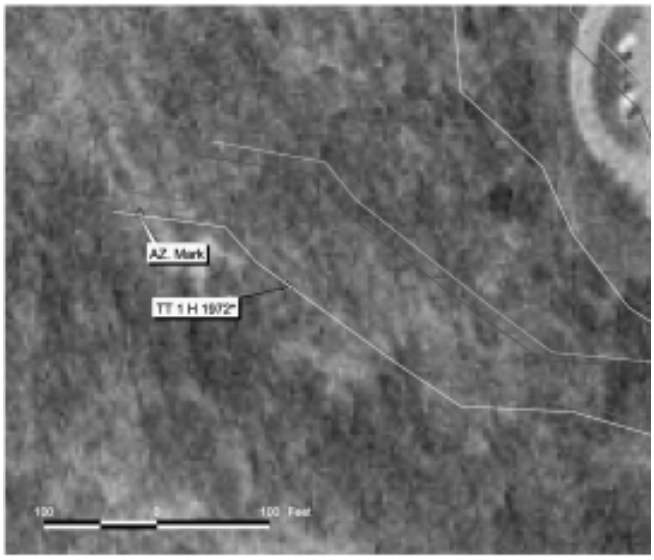


Figure 3 Discrepancy in cave passage locations

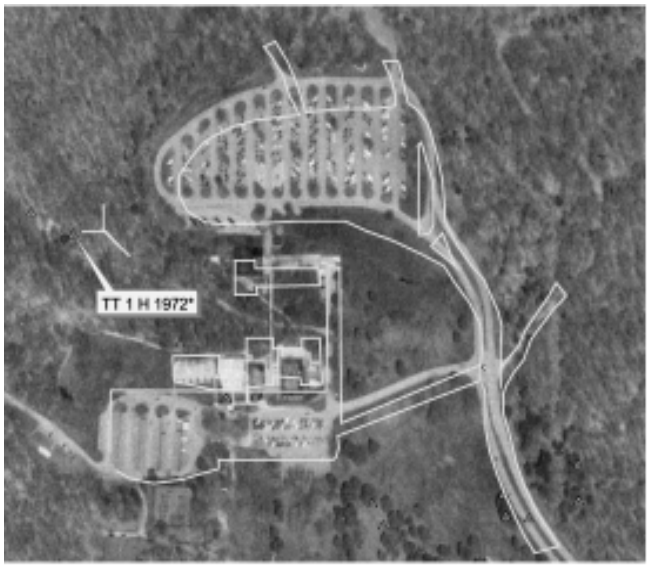


Figure 4: DOQQ with Park Visitor Center overlayed on cave passage

The Mammoth Cave data that was so spectacularly displaced was originally in SMAPS feet, which were converted to Compass feet (prior to Fish's correction of Compass code), then converted to ArcView meters (prior to Szukalski's correction of CaveTools code). Fortunately, because the resulting displacement was so conspicuous, it brought the problem to light.

Fish notes, "I have done a lot of research on this issue. The problem is more pervasive than I had thought and it appears to affect ALL cave survey programs and ALL GIS software." [12] His *Compass and Tape* article should be required reading for anyone using different software packages to work with their data, or anyone converting data from one set of units to another.

Even after all such data conversion errors have been corrected, there still remain the different algorithms by which different programs process data. This became strikingly apparent when four survey data shapefiles were registered to a geodata file.

The process began with a single CRF data set. It was imported into both Compass and Walls, where it was converted from the CRF datum and feet to UTM, NAD27 and meters by each program. Copies of the data in the original CRF datum and units were retained in both Walls and Compass. There were then two Walls sets of the data (in both CRF and UTM datums) and two Compass sets of the data (in both CRF and UTM datums).

Conversion to shapefile format was performed on all four of these data sets, and the results superimposed on a DOQQ of the study area. (Figure 1) All survey data files were registered to a Walker benchmark located near the Violet City entrance to Mammoth Cave. (Figure 2).

Comparison of the differing locations of the converted cave passage line plots to known and well-defined surface features made it graphically clear that data processing algorithms also play a key role in the final result. Although a single original CRF data set in SMAPS was the source file fed into each transformation pathway, variations of approximately 100 feet over a linear distance of approximately 8,000 feet were noted in the final locations of cave passages in relation to points on the DOQQ image (Figure 3), depending on datum and software.

Nor do problems of working with different data sets begin and end with cave survey and GIS software. It has long been known that the geodata files to which cave survey data may be registered for use in GIS applications are not in alignment with each other. Figure 4 shows a section of a DOQQ in which are visible the Park's visitor center, a couple of parking lots and other facilities. Over this are lines traced around some of the same features on a DRG for the same area. The "Y" is a standard symbol for a cave entrance, and denotes the location of the Historic Entrance to Mammoth Cave on the DRG. The triangle labeled "TT 1 H 1972" is a location on the cave floor beneath the dripline at the midpoint of the entrance passage, established by the Natural Sciences Resource Study Group in 1972 during work on the Walker benchmark net.[13] The dot is the author's "eyeball" estimate of where the entrance "really" is on the DOQQ.

Cave survey data can be tied in to or registered with surface data at various stages in the data collection and conversion process. Surface data can be collected specifically as an extension of the underground survey net. Existing surface data can be incorporated into legacy or newly created cave survey data. A shapefile created from cave survey data can be registered to a geodata file that contains surface data of varying degrees of precision and accuracy.[14,15]

However, in order for the result to be useful for management purposes requiring both high accuracy and high precision, the surface data set to which the subsurface data is to be matched must be chosen in advance since existing standard surface data formats are not themselves precisely or accurately aligned with each other. Cave survey data registered to one format, e.g., DOQQ will not be in registration with other formats, e.g., DRGs, DLGs, or DEMs. Before embarking on any major project, selection of a final standard surface data set becomes a priority.

To provide information that might assist in the surface data selection process, as well as offering use-

ful metadata about the cave survey data and complying with federal metadata requirements, David McKenzie and the author created an expanded shapefile format for use with Walls. (Appendix 1) The expanded format allows users to access metadata directly within ArcView. In addition, it contains a field – Sheetname – that assigns each station in a processed station shapefile to the appropriate CRF map sheet. This allows MCNP to track the content and status of CRF cave survey data as it is conveyed from CRF to MCNP. Finally, the shapefiles produced by Walls can be parsed by SMMS, MCNP's current standard metadata management software, to produce FGDC compliant metadata.

Conclusion

The results of this study indicate that the most critical problems when utilizing cave survey data for resource management at Mammoth Cave National Park currently arise not in data collection, but in data management – including data processing. A crucial component of data management is metadata that is relevant to the data sets being manipulated and integrated, including a history of any previous data manipulation. Data management should also include thoughtful and careful long term planning for final data uses and needs since these will partly determine appropriate data transformations.

[1] "Metadata" is data about data. It is data that describes the content, quality, condition, and other characteristics of data. Federal agencies are required by Executive Order 12906 (April 11, 1994) to include metadata with all digital geospatial data. Executive Order 12906 also established the National Spatial Data Infrastructure and adopted the FGDC (Federal Geographic Data Committee) Content Standard for Digital Geospatial Metadata to provide a consistent approach and format for the description of data characteristics. The standard, and an electronic workbook are available at: ***http://www.fgdc.gov/metadata/metadata.html***

[2] DEM is an acronym for Digital Elevation Model, DLG is an acronym for Digital Line Graph, DOQQ is an acronym for Digital Orthophoto Quarter Quad, and DRG is an acronym for Digital Raster Graphic

[3] Compass is available at: http://fountainware.com/compass/
Walls is available at: http://davidmck.home.texas.net/walls/

[4] Peters, D., *System Design Strategies*, Environmental Systems Research Institute, Redlands CA. 2001.

[5] Nabil, A. and Gangopadhyay, A., *Database Issues in Geographic Information Systems*. Kluwer Academic Publishers. Norwell, MA. 1997

[6] Groot, R. and McLaughlin, J. *Geospatial Data Infrastructure: Concepts, Cases and Good Practice*. Oxford University Press. New York, NY. 2000.

[7] URISA, *GIS Database Concepts: A Tutorial*. Urban and Regional Information Systems Association. Park Ridge, IL. 1999.

[8] Hohl, P. *GIS Data Conversion: Strategies, Techniques and Management*. Onward Press, Albany, NY. 1998.

[9] Hosley, R.J., *Bench Marks in Mammoth Cave, Kentucky*, Natural Sciences Resource Study Group, 1973

[10] Fish, L., Email: August 2, 2000

[11] Fish, L., "The International Foot versus the U.S. Survey Foot or the case of the Galloping Caves" *Compass and Tape*, Vol. 15, Issue 2, No. 50, p.13.

[12] Fish, L., Email: April 18, 2001

[13] Hosley, R. J., *Bench Marks in Mammoth Cave, Kentucky*, Natural Sciences Resource Study Group, 1973, p.4

[14] U. S. Geological Survey, Standards for Digital Orthopohotos: National Mapping Program Technical Instructions.

[15] U. S. Geological Survey, Standards for Digital Raster Graphics: National Mapping Program Technical Instructions.

APPENDIX 1

DESCRIPTION OF WALLS CAVE SURVEY SHAPEFILESFOR MAMMOTH CAVE NATIONAL PARK
VERSION DATE: 2001-06-15

This document describes the data set that will be supplied periodically to Mammoth Cave National Park by the Cave Research Foundation. Each named file set (indicated below by the "filename" prefix) will consist of at least four shapefile assemblies and a separate metadata table containing information about the set as a whole. The current version of this document will also be supplied.

VECTOR DATA (SHAPEFILE ATTRIBUTES - FILENAME_V.DBF)

A. Field Description	**Field Name**	Field Type	Field Size
CAVENO	Text	4	Number assigned by MCNP (metadata table field value).
CAVENAME	Text	64	Name or project title associated with cave (tracked by MCNP).
CAVEAREA	Text	128	Name hierarchy associated with vector's location in cave. See **Note 1**.
SURVEYNAME	Text	48	Letters (often just one) identifying survey where vector measurements were recorded. Alternatively, it can be a long survey title. See **Note 2**.
FSBNUMBER	Text	4	Field survey book number if applicable. See **Note 2**.
DATAFILE	Text	8	Base name of raw survey data file containing defined vector.
DATAHIST	Text	128	Data processing history (metadata table field value).
SURVEYDATE	Number	8	Date of vector measurement, format YYYYMMDD.
FR_NAME	Text	17	Name of 'FROM' station. See NAME in station table and **Note 4**.
TO_NAME	Text	17	Name of 'TO' station.
LENGTH	Number	10.2	Length of measured vector in meters.
AZIMUTH	Number	6.2	Azimuth of TO station from FROM station (grid North degrees).
INCLINE	Number	6.2	Incline of vector from FROM station to TO station (degrees).
CTR_EAST	Number	12.2	UTM NAD27 easting of vector's midpoint.
CTR_NORTH	Number	12.2	UTM NAD27 northing of vector's midpoint.
CTR_ELEV	Number	12.2	Elevation ASL of vector's midpoint in meters.
ATTRIBUTES	Text	40	Named vector attributes separated by vertical bars. See **Note 3**.
LINETYPE	Text	8	A string identifying an assigned line style in Walls.

SURVEY STATIONS (SHAPEFILE ATTRIBUTES - FILENAME_S.DBF)

Field Name	**Field Type**	**Field Size**	**Field Description**
NAME	Text	17	Station name. Usual format for MCNP: <FSB No.><Survey etter><Number> (Example: 196A200) Other formats are technically possible. See **Note 4**.
X	Number	12.2	X coordinate in meters: UTM Easting, Zone 16S, Datum NAD27 CONUS
Y	Number	12.2	Y coordinate in meters: UTM Northing, Zone 16S, Datum NAD27 CONUS
Z	Number	12.2	Z coordinate in meters: Elevation ASL
LEFT	Number	8.1	Distance in meters to left wall. N/A if this and the next 4 field values are zero.
RIGHT	Number	8.1	Distance in meters to right wall.
UP	Number	8.1	Distance in meters to the ceiling.
DOWN	Number	8.1	Distance in meters to the floor.
LRUD_AZ	Number	8.1	Observer's facing direction in degrees when measuring LEFT, RIGHT, UP, and DOWN.
SHEETNAME	Text	10	Name of sheet on CRF Index of Map Sheets (not yet initialized by Walls).

ADDITIONAL SHAPEFILES

The survey station shapefile described above contains one record for each established location in the project, including the "fixed" control points. (The latter are *not* represented in the vector shapefile except possibly as FR_NAMEs and TO_NAMESs of compass and tape survey measurements.) The shapefile export function of Walls can optionally provide two additional shapefiles involving smaller subsets of stations. As themes in ArcView, they can be used to mark and/or label special categories of stations, such as benchmarks and entrances.

Flag shapefile: Survey data files can define any number of named station attributes: Cave Entrance, Benchmark, Walker BM, etc. The station-attribute pairs are submitted as a separate shapefile with base name **filename_F**. This corresponds to the FLAGS shapefile export option of Walls. There can be multiple attributes per station. The flag attribute table has the first four fields of the station attribute table plus a 64-character FLAGNAME field.

Note shapefile: Long descriptions can also be assigned to particular stations. Station–description pairs are submitted as a separate shapefile set with base name **filename_N**. This corresponds to the NOTES shapefile export option of Walls. There is at most one such description per station. The note attribute table has the first four fields of the station attribute table plus a 64-character NOTE field.

METADATA TABLE (FILENAME_.DBF)

The metadata table, **filename_.dbf**, is a customizable one-row table that conveys information about the content of the shapefiles as a whole. Its structure and content is defined in a text file, **filename_.def**, which Walls processes just prior to shapefile export. The particular .def file that was used to generate the table will also accompany the shapefiles. The following table structure is an example of what might be produced. Note that the first five fields are always present and that FILENAME, PROC_DATE, and SURVEY_SW will be automatically assigned values by the export function.

Field Name	Field Type	Field Size	Field Description
CAVENO	Text	4	Required: Unique number assigned by MCNP (duplicated in vector shapefile).
FILENAME	Text	8	Required: Base name for the shapefiles (GIS theme) transferred to MCNP.
PROC_DATE	Number	8	Required: Date survey data file was converted to shapefiles (YYYYMMDD).
DATAHIST	Text	128	Required: Data processing history (duplicated in vector shapefile). See **Note 5**.
SURVEY_SW	Text	40	Required: Name of cave survey software and version.
GIS_SW	Text	40	Name of GIS software and version.
HORZ_UVE	Number	8.2	Horizontal component unit variance estimate. See **Note 6**.
HORZ_LOOPS	Number	8	Horizontal component loop count.
VERT_UVE	Number	8.2	Vertical component unit variance estimate.
VERT_LOOPS	Number	8	Vertical component loop count.

NOTES

1. The shapefile export function of Walls supplies for each survey vector a hierarchical area name based on named branches of the project tree. Whether or not a given branch node contributes to the hierarchy is a property setting labeled “Name defines segment”. The area name is stored in the CAVEAREA field, where vertical bars separate name components. Example: Historic Section | Albert’s Dome | Beyond Henry’s.

2. The SURVEYNAME field value is obtained from the title assigned to the survey data file (not the actual file name), which is indicated in Walls as a project tree leaf title. In CRF projects, the title will typically be a number followed by one or more letters, such as “1320A,B”. The numeric prefix, in this case, will be interpreted as the field survey book (FSB) number while the remaining text is considered the survey name. If the leaf title contains no numeric prefix then the shapefile’s FSBNUMBER field is blank.

3. The ATTRIBUTES field of the vector shapefile contains a list of “flag-like” properties that may have been assigned. In Walls, the attribute names are not predefined but are created and assigned by #Segment directives in the data files. The attributes are anything considered important by the surveyors or data manager (“Surface”, “Underwater”, “Needs resurvey”, etc.) and can control how surveys are displayed on maps. Like the CAVEAREA field, the ATTRIBUTES field contains a list of names separated by vertical bars.

4. Except in special cases (e.g., Walker benchmarks like TT8W), the MCNP station names should conform to the CRF naming convention (<FSB No.><Survey letter><Number>). In Walls projects, a name can also have a prefix qualifier, delimited by a colon, to ensure uniqueness across a project with multiple caves or sub-projects. (Example: HISTORIC:TT8W.) Unprefixed names are limited to 8 characters in length while prefixes technically can be up to 128 characters long. Having concluded that prefixes of 8 characters or less will be sufficient if needed at all, we have chosen a 17-character field length for station names in MCNP shapefiles.

5. The length of the metadata table’s DATAHIST field can be made larger than 128; however, only the first 128 characters will be used as a vector shapefile attribute. The shapefile’s DATAHIST field has a fixed length of 128.

6. The unit variance estimate (UVE) is a consistency measure closely analogous to sample variance. It should correlate with expected survey accuracy when there is a sufficient number of surveyed loops. Smaller UVEs are better. The best cave surveys typically produce UVEs with values less than 2.0. The loop counts measure the significance of UVEs and allow those from different data sets

Obituary: Mike Yocum

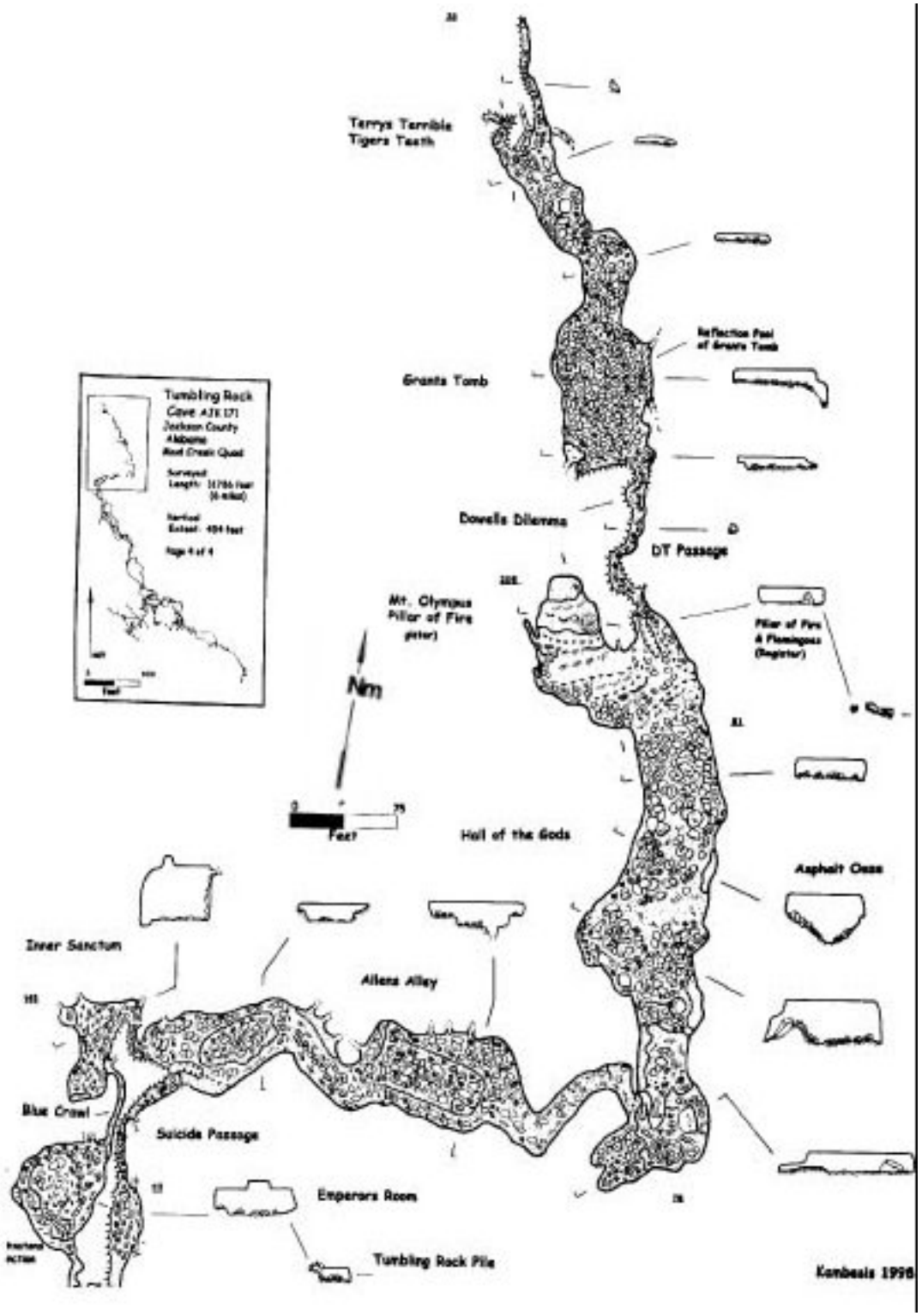
Long-time cave explorer, surveyor and cartographer Mike Yocum passed away suddenly on May 17, 2002. Mike was an avid cave mapper and cave project participant, coordinator and organizer in many different projects in Kentucky and in Tennessee including Hidden River Cave and Roppel Cave (KY) and Blue Spring Cave, TN to name just a few.

He was very active with the Cave Research Foundation and worked as Eastern Area Operation Manager at Mammoth Cave, Kentucky in the mid-ninties. He served as director of CRF's Educational Resource Development Program and produced video footage that would be incorporated into Mammoth Cave National Park's Interpretation Division and Visitor's Services program. He also produced maps to be used for interpretation purposes by the Park. Mike directed CRF's GIS Resources Development Program which he initiated to provide GIS support, consultation and resources for CRF's internal projects.

Mike was also the liaison for data transfer between CRF and Mammoth Cave National Park. The project was the basis for the article published in this issue of *Compass and Tape* which he submited, shortly before he died. The data transfer project was just one of many in which he put in a tremendous amount of his time and energy.

I started caving with Mike in the early nineties and we spent many hours underground pulling tape and telling caving stories. He had a sharp sense of humor, displayed an obessive attention to detail which sometimes drove me crazy, but could talk cave mapping for hours which endeared him to me forever.

Mike will be greatly missed by those of us who spent many hours working with him on our mutual projects both above and underground.


Terrys Terrible Tigers Teeth
Grants Tomb
Dowells Dilemma
DT Passage
Mt. Olympus Pillar of Fire
Hall of the Gods
Asphalt Oasis
Inner Sanctum
Allens Alley
Blue Crawl
Suicide Passage
Emperors Room
Tumbling Rock Pile
Tumbling Rock Cave
Jackson County
Alabama
Kenbesis 1998