Compass & Tape

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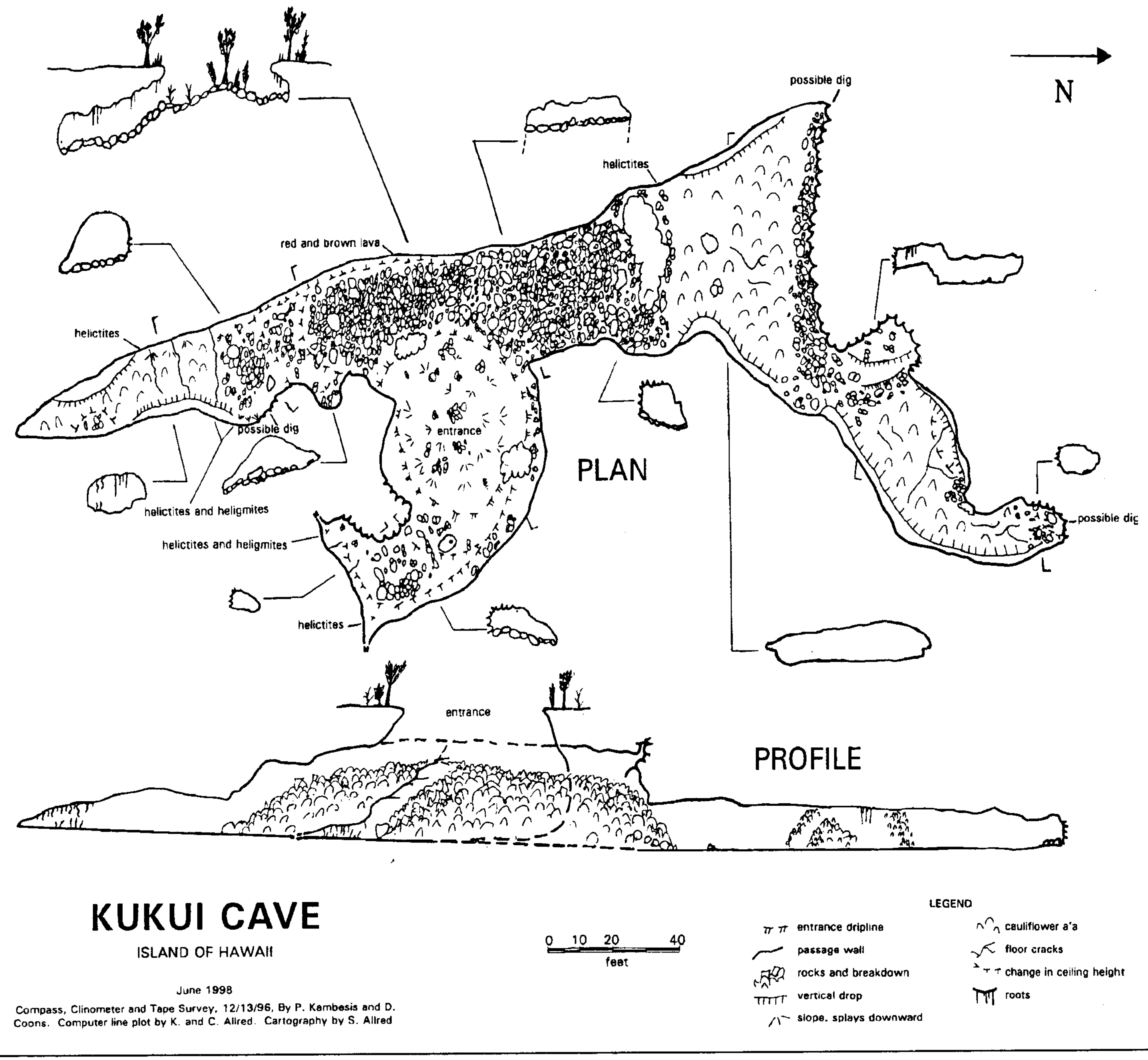

Survey and Cartography Section

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

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

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

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

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

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

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

Overseas Members: SACS welcomes members from. 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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1998 Cartography Salon - Junior Category

From the Editor:

The 1998 Cartographic Salon was a departure from the usual. Salon Chair Don Coons added several new categories, managed to suck in a whole slew of judges, and pulled off one of the most interesting and fun salon in years. For the third year in a row, a computer generated map earned the Best of Show. Actually, the BOS was a series of 28 maps (illustrating various attributes of Crystal Cave, California) and Joel Despain and Greg Stock walked away with the honors for that one. Just goes to show what one can do with that copy/paste button.

Hazel Barton, who co-chaired the salon, will be the big kahuna for the 1999 Cartographic Salon in Filer, Idaho. Beware to those who are "judge-a-phobic" - Hazel will be trolling for potentials. (If SACS could only clone Dick Graham, there would be no lack of willing judges.)

The Editor apologizes to Bob Thrun for taking so long to publish his latest article - all I can say is bad printer drivers and too much humidty. Anyway, if you're into closure (of the loop variety) check out Bob's article. If you don't understand it, read Larry Fish's rebuttal. And if you're still confused, consider taking up survey in lava tubes - mapping voids enclosed in magnetite really changes ones "closure" standards

And finally, look over Dasher's questionnaire on cave data reduction/plotting programs. It will certainly help you determine what to look for in cave data handling software.

Oh, and one more thing. Cruise to the SACS website (http://www.caves.org). Its been revised and updated with a focus shift from information about SACS, to more of an emphasis on resource material and links for cave mappers and cartographers. Comments and suggestions are always welcome.

Now, if I could only get that 00000 pen to work....

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Submissions

All types of materials related to cave survey, cartography and cave documentation are welcome for publication to *Compass and Tape*. Manuscripts are accepted in ANY form but are most welcome on magnetic media (3.5 inch diskettes or CD-ROM -- in IBM compatible or Mac format) or as attached email files. Typed material is acceptable and we will also take handwritten material (as long as it is legible). Artwork in any form, shape or size is also welcome.

Send all submissions for Compass & Tape to:

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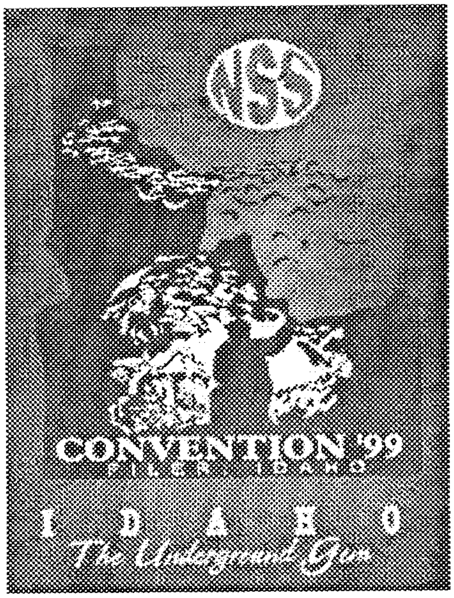


1999 NSS Convention - Filer, Idaho
Survey and Cartography Section

CALL FOR PAPERS

This is a call for papers for the Survey and Cartography session at the 1999 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 beneit others or are encountering problems that someone else may have solved. In either case, an informal session presentation would be appropriate.

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

Presentations can be on any topic related to any aspect of cave mapping, and the material 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, who is coordinating the session, 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 15, 1999. If you want to submit your abstract via email please send it to Bob Hoke (the alternate session coordinator) at **bobhoke@smart.net**

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

Survey & Cartography Section Minutes

George Dasher, SACS Secretary

The 1998 meeting of the Surveying and Cartography Section of the National Speleological Society was held on Thursday, August 6th, 1998 in conjunction with the NSS' annual convention. The Convention took place at the University of the South in Sewanee, Tennessee. The Section meeting was held in Blackman Hall of the Wood Laboratory Building. Attending were the following 17 members and friends of the Section:

Darrell Adkins, Roger Bartholomew, Rich Breisch, Todd Bryan, Berry Chute ,Don Coons, Hubert Crowell, George Dasher, Frank Filz, Walt Hamm, Bob Hoke, Pat Kambesis, Kirk MacGregor, Roger Ryan, Bob Thrun, Carol Vesely, Arnie Weisbrot

Chairman Carol Vesely called the meeting to order at 12:53 pm. She thanked Roger Bartholomew for the excellent job he had done in running the morning session, and she said that she had nothing to report.

Roger then gave his Vice-Chairman report. He said he had gotten a few more papers this year, and had thus had to phone less people beforehand to solicit papers.

Secretary George Dasher said that he had done nothing since the previous year's meeting, and that nothing had been required.

Treasurer Bob Hoke said the Section "has more money than we know what to do with." He said SACS has approximately 211 members and $3882, that SACS makes money on every issue of the *Compass and Tape*, that the recent color cover was a donation by Bob Richards, that the *Compass and Tape* gives only a few free issues, and that we exchange only with Compass Points, the British equivalent of the *Compass and Tape*.

Editor Pat Kambesis then said that two issues of the C&T had recently been mailed, and that she plans to complete another immediately after the Convention. She also said that she had recently constructed a SACS web page, and that this is linked to the NSS page. She said that the SACS web page included general information on the Section, a call for papers, and some Convention information.
She said it cost $12 per year, and she had made a decision, in consultation with Bob Hoke.

Bob Hoke said that the web page had already brought in two new members. Arnie Weisbrot said that a set of the NSS cave symbols should be included for people to download. Bob suggested that the *Compass and Tape* bibliography could be included. George Dasher said that he wasn't sure he could locate that bibliography as he had completed it two computers ago. Everyone agreed that Pat was right to have spent the $12.

Don Coons next gave a report on the Cartographic Salon. He said that this year he had experimented breaking the Salon into several categories with different judges for each category. He was "well satisfied" with the results. The Salon had been much more complicated and there had been six categories. The largest and most popular of these categories had been the Open Salon, where over 40 maps had been entered. The judges for this category had been Dick Graham, Rod Horrocks, and Paul Burger. Don thanked all the judges for their hard work.

The next category were the computer maps, and had been judged by Aaron Addison, Mike Yocum, and Bernie Szukalski. This had been divided into two subcategories—computer-generated maps and monitor-viewed maps. Don had entered one of his own maps in this last group—Obscure Magnificence Cave, which is Alabama's deepest cave. He had done this to get the category "going," and he had subsequently disqualified his entry because he was this year's Cart Salon chairman.

The third category had been the Junior Speleological Society maps, and this had been the "most fun." There had only been three entries, and two had been so good that they were originally mistaken for adult maps and entered in the open category. The judges here were Pat Kambesis, Carol Vesely, and Hazel Medville.

The fourth category had been published maps. There were seven entries and the judges were Dave Bunnell and Bob Richards. Don said that one good thing about this year's Salon was that an individual, such as Bob, could enter in one category and judge in another.

The fifth category was experimental. There were no entries in this group.

The six category was First Time Entries. Five people entered this group, and one green ribbon was awarded. The judges were again Dick Graham, Rod Horrocks, and Paul Burger.

Don said over 80 maps overall had been entered. The Medal Award was given this year to Joel Despain and Greg Stock for their computer-drawn map of Crystal Sequoia Cave, California. There was some general discussion of the Salon, and Don said that each judge will be given a critique form in which to assess the overall Salon. These will be printed in an upcoming *Compass & Tape*.

Hazel Barton will be the 1999 Cartographic Salon Chairman. There was then a call for a 2000 Cart Salon Chairman. No one volunteered. (Secretary's Note: Rod Horrocks later volunteered for this job.)

Don concluded his report by saying that he appreciated the opportunity to chair the Salon and that he "enjoyed doing it."

Hubert Crowell then gave a report on this year's surveying contest. He said that six survey teams had entered the Salon, and that Art and Peg Palmer had won the contest with a 0.14% error—a new "world's record." Hubert also said that

Bob and Bob had donated a $20 gift certificate and that this, together with the $10 given by SACS, had allowed him to award the winners $30.

Carol Vesely said there was quite a turn out for Monday's Survey and Cartographic Workshop, and that the students had been a very mixed group. Carol said that Pat Kambesis had led the surveying part with Carol's assistance, and that Carol had led the cartographic part with Pat's assistance. Carol also said that the in-cave portion had been in Dry Cave, which—as it turned out—was located a lot further from the Convention site then either Carol or Pat remembered.

Carol said that Bob Gulden and Cyndie Walk had assisted with the workshop, and that they had been a great help. She also advised that, if the workshop is repeated at another convention, then more assistance will be required. Carol said that the workshop went really well, and that—in the afternoon—some people drew up the sketches they had made that morning in Dry Cave while other persons drew up sketches that they had brought with them.

Carol next said that the minutes of the 1997 SACS meeting had been published in a recent C&T and that no one had complained. She then asked if there was any old business.

Arnie Weisbrot said that he had presented a paper and made a motion to standardize the different sizes of map sheets at the 1997 SACS Session. He said that this standardization would include the size of the sheets, the title blocks, and the margin drawing number block—as specified in ASME Y14.1 and 414.1M. Those maps agreeing with these standards would be awarded bonus points in the Cart Salon.

Carol asked why standardize, and Arnie replied that standardization would make it easier on the cartographers, it would economize, it would simplify filing, it would ensure completeness, if would simplify publication, and it would simplify electronic exchange. There was some general discussion, chiefly by Carol, Bob Hoke, Arnie, and Roger Bartholomew, and Bob Thrun. It was also noted that Bob Hoke seconded Arnie motion in 1997, and that voting on the motion had been delayed to allow the information to be disseminated via *Compass and Tape*.

Carol noted that the Cart Salon part seemed to be the sticking point of the issue. George Dasher said that the Cart Salon judges had the ultimate say in whether or not bonus points could be awarded for any criteria. The discussion became quite lengthy and—in the end—Arnie withdrew his motion. Hubert Crowell immediately remade the motion without the Cartographic Salon bonuses. Roger seconded the motion, Carol called for discussion—there was none, and a vote was taken. This was four in favor, nine opposed, and one undecided. The motion failed.

Hubert next brought up the issue of SACS purchasing video equipment. He said the price of this equipment is going down and the technology is going up, and he recommended that the Section again hold off on purchasing the equipment. No one had any objections to this plan.

Hubert then brought up the prizes for the Convention Surveying Course. He made a motion that $40 be allocated for three prizes—1st, 2nd, and 3rd place. Arnie seconded the motion, there was some discussion, and a vote was taken. The motion passed unanimously.

Carol then asked if there was any new business. Bob Thrun said it would nice if someone would review the presently-available cave survey programs. He said that this "someone" should type in the data and take the program as far as possible. They would then determine what is good and not good about each program. Bob said that he should not be the person to do this evaluation. No one volunteered as this would be a fair amount of work.

Bob Hoke asked if it would be better to do this in the form of a questionnaire, and a casual reviewer might miss some of the programs options. Darrell Adkins said that the evaluation should include the data entry process. George Dasher said he would put together a draft questionnaire (See page 6 of this issue of *Compass & Tape*)

There was no additional new business, and Carol asked if all of the officers would be willing to continue with their positions—all were, but George said he probably would not be attending the 1999 convention. Barry Chute moved that the current slate of officers be accepted by acclamation, Arnie seconded the motion, and it was passed unanimously.

Carol closed the meeting at 1:55 pm.

1998 Cartographic Salon
Sewanee, Tennessee

The 1998 Cartographic Salon was chaired by Don Coons (IL) and co-chaired by Hazel Barton (CO). A total of 80 maps were submitted for judging (40 of those in the Open category). Coons added a number of new categories which were judged in addition to the standard Open Category. These included: Computer maps (subcategories: hard-copy and monitor-viewed), Junior Category, First-time-Entry Category, Published Maps Category and Experimental Category. All categories had entries with the exception of the Monitor-View Computer and Experimental categories.

Judging took place on Monday through Thursday of Convention Week. Awards were presented on Thursday evening. On Friday morning, a map critique was held so that the entrants and judges could discuss judging criteria and talk about specific maps. A large herd of judges include:

Open Category: Paul Burger, Rod Horrocks, Dick Graham

Junior Category: Pat Kambesis, Carol Vesely, Hazel Medville

First Time Entry Category: Paul Burger, Rod Horrocks, Dick Graham

Published Maps Category: Dave Bunnell, Bob Richards

Computer Hard-Copy Category: Mike Yocum, Aaron Addison, Bernie Szukalski

Following are the results of the 1998 NSS Cartographic Salon:

Medal Winner - Best of Show

Crystal Cave, CA, Joel Despain & Greg Stock

Blue Ribbon - Merit Awards

Caves of Cave Run	Tom Spina	Open Category
Dig-Dug Cave	Hazel Barton	Open Category
Selected Caves on Fox Mountain, GA	Brent Aulenbach	Open Category
Ka'Eleku Caverns, HI	Bob Richards	Open Category
Kukui Cave, HI,	Soren Allred	Junior Category
Sotano De Los Tres Ojos Verdes, Mexico	Marion Ziemons	Published Maps Category
Crystal Cave, CA	Joel Despain & Greg Stock	Computer Hard Copy Category

Green Ribbon - Honorable Mention

Ch'En P'Ix	Mike Futrell	Open Category
Obscure Magnificence Cave, AL	Pat Kambesis	Open Category
Buttress-Buttress, Gully Cave, CO	Hazel Barton	Open Category
Alabama Cave	Hazel Barton	Open Category
Goats Grave Cave	Carlene Allred	Open Category
Root Cellar Cave	Mick Sutton	Open Category
Den Cave	Walt Hamm	Open Category
Dravosburg Cave	Walt Hamm	Open Category
Broken Biscuit Cave	Hazel Barton	Open Category
Dr. Bellou Section, Kazumura Cave, HI	Flint Allred	Junior Category
Indian Ladder Cave, WV	Luke Bowman	Junior Category
Tombstone Cave, KY	Ron Fulcher, Jr.	First-time Entry Category
Poison Ivy, Cave	Jerry Wallace	Published Maps Category
Tumbling Rock Cave, AL	Pat Kambesis	Published Maps Category
Wiley's Cave, TX	Bob Richards	Computer Hard Copy Category

Data Reduction/Plotting Program Questionnaire

by George Dasher
(with some assistance from Larry Fish)

The following is a questionnaire put together to evaluate the different cave data-reduction/plotting survey programs currently available. **Input is welcome both from the individual program authors as well as program users.** Please keep your answers brief, as we want only enough information to compare your program to other programs. Also please add additional questions if you feel that the current questions do not adequately address what your program can do.

If you need to ask questions, my contact addresses are

George Dasher
63 Valley Drive, Elkview,
West Virginia 25071.
email: wvcaver@juno.com
phone:304-965-13915

The questionnaire should be returned to me at either one of the above addresses, or at my work e-mail which takes attachments. That address is:

dasher@mail.dep.state.wv.us

Please be advised that this questionnaire was officially requested by SACS, and that our ultimate goal is to publish some a report in the *Compass and Tape*. Keep your answers to those questions brief also. Submission deadline is May 15, 1999.

General

Please circle whether you are the author of the program in question or are you a user?

Program Author User

A1: What is the name of the program?

A2: Who wrote the program?

A3: Who is filling out this questionnaire?

A4: What hardware is required to run the program?

A5: What software is required?

A6: In what language or software is the program written?

A7: When was the program first written? Major modifica tions?

A8: In what manner is the program operated (i.e., formatted memos, Windows, DOS with internal memos, DOS with data files, something entirely different, etc.)? If Windows, then what version of Windows?

A9: What are the good points of the program?

A10: Bad points?

A11: Unique things?

A12: How user friendly is the program?

A13: Does the program cost money? If so, how much?

General Data Input

B1: From what software or programs can the raw data be inputed (i.e., Lotus,Qpro, text files, other cave survey programs, etc.)?

B2: When entering the data by hand, is the input via formatted menus, text files, spreadsheets, etc.?

B4: In what mode is the data stored (i.e., ascii, individual program language, etc.)?

B5: Can data files be copied and/or backed-up without the use of the program?

Individual Data Input

C1: What variables can be entered regarding the overall cave survey?

C2: What variables can be entered regarding each individual survey?

C3: Can text notes be entered with an individual survey?

C4: How many different variations of the individual survey shot data can be entered (i.e., foresights only, backsights, backsights only on compass, tape in decimal feet, tape in inches, data in metric, depth gauge readings, etc.)?

C5: Can left-right floor-ceiling dimensions be included with the individual survey shot? Are these limited only to one value per dimension?

C6: Can text notes be entered with a given survey shot?

C7: What is the general manner in which the survey data is entered (i.e., From Station, To Station, Survey Distance, Foresight Azimuth, Foresight Inclination)?

C8: In general, how many key strokes are required to enter a single line of survey data?

C9: Can the individual survey shot data be entered randomly, or must it be entered subsequentially? Can the data be reordered once in the program to match the order surveyed, or to some other criteria?

C10: What tricks have been incorporated into the program to make data entry easier (i.e., does the program automatically assume that the From Station is the previous survey shot's To Station, does the program automatically add the letter designation to the station number, etc.)?

C11: What is required to change data (i.e., input via menus, editing a spreadsheet, editing a text file, etc.)? In general, how many key strokes are required to change a single azimuth?

C12: If the survey has been defined as including backsights, how is the backsight "turned off" if none was taken for the individual survey shot?

C13: What is the maximum number of survey shots the program can handle?

C14: What is the maximum number of surveys the program can handle?

Magnetic Declination

D1: Does the program adjust for magnetic declination?

D2: Is this adjusted by individual survey, for all surveys, or can the user choose between the two options?

D3: Can magnetic declination be turned off?

Loop Closure

E1: Will the program close loops?

E2: Is loop closure simultaneous or subsequential?

E3: If the loop closure is subsequential, can multi-connected loops be closed?

E4: By what parameter is the closure weighed (i.e., number of survey stations, surveyed distance, horizontal distance, etc.)?

E5: Can the order the loops are closed be weighted? By what parameter? By the user s choice?

E6: Can the loop closure be turned off and the coordinates printed and/or the loop plotted uncorrected?

E7: Are the uncorrected coordinates displayed in the data lists, or are only the corrected coordinates listed?

E8: What parameters are outputted for each loop closure (i.e., total error, horizontal error, X error, Y error, Z error, etc.)?

E9: Does the program detect blunders? If so, what kind of blunders will it detect? By what method? Does the blunder correction equal automatic correction? Can the blunder detection be turned off?

Output

F1: Is the ultimate goal of program digital or paper?

F2: What is the general form in which the data is outputted (i.e., printouts, plots, etc.)?

F3: In what mode is the outputted data stored (i.e., ascii, individual program language, etc.)?

F4: Can the program export data to other cave survey programs?

F5: Is the raw spherical data located in the same place as the rectangular data?

F6: Is a print preview available so you can see what the printout will look like before it is printed?

F7: What data is outputted regarding each individual survey shot (i.e., raw spherical data, final rectangular data, etc.)?

F8: Can data be outputted regarding the individual surveys? If so, what is this data (i.e., surveyed length, horizontal length, average survey shot length, etc.)?

F9: What data is outputted regarding the overall cave survey (i.e., surveyed cave length, horizontal cave length, cave depth, average survey shot length, date and time of the data run, etc.)?

F10: Does the program total cave length in horizontal distance, surveyed distance, or both?

F11: Can data be excluded when totaling the length or depth of the cave? If so, what data can be excluded (i.e., circumference surveys, splay shots, bad data, overland surveys, etc.)?

F12: Can data be excluded for other criteria?

F13: Can you measure the distance and angle between two arbitrary survey stations?

F14: Does the program support, read, and display information from database programs for use in cave inventory projects?

Plotting

G1: Does the program plot?

G2: Does the program plot to the screen, to paper, or to both? (Note: If the program plots to both the screen and paper, then Questions G3 through G10 should be answered twice once for each medium.)

G3: Does it plot at a fixed scale or user-variable scale?

G4: Does the Program plot to magnetic north, true north, or to the user's preference?

G5: Are there any restrictions on cave size, coordinate number size, or paper size?

G6: What information can be included with each survey station (i.e., station number, elevation, etc.)?

G7: What information can be included with each survey (i.e., survey name, designation, personnel, etc.)?

G8: What information can be included on the overall plot (i.e., title block, north arrow, bar scale, labeled entrances, cave length, cave depth, personnel, time and date of data run, etc.)?

G9: Can different colors be used to show different information, such as depth, survey, year, section, etc.? If so, then what information can the colors show? Can the range and color value be adjusted?

G10: Can the program plot a profile view?

G11: Can you locate or identify surveys and stations by clicking on them with the mouse? Can you "bring up" other information with the mouse?

G12: Can individual areas of the cave be isolated and "zoomed in" on? Can these individual areas then be printed?

G13: Can the plot be panned?

G14: Can the plot be rotated? If so, in one, two, or three axis?

G15: Does the program support stereo viewing? If so, is it two-color or side-by-side?

G16: Is the refresh automatic? If so, then what is the time between refreshes?

Cartographic

H1: Can the program output the data to drafting computer programs, such as AutoCAD?

H2: Does the program have cartographic capabilities?

H3: Can the program display a representation of the passage walls based upon the left, right, floor, and ceiling data? If so, what auxiliary features are available, such as smoothing, shading, colors?

H4: Can the program display a legend, bar scale, depth bar, north arrow? Which north?

H5: Can bitmap images be imported so that the cave features can be plotted on topographic maps, geological maps, aerial photographs, etc?

H6: Can the program model or display surface terrain above the cave? Can the program read DEM files or similar terrain-modeling information?

H7: Can the color-by-depth be tilted to match the dip of the strata or the dip of the cave?

H8: Can the surveys be tilted to match the dip of the strata or the dip of the cave?

H9: Can the colors be selected or adjusted? Line width? Fonts? Font size?

Other Comments:

Please submit questionnaire to George Dasher by May 15, 1999

A Comparison of Simultaneous and Sequential Closure Adjustment Methods

by Robert Thrun

Most cave survey data reduction programs use a simultaneous least-squares closure method. One notable exception is COMPASS by Larry Fish, which uses a sequential closure method with the best loops being closed first. CavePlot by Dave Herron uses a similar method. CAPS by Hubert Crowell uses a cruder sequential method. KARST by Garry Petrie uses a "simulated annealing" method. Other than these programs, all current programs use some form of simultaneous least-squares adjustment

Larry Fish claims that the main advantage of the best-loops-first method is that it prevents the good loops from being contaminated by the errors in bad loops.

I have two objections to sequential closure adjustment. The first is that it throws away information. Before I adopted a simultaneous adjustment method I surveyed a small maze cave. There was a major junction less than 200 feet from the entrance. There were two main routes to it, plus branching and a cross-connection, giving 5 or 6 reasonable routes from the entrance to the junction. These gave various locations a few feet apart for the junction. There was no reason to favor any of these locations over another. If I chose one location or averaged two routes, then I would be ignoring the others. The loops involving intermediate junctions would also be ignored.

If there are multiple surveys between two junctions, the sequential method will use the average of two surveys that closely agree. The simultaneous method will use the average of all the surveys.

The other hazard with sequential adjustment is that an excessive amount of adjustment may be dumped into the last section to be adjusted. The advocates of best-loop-first adjustment claim that this will probably have a blunder and it should have a large adjustment.

Fish said "the best approach has to accomplish three things:

1. It must be able to deal with blunders.
2. It must be able to deal with random errors.
3. It must be able to deal with a mixture of both."

In order to demonstrate the problems of sequential closure adjustment to others, I decided to make some test cases and see how close simultaneous and sequential methods come to the "correct" measurements. I don't know how to make artificial test cases with realistic or typical blunders, but random errors are easy to simulate. I made a square grid with 30-foot level survey shots and added random errors from a normal distribution. This represents a best case situation for the least-squares simultaneous adjustment, but the sequential method should be able to handle it too.

I used a standard deviation of 0.1 feet for the distance measurements and 2.0 degrees for the horizontal and vertical angles. The length error is less than I would use and the angle errors are more, but they were suggested in Section 20.8.3 of the COMPASS.TXT file. When I speak of "errors" I mean the differences between the simulated or adjusted survey shots and the perfect grid.

The test cases were run through my CMAP program as an example of simultaneous adjustment and COMPASS as an example of sequential adjustment. Figure 1 shows an unadjusted 20 by 20 grid. CMAP was used to make Figure 1 because COMPASS does not show an unadjusted plot with the closure errors hanging open. Instead, COMPASS always connects the last shot of a loop to the closing station giving the appearance of an adjusted survey. The arrangement of the data into north-south lines with individual shots to the west is due to the order in which the data were generated.

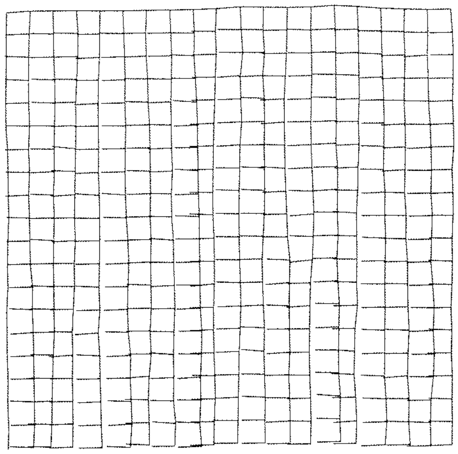


Figure 1. 20 by 20 grid, unadjusted

Figures 2 and 3 show the survey after simultaneous and sequential adjustments. The simultaneous adjustment appears to have less errors than the sequential adjustment. The errors remaining after the sequential adjustment appear to be arranged in columns. These columns are an artifact of the ordering of the unadjusted data and the way that COMPASS detects loops and will be discussed later.

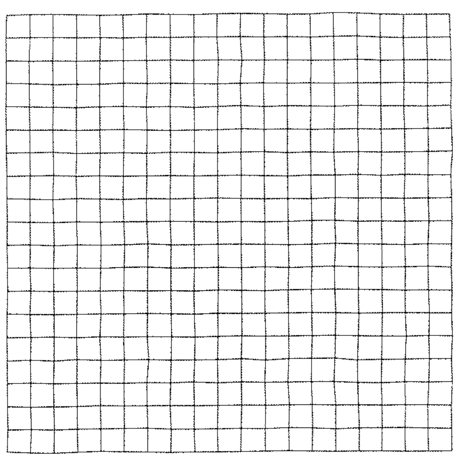


Figure 2. 20 by 20 grid adjusted by CMAP

To get a more precise idea of how the errors were changed by the two adjustment methods, I evaluated the standard deviation and extrema of the errors. Table 1 gives a comparison of the original errors, and the errors after simultaneous and sequential adjustment. These results are typical. The simultaneous adjustment reduces the standard deviations (S.D.) of the angle errors and their minima and maxima to about 0.6 to 0.8 of the original values. The sequential adjustment slightly increased the S.D. of the horizontal angles and almost doubled the S.D. of the vertical errors. The minima and maxima of the angle errors were increased by a larger factor than were the S.D.s. The errors after the sequential adjustment are like a survey with a few blunders in that the size of the largest errors are out of proportion to the standard deviations. Both adjustment methods had the angle errors feeding into the distance errors, with the sequential method having much larger distance errors.

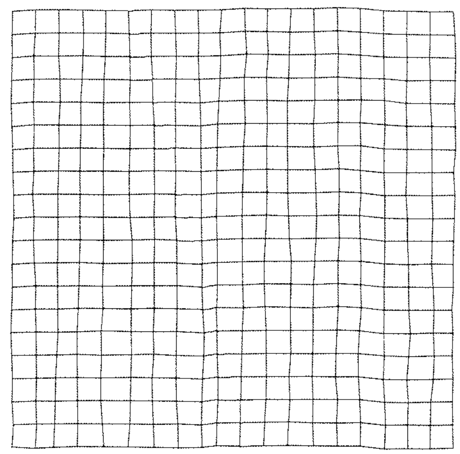


Figure 3. 20 by 20 grid adjusted by COMPASS

Table 1. Comparison of errors with simultaneous and sequential adjustment.

20 by 20 grid, original data

	Mean	S.D.	Min.	Max.
Distance:	0.001	0.099	-0.292	0.344
Azimuth:	-0.035	1.961	-5.131	6.305
Elevation:	-0.125	1.915	-5.375	6.075

Grid adjusted by CMAP (simultaneous)

	Mean	S.D.	Min.	Max.
Distance:	-0.018	0.413	-1.462	1.317
Azimuth:	-0.035	1.183	-3.980	3.810
Elevation:	-0.126	1.385	-4.077	4.305

Grid adjusted by COMPASS (sequential)

	Mean	S.D.	Min.	Max.
Distance:	0.124	2.331	-13.010	9.130
Azimuth:	-0.112	2.165	-9.260	8.120
Elevation:	-0.369	3.895	-22.800	14.360

The way angle errors feed into the distance errors affects both methods. To avoid this I made some grids with balanced errors, 1.0 degrees S.D. for the angle errors and 0.5236 feet for the distance errors. This made the error distribution the same in all directions. This test case is even more favorable to CMAP. Table 2 compares the adjustment methods for a 20 by 20 grid with balanced errors. These results are typical. The simultaneous adjustment reduces the S.D.s to 0.70 to 0.75 of their original value. The sequential adjustment more than doubles the S.D.s, making the errors worse than what they started with.

Table 2. Effects of adjustment on a grid with balanced errors.

20 by 20 grid with balanced errors

	Mean	S.D.	Min.	Max.
Distance:	0.013	0.510	-1.852	2.067
Azimuth:	-0.010	0.993	-2.820	3.157
Elevation:	0.024	0.965	-3.308	3.393

20 by 20 grid adjusted by CMAP

	Mean	S.D.	Min.	Max.
Distance:	0.005	0.370	-1.078	1.622
Azimuth:	-0.010	0.703	-1.773	2.135
Elevation:	0.024	0.686	-2.056	1.976

20 by 20 grid adjusted by COMPASS

	Mean	S.D.	Min.	Max.
Distance:	0.057	1.034	-3.810	3.920
Azimuth:	-0.112	1.905	-6.720	7.530
Elevation:	0.072	2.078	-7.340	7.300

When I sent some of my early results to Larry Fish, he tried to duplicate them with 4 by 4 grids and did not get the bad results like I did with a 20 by 20 grid. I then tried 4 by 4 grids. The sequential adjustment changed the S.D.s only slightly. The simultaneous adjustment consistently reduced the S.D.s to 0.7 to 0.8 of the original errors.

With much larger grids, like 50 by 50, the sequential method performed even worse than for 20 by 20. The simultaneous method again reduced the errors by a factor of 0.70 to 0.75. Table 3 gives the results. As you can see, some of the errors are very large after the sequential adjustment. I used balanced errors in the unadjusted data. The errors used for Table 1 give worse results for both methods.

Table 3. Comparison of simultaneous and sequential adjustment on 50 by 50 grid.

50 by 50 grid with balanced errors.

	Mean	S.D.	Min.	Max.
Distance:	0.009	0.520	-1.724	1.834
Azimuth:	0.000	1.018	-3.991	3.529
Elevation:	0.019	1.005	-3.696	4.210

Grid adjusted by CMAP (simultaneous)

	Mean	S.D.	Min.	Max.
Distance:	0.001	0.365	-1.278	1.432
Azimuth:	0.000	0.730	-3.204	2.470
Elevation:	0.019	0.723	-2.696	2.604

Grid adjusted by COMPASS (sequential)

	Mean	S.D.	Min.	Max.
Distance:	0.071	1.608	-7.350	8.330
Azimuth:	0.031	3.354	-14.740	23.100
Elevation:	0.202	3.454	-21.640	16.880

One of the claimed advantages of sequential adjustment is the handling of blunders. I reversed a shot in the middle of the survey shown in Figure 1. The sequential adjustment performed exactly as advertised and gave the same result as if the blunder were not there. The simultaneous adjustment gave the result shown in Figure 4. The blundered shot got adjusted down to approximately zero length. However, much of the rest of the grid is not distorted by the blunder. The interesting thing is that the errors from the reversed shot don't propagate very far into the adjusted survey network. The effect damps out one or two loops away from the blunder. In a normal survey, the blunder would be smaller in relation to the loop and its effect would be less. Table 4 shows the error statistics for the survey with the blunder and with the 6 immediately adjacent shots left out of the statistics. If we ignore the blunder and the shots next to it, the simultaneous adjustment is better than the sequential adjustment.

The blunder whose effect is shown in Figure 4 and Table 4 was a reversed shot in the east-west direction. I reversed a shot in the north-south direction. The simultaneous adjustment gave a result like Figure 4 rotated 90 degrees. The sequential adjustment gave a much different result. Figure 5 shows that a single blunder can progagate to other loops in a sequential adjustment. I won't bother tabulating the error statistics for Figure 5.

Table 4. Errors in grid with blunder after simultaneous adjustment.

Grid with blunder adjusted by CMAP

	Mean	S.D.	Min.	Max.
Distance:	-0.083	1.304	-28.562	8.5814
Azimuth:	-0.006	2.148	-20.788	24.146
Elevation:	-0.039	2.700	-4.078	63.770

Grid with blunder adjusted by CMAP (blunder and 6 adjacent shots omitted)

	Mean	S.D.	Min.	Max.
Distance:	-0.077	0.660	-8.415	2.983
Azimuth:	-0.038	1.341	-5.276	5.172
Elevation:	-0.124	1.388	-4.078	4.306

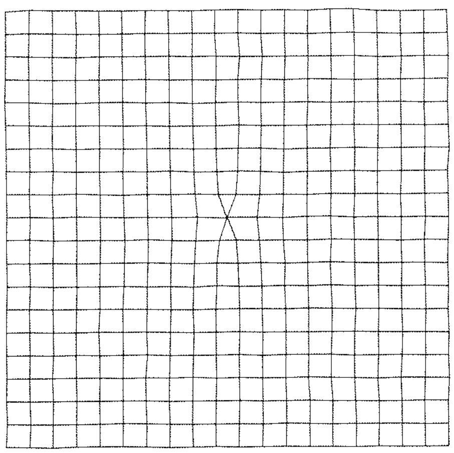


Figure 4. Grid with an east-west blunder adjusted by CMAP

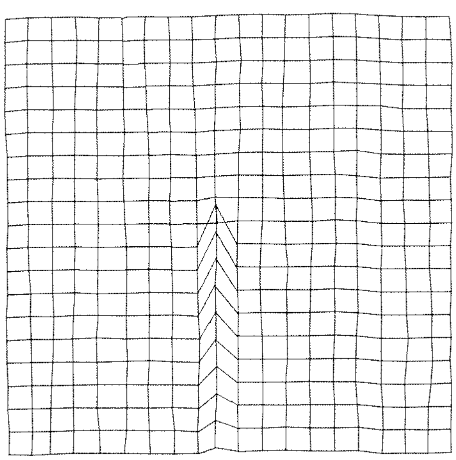


Figure 5. Grid with with a north-south blunder adjusted by COMPASS

What is going on?

One clue is the pattern of north-south columns in Figure 3. This pattern occurs consistently. I took a closer look at the loops that were adjusted by COMPASS. Fish said "Basically, you want to locate all the individual loops, calculate standard deviations for each loop and then sort them into a list ordered from best to worst." It would be impractical to find *all* the loops because there are an extremely large number of them. I imagined that COMPASS would find a simple set of loops like those in Figure 6. COMPASS finds a set of overlapping loops as shown in Figure 7. The overlapping loops form north-south columns because of the order in which the data were generated and the way COMPASS finds loops.

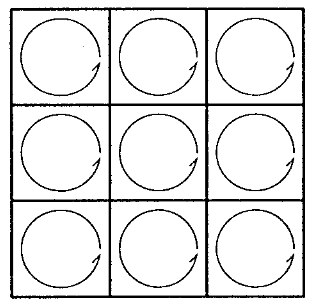


Figure 6. A simple set of loops.

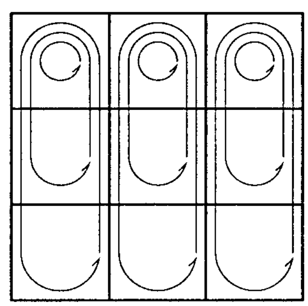


Figure 7. Overlapping loops found by COMPASS.

The sequential adjustment process forms long chains of adjusted loops. When the last few shots are incorporated into the adjusted network, they will have their endpoints determined by the chains of adjusted loops. If single shots close the final gaps between chains of loops, then these shots will have their measurements ignored in the closure adjustment! The default in COMPASS is to rate loops by percent error. This may favor the larger loops, but rating loops by absolute error still produced a pattern of columns similar to Figure 3.

Again, it should be emphasized that the larger the network, the more the sequential adjustment process increases random errors. I suspect this would be true with any ordering of the sequence; just the shape of the chains or clusters of closed loops would change.

Some users of sequential adjustment advocate closing the outer loops first. In the general case it may be hard to define "outer". What if the survey is in the shape of a cube? For most caves, and particularly for maze caves, it is possible to form an outer loop. If the outer loop has a blunder, the blunder would be propagated inward.

The blunder propagation shown in Figure 5 is caused by the same thing that causes the overlapping loops. COMPASS does not examine all possible loops. The "best" loop is chosen from those that are examined. The first survey to a station is involved in all the examined loops that lead to the station. How this produces Figure 5 would require a complicated explanation. The basic problem can be shown by a simple example with two stations and three 'survey routes' between them.

A1	A2	10.0	90.	0.0
A1	A2	50.0	90.	0.0
A1	A2	51.0	90.	0.0

COMPASS finds and ranks two loops, consisting of the first and second shots and the first and third shots. Since 10 and 50 feet make a better loop than 10 and 51 feet, the adjusted distance between A1 and A2 is the weighted average of 10 and 50 feet. (This is 16.67 feet because of 1/length weighting.)

Instead of decreasing the influence of a blunder, the use of the first survey to a station by COMPASS actually insures that a blunder in the first survey will be used in the adjustment and possibly be propagated to other loops.

Pro and Con

When I presented an earlier version of this paper at the 1998 NSS Convention, Steve Reames followed it with a paper on The Advantages of Sequential Closure Methods. His arguments were as follows:

1. If you have good loops, the closure adjustment method doesn't matter.

2. There is a defect in the least-squares algorithm. SMAPS (another computer program) changed the angle of a shot at the entrance of Groaning Cave from 265 degrees to 336 degrees even though that shot was not involved in any loop.

3. COMPASS has good blunder detection, which is more important than closure adjustment. COMPASS finds blunders and even suggests corrections.

How accurate should a cave survey be? Most cave maps are not accurate enough for digging a new entrance, but are more than accurate enough for route finding. Many cave surveyors seem to be concerned about accuracy. If they were not concerned about accuracy, they might use cheaper instruments. As you can see from the statistical tables, the sequential method increases the errors. Look at the size of the errors after sequential adjustment. How accurate do you try to make your surveys? Is the remaining accuracy good enough? Can you see the difference on the finished map? Do you mind deliberately decreasing the accuracy? The added errors are not distributed evenly throughout the survey. Instead, they are concentrated in a few large errors, much like mild blunders.

I can't speak for SMAPS. CMAP, like any computer program that solves simultaneous linear equations, has numerical roundoff error. CMAP adjusted the section at the entrance of Groaning Cave, which is 100 feet long, by 0.01 feet. This was done using single precision arithmetic.

The handling of blunders does not require sequential adjustment. CMAP reports blunders as large error ratios. The unadjusted plot is a good tool for refining the location of the blunder. It is up the user to correct the blunder. Many blunders are bad tie-ins. A sequential adjustment method does nothing about tie-ins. COMPASS has a blunder handling routine that helps to correct bad tie-ins. There is no reason why the same procedure can't be used with any adjustment method. WALLS, a program by David McKenzie, has better least-squares adjustment than CMAP. WALLS detects blunders and suggests corrections in a way that is as good or better than COMPASS.

References:

Larry Fish, COMPASS.TXT, documentation file distributed with COMPASS

Larry Fish, "The Problem With Least Squares Loop Closure", Compass & Tape, Vol. 13, Issue 1, No. 41, May 1997, also in Compass Points No. 15, March 1997

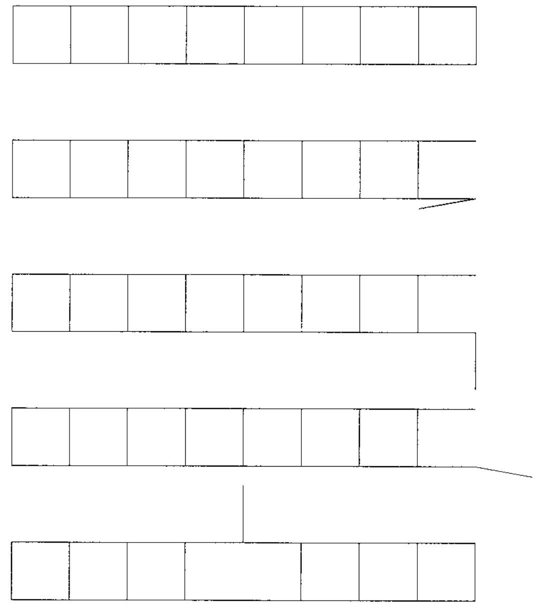
Additional Comments on Adjustment Methods

Robert Thrun

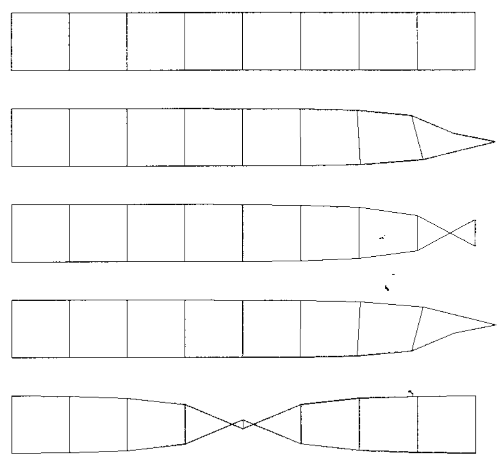
In my previous article, I pointed out that COMPASS always uses the first survey to a junction in every loop that goes to that junction. This will affect the sequential adjustment of a survey with blunders and can lead to blunder propagation. I should emphasize that this is the behavior of just one program. Other sequential adjustment programs may find loops differently.

The sequential adjustment of random errors by COMPASS may also be affected by the loop-finding method. A random error in the first route to a junction will be propagated to later loops. This may contribute to the increase of random errors in networks. I have no way of testing this without having a best-loops-first program that finds a different set of loops. Reordering the data will not eliminate overlapping loops found by COMPASS. I have no Mac to run CavePlot, the only other best-loops-first program.

Also, the blunder I tested was in the middle of a large, well-connected grid. It's effect may not have progagated very far into a least-squares adjustment because the surrounding stations were braced on all sides by more of the grid. The opposite of a location in the middle of a large grid would be a location at the end of a narrow series of loops. To see how a blunder would propagate with less bracing, I made several sets of data with a single compass blunder. There were no random errors to confuse the effects a blunder. The top illustration shows the raw data with no blunder. The other illustrations show various blunders.



The next set of illustrations shows the same sets of data after a simultaneous adjustment. You may see for yourself how much the blunder propagates and contaminates good loops.



REBUTTAL: SIMULTANEOUS VERSUS SEQUENTIAL LOOP CLOSURE

By Larry Fish

Bob Thrun's article in this issue of *Compass and Tape* compares loop closure techniques. In the article, Bob criticizes the sequential loop technique used by COMPASS. There are several problems with these criticisms and the data used to arrive at the conclusions:

I. BOB'S DATA IS NOT RANDOM.

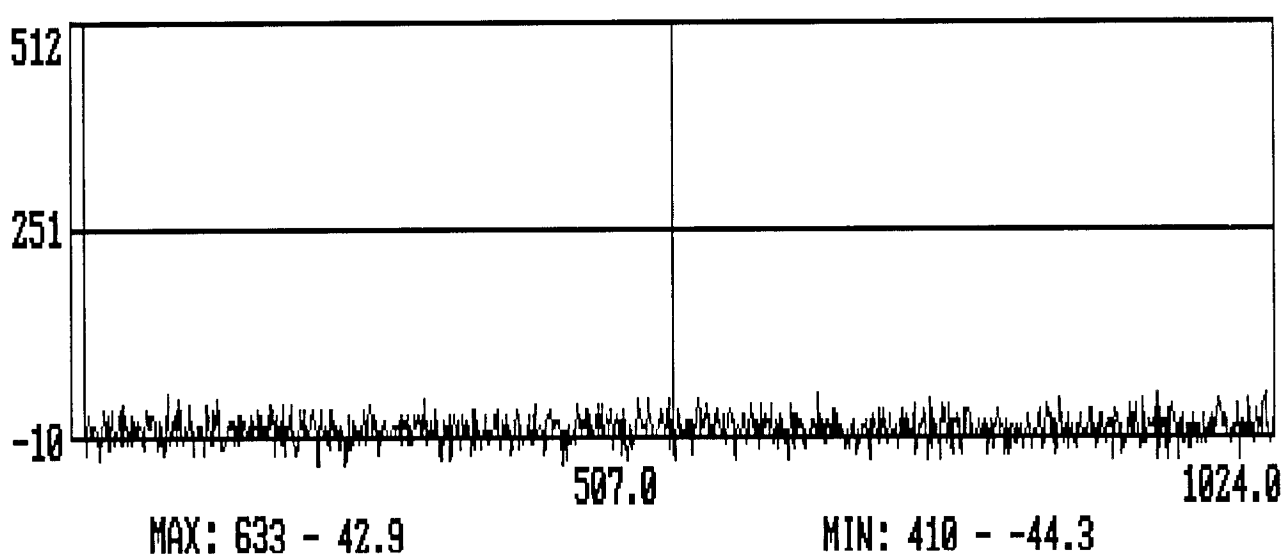
In order for Bob's tests to be valid, the data he is using must be random. A visual examination of the data shows that it is not random. To verify this, look at Figure 1 (20 by 20 grid, unadjusted) in Bob's article. You can easily see patterns in the data. If you look closely at the columns, you can see that the columns vary in width, whereas the rows do not. Moreover, the columns show patterns of wider and narrower columns. For example, look at the ninth column from the left in Figure 1. It is consistently narrower than the rest of the columns. In addition, there are other columns that are persistently wider or narrower from top to bottom. The same anomalies do not appear in the rows. Just rotate Figure 1 so you are looking from east to west. Although the rows jog back and forth a bit, they are consistently the same width.

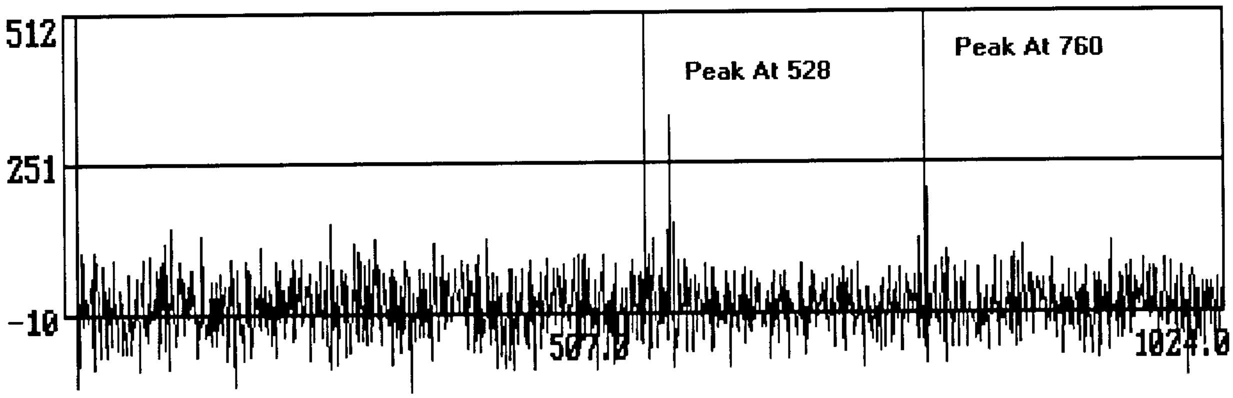
This is not the kind of behavior you would expect from random errors. At the very least, you would expect the rows and columns to show a random variation of height and width. In fact, it appears to me that there is an artifact in the random number generator used to produce this data which produces a repeating pattern. Computer generated random numbers are notorious for having non-random patterns in them like this. In Chapter 6 of *The Art of Scientific Computing*, it says: "Now our first and perhaps most important lesson in this chapter is: be very, very suspicious of system-supplied random number generators....If all scientific papers whose results are in doubt because of bad random number generators were to disappear from library shelves, there would be a gap on each shelf about as big as your fist." Most random number generators used in computer languages these days are based on the "linear-congruent" method which is notorious for having repeated patterns and non-randomness in the least-significant-bits of the data.

The reason the patterns in the random data are important is that Bob makes a point of calling attention to these same patterns in the closed COMPASS data in Figure 3. He says that they are due to a fault in the way COMPASS processes the data. Obviously, the patterns come from non-randomness in the original data.

In addition, the fact that there are patterns in the data Bob is using to test the loop closure means that data is biased in a way that makes LSSE appear to work better. The fact that there are patterns in the data means the original errors are concentrated along the columns. For Bob's tests to be valid, the errors must be uniformly and randomly distributed

Graph 1 - Random data





Graph 2 - Non-random data

throughout his 20 loops. If they are not, COMPASS will do what it is supposed to do and close the worst loops last. If the worst loops fall into a pattern as they do in Bob's data, the pattern will be visible in the result.

The human eye is very sensitive to subtle visual patterns and so just seeing a pattern is not necessarily conclusive evidence of a defect in the random numbers used to generate the data. For this reason, I subjected Bob's data to several tests designed to test the randomness of his data. The tests show strong non-random patterns in the data. One of the tests is called *autocorrelation* and it generates a graph showing how often subtle patterns repeat themselves.

Graph 1 shows what truly random data should look like. Each peak and valley represents a place where the pattern repeats. The numbers along the bottom show the interval at which the pattern repeats itself and the numbers along the side show the intensity of the repetition. As you can see, in truly random data, there are only very small peaks and valleys.

Graph 2 shows Bob's shot-length data. As you can see, there are lots of strong peaks. The biggest peak occurs at 760 but it is **not** an indication of non-randomness. It is caused by the fact that there are only 760 shots in the data Bob sent me. However, the peak at 528 is a strong indication of a a non-random pattern in the data that repeats every 528 samples. This peak appeared not only in the shot length data, but in the azimuth and inclination data. The fact that the number 528 represents the binary number 1000010000 is another strong indication of a problem with his random number algorithm. Other strong peaks and valleys appear at 17, 18, 56, 84, 140, 226, and 296. All these tests prove that the data Bob is using has patterns in it and is not random.

II. BOB IS USING THE WRONG MEASURE.

Bob is using Standard Deviation as the measure of quality for successful loop closure. Standard Deviation measures the **variability** of a particular sample of data. Because of the way sequential survey reduction works, you would expect Standard Deviation to increase. Basically, that is what it is designed to do. With sequential loop closures, the good loops get better and the bad loops either stay the same or get worse. This means that the difference between the largest and smallest error will get larger. This means more variability and thus larger standard deviation. Let me give you a simple example. Let's say you have two loops, one good and one bad. Here is a chart of the errors:

	Good Loop Error	Bad Loop Error	Standard Deviation
Unclosed	2	5	2.1
Sequentially Closed	1	5	2.8
Simultaneously Closed	3	3	0

In this chart, I have illustrated several different scenarios so you can see how standard deviation responds to different situations. The first row shows the unclosed data for the two loops.

In the second row, I show the result of a sequential adjustment. The sequential method closes the best loop first, so the good loop will get better. In the second row, I show how the standard deviation gets larger when you close the good loop first. Since the difference between the good loop and the bad loop increases, there is more variation and a larger standard deviation. The last row shows the result of a simultaneous loop closure. Here the error is averaged across the two loops and the good loop get worse and the bad loop gets better. Because there is very little difference between the two loops, the standard deviation goes to zero. So, LSSE will always improve the standard deviation of the errors, but does that really mean that the quality of the loops has improved?

If this is not enough to convince you that standard deviation is not the way to measure the quality of loop closure, here is an even simpler example:

	Good Loop Error	Bad Loop Error	Standard Deviation
Unclosed	2	5	2.1
Fixed Typographical Error	0.1	5	3.4

In this example, I have fixed a typographical error in the good loop that dramatically improves the quality of that loop. Now obviously, it is a good thing to correct a typographical error, and yet as you can see, the standard deviation increases.

Now the real question is what should you do with the errors? Even without complicated tests and mathematics, the issue is very easy understand. Here is a real world example.

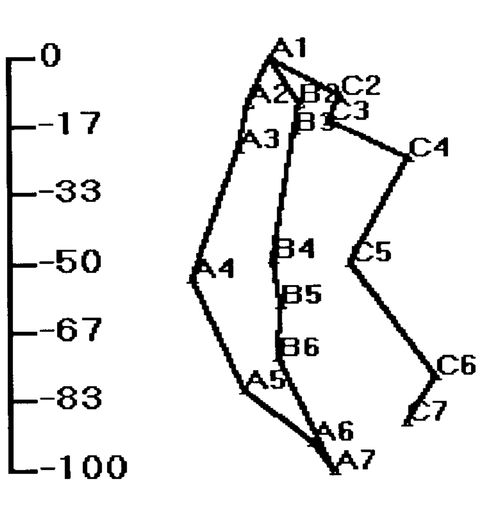
Figure 1 shows two interconnected loops that run from the entrance of a cave to the deepest point in the cave. The cave is exactly 100 feet deep. The loop formed by the "A" survey and the "B" survey closes very well. There is a blunder in the "C" survey, so the loop formed by "B" and "C" closes badly. If you close the loops in COMPASS, the program reports the depth to be -99.6 feet. If you close the loops in Bob's program, CMAP, it reports the depth as -95.8. If you process the data in SMAPS it reports the depth to be -95.5 feet deep. In otherwords, in these programs, the blunder from the "C" has been allowed to contaminate the good loop and both programs report that the cave is 5 feet shallower than it really is.

Because of the fact that the A-B loop closes well, you know that -99.6 foot depth is accurate. Because of the fact that the B-C loop closes badly, you know that the -95.6 is wrong. Why would you ignore this information and average the two loops? Bob makes some hand-waving assertions that COMPASS throws away important survey information, but here is a perfectly clear example of LSSE discarding essential information. LSSE ignores the fact the we have one loop that closes well and simply combines the two errors.

LSSE is based the concept of random errors and uniformly random processes. If all the data in a cave were homogeneously created by a uniformly random process, then you could apply LSSE and get good results. However, caves are surveyed by people of varying abilities, with varying quality of instruments and under various conditions. Thus, there is always a mix of blunders and various levels of random errors. Even when the errors are random, and not blunders, the distribution of the random error varies with the quality of instrument, the skill of the surveyor and the difficulty of the cave. Thus you will have some loops in which the spread of the random data is broader and less trustworthy. Even here, in situations where the errors are random, it makes sense to honor those loops that are statistically proven to be more reliable.

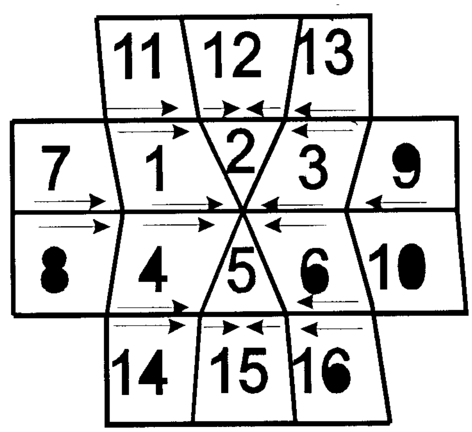
The information about how each INDIVIDUAL loop closes is the most accurate and precise information about the quality of specific parts of the survey data. This means that the surveys in some loops will always be of higher quality than others. LSSE simply throws away this information.

Figure 1



III. BLUNDERS IN LSSE.

Another flaw in Bob's analysis of COMPASS's performance occurs when he looks at blunders. One of the arguments against LSSE is that it spreads blunder errors to other loops in the cave. In his article, Bob attempts to prove that this effect is minimal. In Figure 4 of his article (Grid with an east-west blunder adjusted by CMAP), he shows a single blunder in a mesh of 400 loops. In the text, he comments that the errors do not propagate "very far" from the blunder. He says that the blunder error only propagates to six loops adjacent to the blunder. Six loops seem like a lot to me; but, if you look carefully, you can see that there are really 16 loops around the blunder that have been distorted. Below is a blow up of area around the blunder. I have placed arrows in the drawing to show where the distortions in each loop occur. As you can see, there are 16 loops that are visibly distorted.



Another problem with Bob's illustration is that it tends to visually hide the effect of the blunder. If you have one blunder in the middle of 400 loops, the distortion will appear rather small in the middle of those 400 loops. But how many caves have 400 loops where each loop is only four shots long? Most loops in real caves are much longer, so the effect of a single blunder can spread through a much larger portion of the cave. In a small cave where there are only 10 loops, a single blunder would have a catastrophic effect on the accuracy of the data.

Finally, blunders are much more common than one per 400 loops. For example, in Lechuguilla Cave, 32 percent of the loops have blunders in them. In Wind Cave, 25 percent of the loops have blunders in them. (These are a conservative figure, because it is impossible to tell whether each loop has only one blunder in it.) By extrapolating, I have concluded that in surveys like these, there is at least one blunder in every 40 shots. That means that for Bob's data to be representative, it should have 10 blunders in it.

Paul Burger did a careful study of blunders during a recent resurvey of a nearby commercial cave. He found that one in 20 shots had a blunder. These figures are impressive, because these surveys were very carefully done in relatively easy, well lit, concrete-trailed walking passages. In more difficult caves, the blunder rate goes up rapidly. For example, in Groaning Cave, a cold, wet, alpine cave, 50 percent of the loops are blundered. To further underscore the prevalence of survey errors, the British publication *Compass Points*, recently published an article (March, 1998) describing the analysis of compass errors in an outdoor test-course. Surprisingly, in spite of a relatively simple course and the use of experienced surveyors, there were relatively large compass errors. All of this means that any survey with more than a few hundred shots must have several blunders in it.

IV. PROPAGATION OF BLUNDERS IN COMPASS.

One of the final points in Bob's article is the contention that sequential loop closure itself propagates blunders. What Bob actually points out is a minor flaw in the way COMPASS selects loops. I have since corrected this flaw and COMPASS now performs significantly better than any LSSE programs. In fact, when I processed Bob's test data with the new version of COMPASS, the two blunders in the data sample were completely undetectable in the plot.

Let me explain this in detail. In the article he says: "Figure 5 shows that a single blunder can propagate to other loops in a sequential adjustment." There are several problems with this statement:

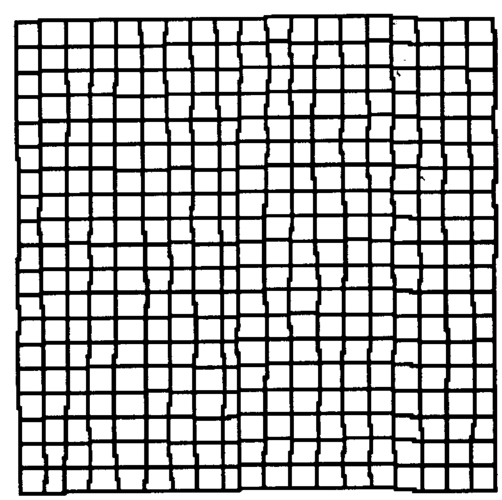
1. BOB'S DATA ACTUALLY HAS TWO BLUNDERS. Bob sent me copies of the data he used to create Figure 5. In spite of his description, I discovered that the data has **two blunders** in it, not just one. They are shot reversals located at shot 1010-1110 and 1010-1011. In addition, the data Bob uses in Figure 4 to test his program (CMAP) only has one blunder in it. (As you will see below, when I test CMAP with the "two-blunder-data," the map is considerable more distorted.)

2. THE PROBLEM IS NOT CAUSED BY SEQUENTIAL CLOSURE. As I stated above, COMPASS has a flaw in the way it defines loops. COMPASS defines loops based on the order the data was entered into the computer. For sequential loop closure to work properly, the program should choose the smallest possible loops. This is essential because it confines blunders to the smallest part of a cave. Thus, when there is more than one way to define a loop, COMPASS should always choose the smallest possible loop. Sometimes, however, it chooses larger loops.

The method COMPASS uses to find loops is left over from the DOS version where slow computers and small memory required a simplified method. Normally, this method works fine, but if the shots are entered in an un-natural order, COMPASS will not choose the smallest loops. Most of the time, this is not a problem because the data is entered in a natural order as it is surveyed. Bob's data is a special case. Each row is entered in sequence and each column is entered in sequence. It would be like surveying all north-south passages all at once and then surveying all west-east passages. No cave would ever be surveyed in this way. When COMPASS closes Bob's data, it chooses larger loops than it should for proper sequential closure. Thus the problem is not with sequential closure, but with COMPASS.

To verify that the problem is caused by the fact that COMPASS uses shot order to select loops, I changed the order of two shots in Bob's data. (I changed no measurements.) When I did this, COMPASS is so successful at dealing with the data that blunders become completely invisible.

Even though it is very unlikely that you would ever encounter this problem in real world data, COMPASS should be able to deal with any sequence or configuration of cave data. For this reason, I have modified COMPASS's loop selection routines to correct the problem. Below is a plot of the exact same data (with two blunders) closed with the new COMPASS routines:



As you can see, the blunders are completely invisible. In fact, COMPASS handles two blunders better than Bob's program handles one. To make the argument clearer, I extracted the nine loops immediately surrounding the two blunders and ran them through CMAP and the revised version of COMPASS (See Figure 3).

The plot on the left shows the result with CMAP after

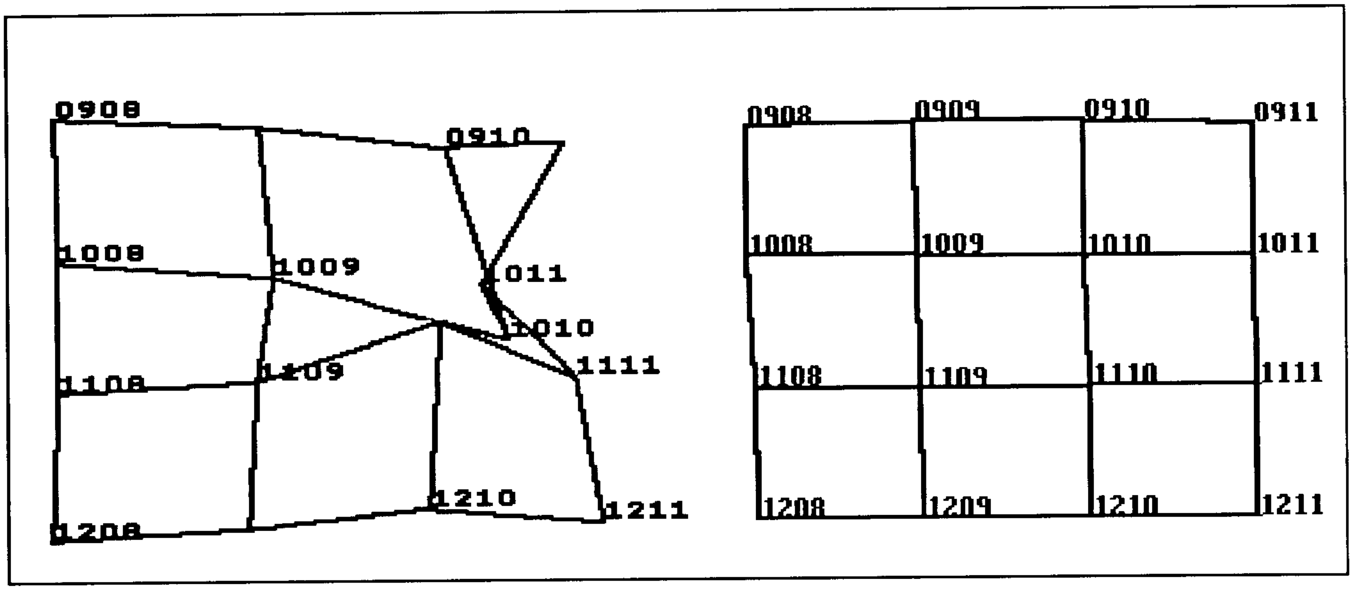


Figure 3

closing all loops. The plot on the right shows the result with the revised version of COMPASS closing the loops. The blunders are shot-reversals on shots 1010-1110 and 1010-1011. As you can see, the CMAP plot is severely distorted. I ran the same data through several other popular programs that use LSSE and found exactly the same pattern of distortion.

VI. USING RANDOM DATA.

Now that it is clear that the sequential method handles blunders better than LSSE, we still have the question of how well the sequential method does with random data. Since Bob's data is clearly not random, I decided to run the same kind of experiment with truly random data. I generated a set of loops similar to Bob's. I used a random number generator that has been extensively tested for randomness. (It passes five different tests for randomness, is free of sequential correlation, and does not use the notorious linear-congruent algorithm that is used in most computer languages.) The data consisted of a grid of nine loops with shots at 90 and 180 degrees and lengths of 30 feet. I then perturbed the azimuths by +/- 1 degree, inclinations by +/- 2 degrees and lengths by +/- 1 foot.

(Note: I chose to use SMAPS for this test because it supports SEF import and export of data. This allowed me to automate the process of generating and processing data. This made it easy to test dozens of data sets without error-prone manual data entry. SMAPS is also a well-respected third-party program that uses LSSE.)

Once I generated the random data set, I processed this data using both the SMAPS and COMPASS loop closers. I then subtracted the resulting closed loops from the un-perturbed data and calculated standard deviations for each component of the data. I repeated the process with the same parameters to get different data sets. I also repeated the process with different random factors. I found a good deal of variation in the results between different data sets even with identical random factors.

Part of Bob's argument is that COMPASS did not improve the standard deviations for the data whereas his program did. As I have already said, when COMPASS processes non-random errors, the standard deviation is expected to increase. However, with truly random data, I could find no case in which COMPASS did not improve the STDs. I did find instances in which SMAPS made the STDs worse than the original data. I also found that with some random sets, SMAPS did slightly better than COMPASS at approximating the pre-randomized data and with other sets, COMPASS did better. As I would expect, COMPASS did better when with larger errors. Here is the result of the worst and best runs for COMPASS:

	SMAPS			COMPASS		
	East	North	Vert	East	North	Vert
Original	0.85	1.16	0.82	0.85	1.16	0.82
New STD:	0.63	0.55	0.51	0.75	0.89	0.73

Here is a summary of the best run for COMPASS:

Original:	1.59	2.28	1.40	1.59	2.28	1.40
New STD:	1.61	1.94	1.25	1.45	1.66	0.97

Since I generated and processed about a dozen data sets, I could see that the quality of the closure varies a great deal. Even when the same randomizing parameters were used, one run could be very different from another. This is to be expected. Just as you can get 20 heads in row flipping coins, you can also get random data sets that will favor one loop closing system or another. You can see that in the last data set above SMAPS actually made the east component of the data worse than the original. I suspect that if I ran through enough samples, I could find a random data set where COMPASS would make the closed data worse than the unclosed data. Nonetheless, the important point is that all the results are very close to each other.

Further, I have always said that LSSE was the better algorithm when you have survey data with completely random errors. The problem is that you seldom have completely random errors in survey data. Even when you only have random errors in a data set, random errors by the very nature are so small that the differences are negligible.

SUMMARY.

Bob seems to be combining two arguments that do not have anything to do with each other. He begins by arguing that sequential loop closure doesn't work but to prove it, he points at bugs in COMPASS. Obviously, bugs in COMPASS do not prove or disprove the efficacy of sequential loop closure.

It is, of course, true that COMPASS has bugs. All programs have bugs. As the infamous computer guru Dr. Wayne Wall once said, "all non-trivial programs have bugs." COMPASS is certainly a non-trivial program and there is list on the internet listing hundreds of bugs that I have fixed in COMPASS. But the important point is that when I fixed the loop-selection-flaw in COMPASS, it performs significantly better than any LSSE program when dealing with blunders. In addition, it deals with **random** data on a par with other programs.

Note: The next release of COMPASS will have the new loop selection algorithms. Also, I have posted an archive on the web containing all the test files used in preparing this rebuttal. In addition, the archive contains the executable and source for the program I used to test the randomness of Bob's data. The address is:

ftp://ftp.iex.net/users/lfish

The filename is: rebuttal.zip

In the Spotlight: SACS Junior Cartographers

This year's Cartographic Salon included a new category to include young cartographers (under 18 years of age). There were three entrants this year and they all did well in their group. One of the Junior maps was so good that it was mistaken as being an adult entry and was initially placed in the Open Category! Following is some background on the Section's young and upcoming cartographers.

A Green-Ribbon Hornorable Mention went to Luke Bowman. His uncle reports on Lucas' first mapping project (map on back cover of this issue).

INDIAN LADDER CAVE

by George Dasher

My nephew Lucas Bowman and I spent the 1998 Memorial Day Weekend at my parents' cabin in Hardy County, West Virginia. While we were there, we decided to map a nearby cave so that he could enter the map in the JSS category of the 1998 Cartographic Salon. (Actually, this was his mother's idea.)

We wanted to map a cave down the South Fork Valley. This cave was virgin and thus a total unknown; however, I was hoping it would prove to be short and something Lucas could handle for his first-time cave map. Unfortunately the landowner was not home. So...

We drove up the valley and into Pendleton County to a cave that is reported in Bill Davies' Caverns of West Virginia. This cave is much shorter than I preferred, but sometimes you've got to make due with what is available. We hiked up and into the Trumbo River Gap, then waded the river and climbed about 20 feet up a near-vertical limestone cliff to the cave's entrance. I was under strict orders from Mom to bring her grandson home safe, so I was sweating on the climb—not from the exposure, but from the threat from Mom.

Once underground, we climbed up the cave's single passage to its ending—it was shorter than I remembered. Lucas is familiar with the basics of cave surveying as he has helped me set up the OTR compass course on several occasions. He has also entered the contest two or three times and last year won the kids part with a loop closure of 1.38 feet in 211 feet.

Once at the end of the cave's single passage, I showed Lucas how to format the survey book. He wrote down all the critical up-front information, then he sketched and kept the notes. I shot the Suuntos, and we both ran the tape. He asked a lot of questions about what to put on the sketch and what symbols to use, and it was he who decided what passage detail got sketched and what didn't. There was one side lead, and I suggested that he just sketch it in. Lucas first crawled out, then declared we would survey it. We did this, then we surveyed out of the cave and down to the river.

We next returned to the cabin. I had been unable to bring a computer, so we used a calculator and the sine tables in the back of the survey book to figure up the X, Y, and Z coordinates. I tried to explain all of this to Lucas, but it was a little too much. The end result was that I calculated the coordinates and plotted the station locations on the graph paper.

Lucas then put the passage dimensions tick marks on the map, drew in the plan view and the cross-sections, and added the vertical symbols. I explained what symbols to use, generally gave advice, and stayed out of his way. In addition, I told him what overall information—such as the title, bar scale, and north arrow—should be put on the map. He later redrew the map at home in ink. I also told him that it was traditional to put the surveyors' names on the map—his answer was, "I'm not putting your name on my map!"

Oh well...

A Blue Ribbon Merit Award went to Soren Allred for his map of Kukui Cave (displayed on the front cover of this issue of *Compass & Tape*). A Green Ribbon honorable mention went to his brother Flint Allred - but what do you expect when your mom is one of the best cartographers around!

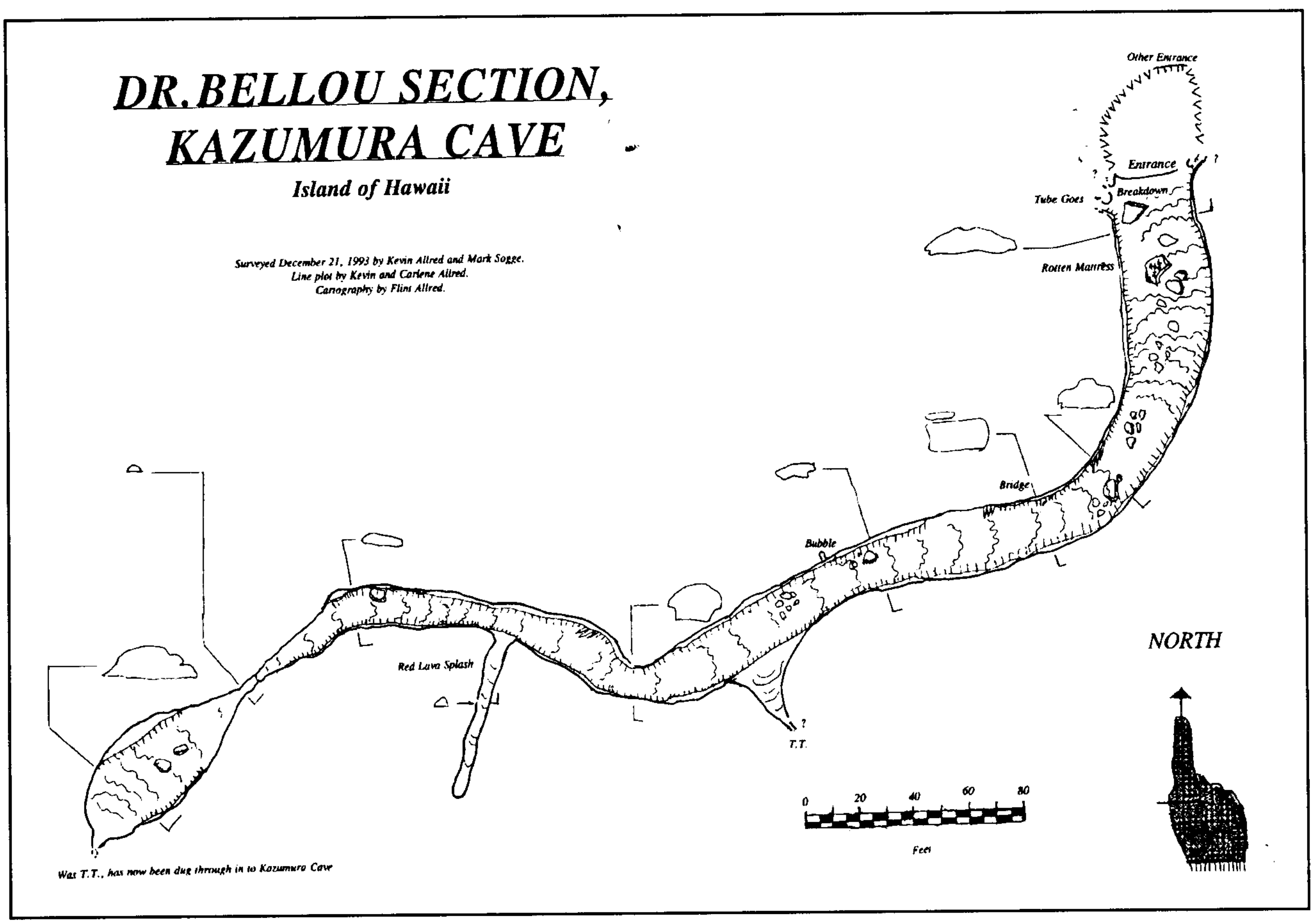
Rising Stars in a Caving Family

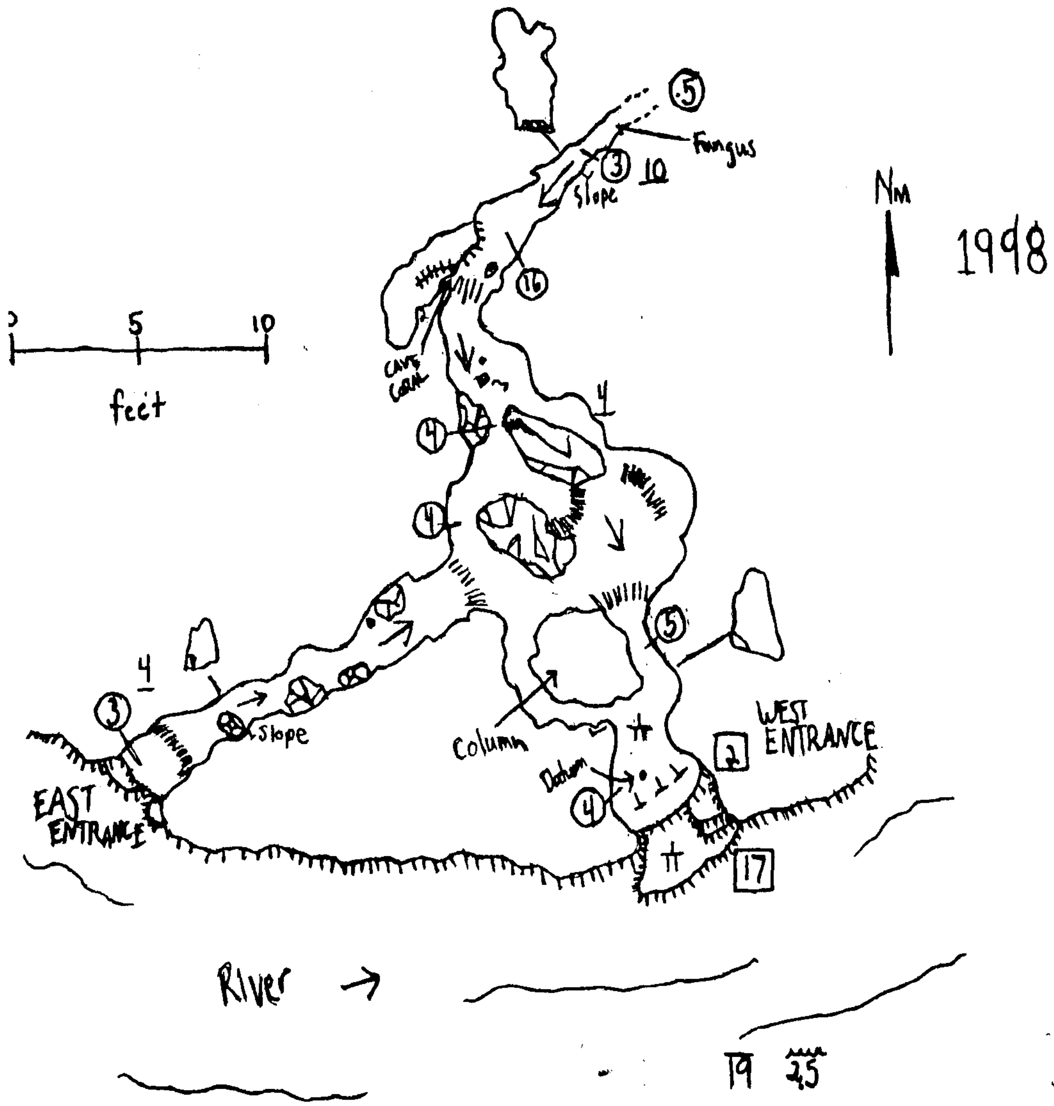
Soren and Flint Allred have grown up in a caving family. Their parents (Kevin and Carlene Allred) have been active cavers for over twenty years and often take the entire family on caving expeditions.

Several years ago, Soren and Flint's dad had been trying to connect Dr. Ballou Cave with Kazumura Cave. The lead he tried to push was too low and tight for him to fit. At one point he got himself jammed so tight that mom had to pull him out. It was time to call in reinforcements - in the form of Soren and Flint. Flint was able to crawl into the tight lead at the end of the cave (on a swimming pool liner to protect him from the grabby, sharp lava), and made the connection between Dr. Ballou and Kazumura Cave - pulling the survey tape along. Since Flint made the connection, he also got to make the map.

In 1997, Soren at that time, 12 years old, became the youngest caver to do the thru-trip in Kazumura Cave. This is a significant accomplishment for a caver of any age since this trip involved 16 rope pitches, over 26 miles of caving with 1100 meters of vertical extent, and an underground camp! Soren's award winning map shows that in addition to being a good, strong caver, he is also on his way to being an accomplished cartographer.

Besides caving in Hawaii, Soren and Flint also participate in caving projects in Alaska.





INDIAN LADDER CAVE
PENDLETON CO.
W.V.

LUKE BOWMAN
MAY 1998

Green Ribbon - Junior Category
1998 Cartographic Salon,
Sewanee, Tennessee