COMPASS & TAPE

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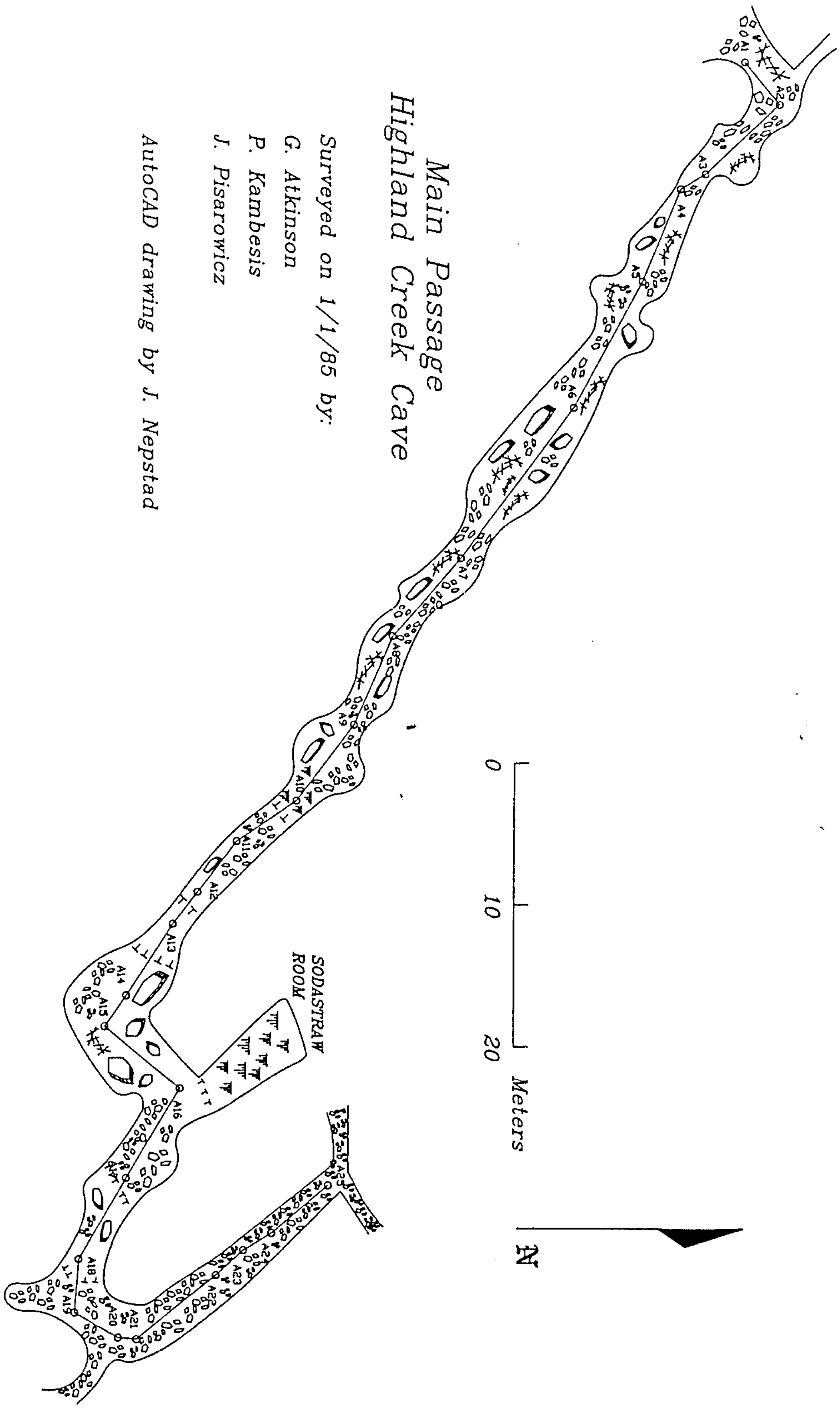

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Survey and Cartography Section - 1988/1989

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Cover: A sample cave map produced with AutoCAD Survey information and passage contents layers have been left on for viewing. (Figure 2 of the CAD applications article by Jim Nepstad of the National Park Service.)

CAD Applications at Wind Cave

by Jim Nepstad

Wind Cave, located in the Black Hills of western South Dakota, is an intricate, multi-level maze of underground passages of incredible dimension. To date, explorers have mapped over 52 miles of these passages, making Wind Cave the seventh longest cave system in the world. All indications suggest that many more miles of cave await discovery. But Wind Cave is much more than just a collection of passageways hidden beneath the hills.

Contained within this maze is an astonishing variety of resources, ranging from items of historical or cultural interest, to magnificent examples of some of the world's rarest speleothems. Woven into this is a tiny, highly specialized, and extremely fragile ecosystem. Managing so many resources with such a high level of susceptibility to human impact is difficult. Making proper management decisions invariably comes down to knowing precisely what resources are located in each area of the cave. For this reason, cave maps have always been invaluable tools for the cave manager.

Wind Cave has traditionally presented its mappers with nontraditional challenges. Perhaps the most daunting of these is the three dimensional maze nature of the cave itself. The entire known cave is contained below a surface area of less than 500 acres. Thus in many areas, several passages overlap at different elevations in the limestone. It is difficult to portray the three dimensional relationships of these passages on a two dimensional piece of paper (see Figure 1). Resources found within the cave have normally been kept off of the map for fear of "cluttering it up", resulting in a map which lacks some of the most critical information concerning the cave. Thus, determining what resources may be found in any particular passage has meant pouring through reams of survey notes, trip reports, and inventory forms - a time consuming process.

In Pursuit of a Better Cave Map

During 1985 and 1986, with the help of some cave radio work carried out by Frank Reid, it was proved that the existing Master Map for Wind Cave was not accurate. Many rooms and passages on the map were shown to be placed several hundred feet from their true positions. Concerned that the map should more accurately portray the relationship between the cave and the overlying surface features and developments, the management at Wind Cave decided that a redrafting of the map was necessary.

The original plan had been to produce a typical ink on mylar drawing of the cave. Since declination changes had to be made in the survey data (the same declination had been used over a thirty year period, during which the declination changed by several degrees), and since radio located passages had to be constrained- thereby vastly complicating the problem of closing the hundreds of surveyed loops in the cave simultaneously - it was immediately apparent that a computer would be necessary.

Initially, the idea was to use the computer to reduce the survey data for the cave's 11,700 survey stations. The resulting coordinates could then be stored away and used to help produce the hand drawn map. But after researching the IBM and IBM compatibles software market, it seemed that we could take it one step further - we could also store the drawing itself (including passage outlines) in the computer with the use of computer-aided- design (CAD) software.

An Introduction to CAD

Just as a word processor is used to manipulate words, sentences, and paragraphs, CAD software is designed to manipulate lines, arcs, circles, and the drawings which contain them. Anything which can be drawn by hand can also be drawn using CAD software. The ability to draw objects on individual "layers" (similar to transparent overlays on conventional drawings) is one of several features which make CAD drawings superior to their paper counterparts. For instance, the plans for a house can be contained in just one drawing, with separate layers for each floor, layers for wiring and plumbing, and even a layer for landscaping. These layers can be viewed one at a time or together in any combination. Once created, they can be plotted at any scale or orientation.

It was the above capabilities which initially attracted us to CAD. No longer did we have to worry about making the map unreadable in vertically complex sections of the cave. By placing each survey station on a layer based on its elevation, we could "turn off" layers in complex areas of the cave to zoom in on the area we were interested in. Layers could be created to portray surface topography, surface developments, and vegetation types overlying the cave, providing visual clues to the links between surface and subsurface worlds.

The software we chose for the redrafting of Wind Cave's map was AutoCAD, published by Autodesk, Inc. Primarily, this was because AutoCAD was (and continues to be) the recognized industry standard. Its huge user base ensures that the program will be constantly evolving. The program's "open architecture" provides programmers with an opportunity to develop add-on programs which compliment the original. AutoCAD is extremely powerful "out of the box", but this feature extends its power significantly. A wealth of information is also available in the form of books, magazines, and user groups making it easier to learn some of the program's finer points.

Methods

The first step in producing our digitized map of Wind Cave was to enter the survey data into a program which could analyze it. The software we chose for this part of the project was SMAPS, Doug Dotson's program for the entry and analysis of cave survey data. Since there are more than 11,700 stations in the cave, representing roughly 40,000 individual measurements, this was no small task. Approximately 600 hours were spent on this part of the project, the end result being a file which contained a unique set of coordinates for each station.

Once this was accomplished, a program was written to read in the coordinates from this list, placing them in an AutoCAD ".dxf" file, a file format which can be used to more or less direct AutoCAD to create a drawing on its own. This file instructed AutoCAD to draw a line between each survey station, and to draw a triangular symbol at the exact location of each station, along with the station's name. This provided the skeleton around which the map would be drawn.

An interesting feature of this line plot is that it takes advantage of AutoCAD's 3D capabilities. The lines between stations are "three dimensional" in that they may be viewed from any possible angle. This provided us with an opportunity to view the profile of the cave for the first time. Other views are providing us with interesting clues into the cave's development by giving us insight into the structural and stratigraphic relationships of the passages.

Once this line plot has been produced, it is possible to add the passage outlines with the use of a digitizing tablet. Passage outlines are drawn with pencil or ink around a line plot, then traced over with the digitizing tablet, which sends a stream of coordinates to the host computer to be stored away. Passage outlines are drawn on layers different from those that contain the line plot, enabling us to turn off the line plot for more artistically appealing maps (see Figure 2 (the C&T cover) and Figure 3).

The Map Becomes a Database

There is another important feature supported by AutoCAD and other CAD packages which we have not discussed yet; attributes. An attribute can be thought of as a tag which can be attached to a part of the drawing. This tag can contain a piece of information concerning that particular part of the drawing. For instance, in a drawing of a house, attributes could be assigned to the door and window symbols. These attributes could contain information concerning the type of door or window needed, its cost, its energy efficiency, and any other information which seems necessary. All of this can be kept invisible if desired.

In the drawing of a cave, attributes could be attached to survey stations. The information which could be stored with each station on a map would include the survey station's name, its X, Y, and Z coordinates, any speleothems present, items of historical and biological interest, information regarding the amount of water present, search and rescue information (rigging instructions, etc.), travel statistics, and any other bits of information which may be acquired in the future. In short, everything known about every survey station in the cave could be included on the map, ready to be accessed at the push of a button.

A cave much smaller than Wind Cave would work quite well with the above scenario. But the amount of information inventory trips are bringing in from the field would quite simply cripple the drawing by vastly slowing down the rate at which it generates on the computer screen. It was therefore decided to store inventory information in dBASE III+ files, with each database record corresponding to a survey station in the cave.

This required a little more creativity, since programs had to be written to interact between dBASE and AutoCAD. At present, we have the capability to search the dBASE files for any set of conditions, at the same time highlighting the survey stations on the AutoCAD map which satisfy those conditions. Even with the huge database and drawing files which Wind Cave generates, this process takes less than five minutes.

It is this important step which takes the digitized map beyond the realm of the traditional cave map. Traditional maps convey most of their information graphically, with little or no text. This is fine for a general overview of a cave. But what if you want to know where all the wet sections of the cave are? What if you want to see all occurrences of a particular speleothem at a particular elevation range? With a little programming, we have unleashed the real power of the digitized map.

The Map Becomes a Collection of Maps

The programs produced at Wind Cave help us mimic one of the greatest talents of a Geographic Information System (GIS), the ability to produce new maps based on the outcome of some kind of query. By manipulating the information stored in the dBASE files, it is possible to produce an almost infinite number of maps from the original. Cross referencing data from two or more fields will produce graphical representations of relationships only dreamed of in the past. What effects are surface developments having on the cave? Do all major aragonite occurrences occupy the same elevation? What fragile areas are experiencing the highest visitations? Maps which will contribute to answering these questions can be produced in very little time. Thus, instead of being limited to one map which attempts to show us everything at once, we have a <u>collection</u> of maps which will show us practically anything we want to know about the cave.

Implications for the Future

By allowing such a vast amount of information to interact with the map, it is expected that digitized cave maps such as the one under construction at Wind Cave will be of tremendous value to cave managers in the future. The decision making process will not only be quickened, but considerably enhanced.

A Final Appeal

Since cavers first began using computers, untold numbers of programs have been written to manipulate cave survey data. There are many benefits (an "I can do better than that" attitude which encourages improvements) as well as pitfalls (a tendency to "reinvent the wheel") to this kind of behavior. In this respect, a certain amount of standardization is desirable.

Now, before I'm lynched by the mobs of cavers who have written their own programs, let me clarify. Cavers take to standards about as well as cats take to water. Therefore, I'm suggesting only the tiniest amount of standardization.

The one thing that all cave survey reduction programs have in common is that they produce a unique set of coordinates for each survey station in the cave. What I suggest is that the caving community agree only to a standardized format for this output. If each cave survey reduction program includes a utility for putting its coordinate list into this format, then all programs written to further manipulate the data (such as many of the programs I've described above) can be shared by the entire caving community, not just the ones that subscribe to a certain cave survey reduction program. This would hopefully provide cavers with a wealth of programs to experiment with, while subjecting them to as little standardization as possible. Food for thought...

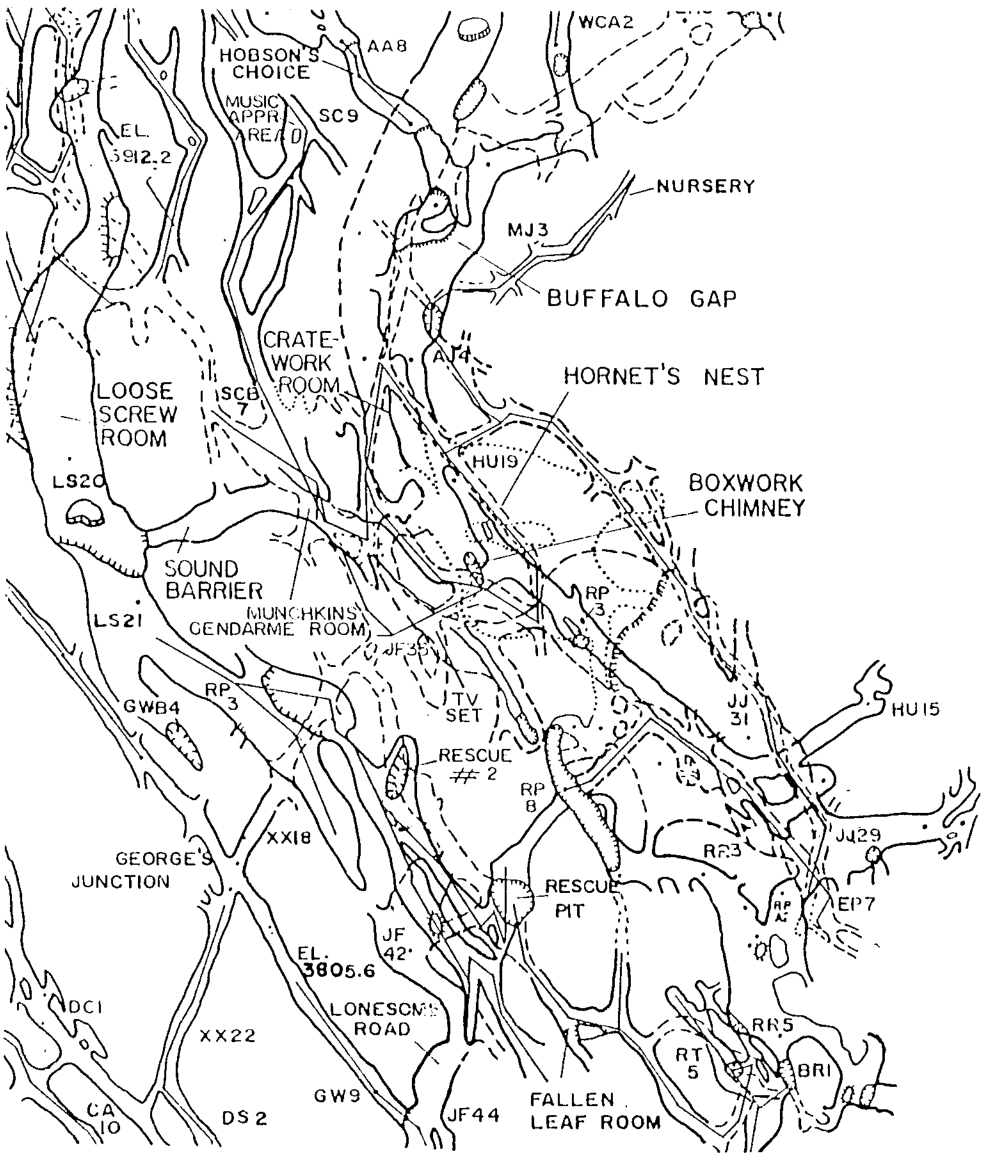

Figure 1
A vertically complex part of Wind Cave. An abundance of areas such as this prevented mappers from including passage features and contents on the map.

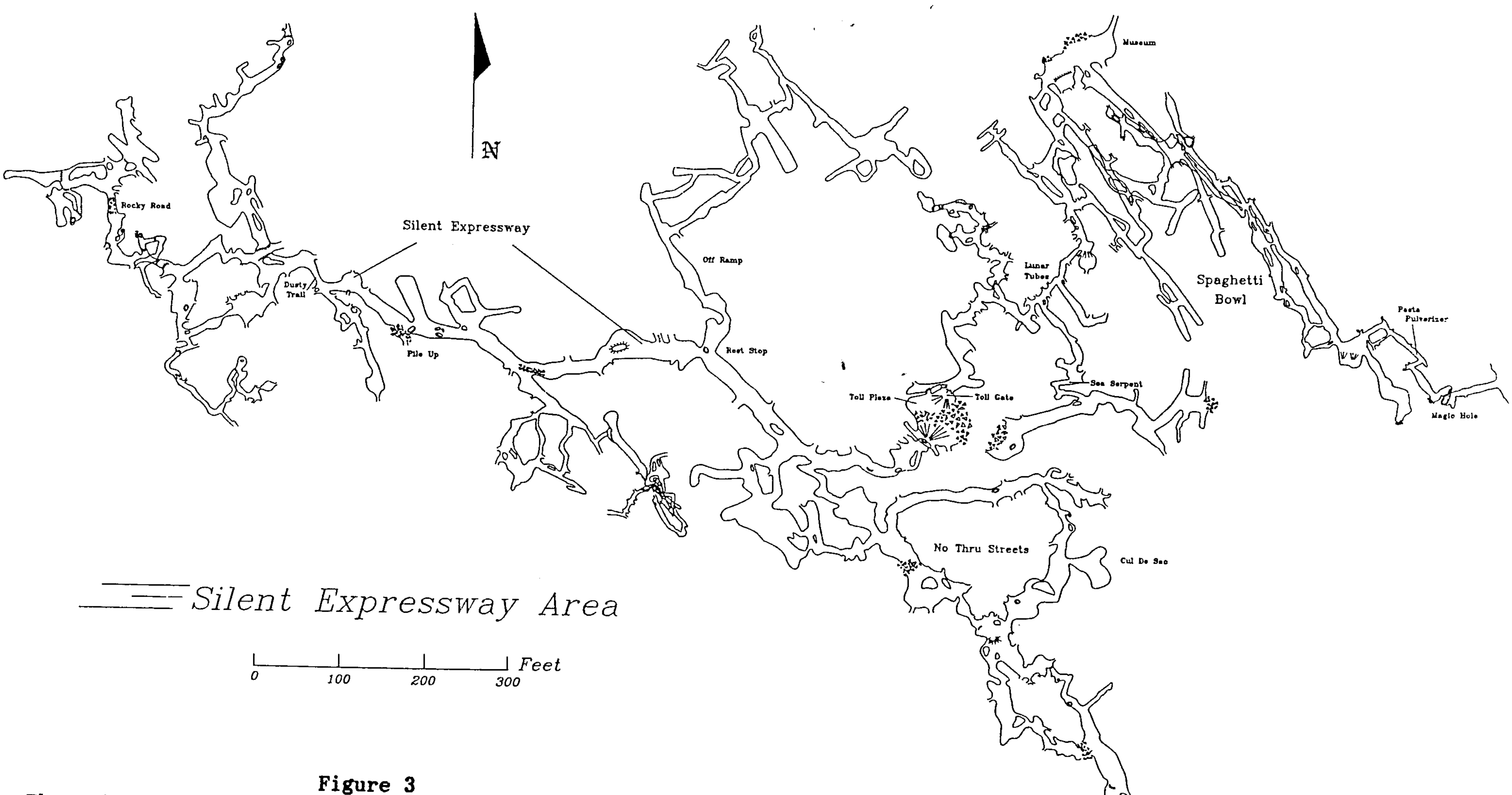

Figure 3

The Silent Expressway area of Wind Cave. Survey information and passage contents layers have been turned off.

50 YEARS OF CAVE MAPPING: A Brief Overview

by John Ganter

Orientation has always been vital to caving, whether the objective is an enjoyable stroll underground or the most quantitative science. Normally interesting questions of location, direction, turns, and distance take on new importance in a linear underground landscape where one cannot see either route or goal. As caving activities have grown more sophisticated, so have the artificial means providing this overall view. All maps say as much about their creators as their subject. Cave maps form a visual history of how NSS members have looked at caves, what they have seen, and what they have chosen to record and remember.

The 1940s and 1950s: The Weekend Reconnaissance

In the early days of the NSS there were caves, it seemed, everywhere. One had only to travel to rural areas and ask. Faced with this abundance, NSS members generally surveyed quickly in order to obtain the general layout of the cave before moving on. A plan map was considered suitable for all but the most complex caves. William E. Davies (1947) summarized the dominant view of mapping as "primarily a job of observation and recording." A.C. Swinnerton (1950) stressed accuracy in determination of the outline and internal elevations of caves, but again leaned towards simplicity and expediency. Perhaps the best examples of this era are the maps in Davies' (1958) <u>Caverns of West Virginia</u> (see Figure 1 and 2) and Henry Douglas' <u>Caves of Virginia</u> (1964). These works resulted from the activities of early NSS members in the eastern metropolis, particularly the Washington D.C. area, over the preceding two decades.

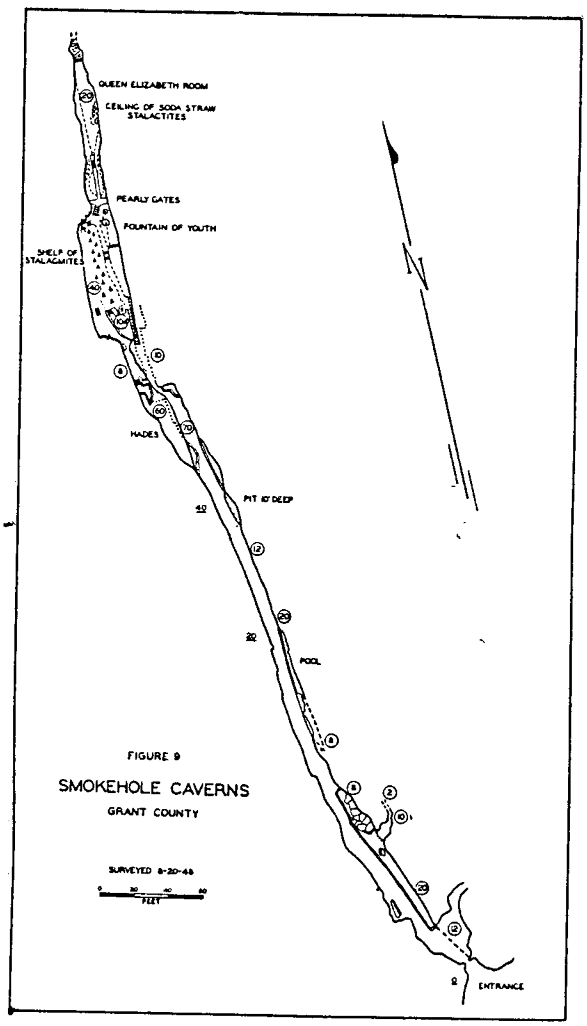

Figure 1: Smokehole Caverns, a 1940s era map from Davies (1958, p. 68).

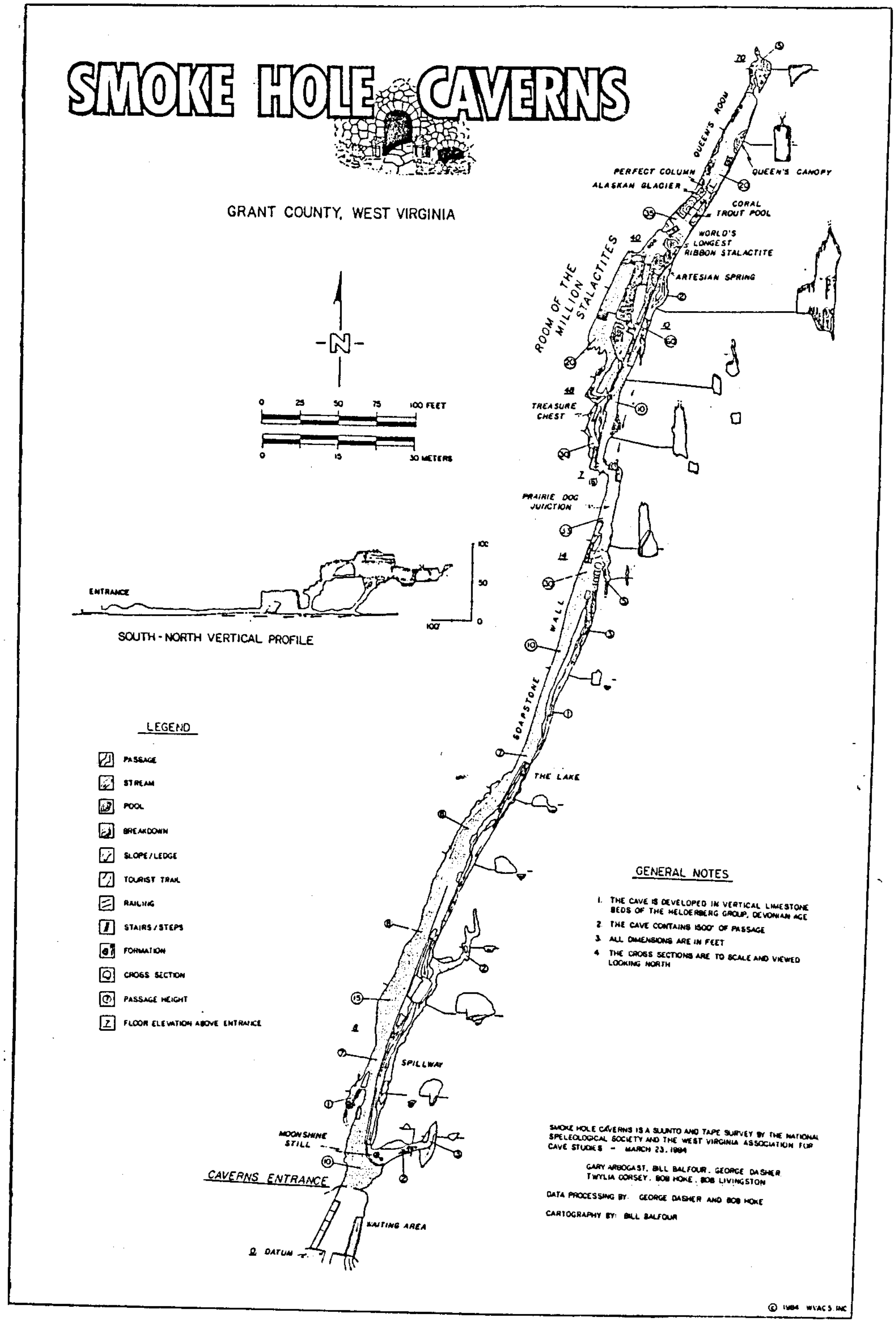

Figure 2 Smokehole Caverns, a 1984 version by Bill Balfour. Note the cross sections, profile, numerous symbols, and text details on the cave and mapping activities.

The 1960s: Big Discoveries at Home and Next Door

The 1960s brought at least as much change to caving as to any other part of society. Increased leisure time, the interstate highway system, and the graduation of post-war babies into their early twenties brought rapid growth to caving. Under this pressure, new caves became scarce, but cavers found that determined exploration over relatively long periods paid dividends. The concept of 'cave system' emerged.

In 1962, Texas cavers brought incredible accounts and slides of their discoveries in Mexico to the NSS Convention. The large, daylit pits were inextricably part of the surface landscape and vast beyond unaided perception. A different sort of map began to appear, incorporating a highly detailed plan and one or more profiles. The cartographer attempted to make vast features comprehensible by artistic realism. The awe in discoveries was conveyed with tiny dots representing the cavers on rope. Orion Knox, a caver and landscape architect, was a leader in this movement; his Pozo de Gavilan (Figure 3) is one of the earliest cave maps to incorporate artistic rendering.

Traces of this artistic approach began to appear in other cave maps, as attention was paid to what a cave 'really looked like,' with detailed and pictorial information on floor composition, etc. This movement had occasionally been foreshadowed by maps from Bernard L. Smeltzer in Pennsylvania (Figure 4) and Gregory "Tex" Yokum in Missouri, but widespread interest had not been aroused.

The 1970s: The Cave Project, Competition and Diffusion

The connection of the Flint-Mammoth system in 1972 was the most-publicized result of a new style of caving: the cave project. Individuals would come from great distances to work, as a community, on a common cave. Good-natured competition, both regional and international, emerged. The goal, the tangible product, and the proof of accomplishment was the cave map.

The ever-increasing collection of survey data was met with mainframe computers, which for the first time relieved the cave mapper of the need to manually reduce and plot the survey. More time was left for creative design and painstaking drafting, as major centers of caving such as the Cave Research Foundation, McMaster University Caving Club and University of Texas at Austin Grotto created and supported community software for their members.

As cavers intermingled, ideas were exchanged and the concept of the map as both science and art diffused. Impressionable novice mappers saw detailed maps and went away impressed. Many footloose cavers, hearing of the continuing discoveries in Mexico, poured through Texas, taking home Association for Mexican Cave Studies (AMCS) publications containing the maps of Orion Knox and his followers.

In 1978, the first NSS Cartographic Salon was organized: at the New Braunfels Texas Convention, appropriately enough (Knox 1978). This was recognition that cave mapping had grown in sophistication and variety, and could stand on its own for analysis and discussion.

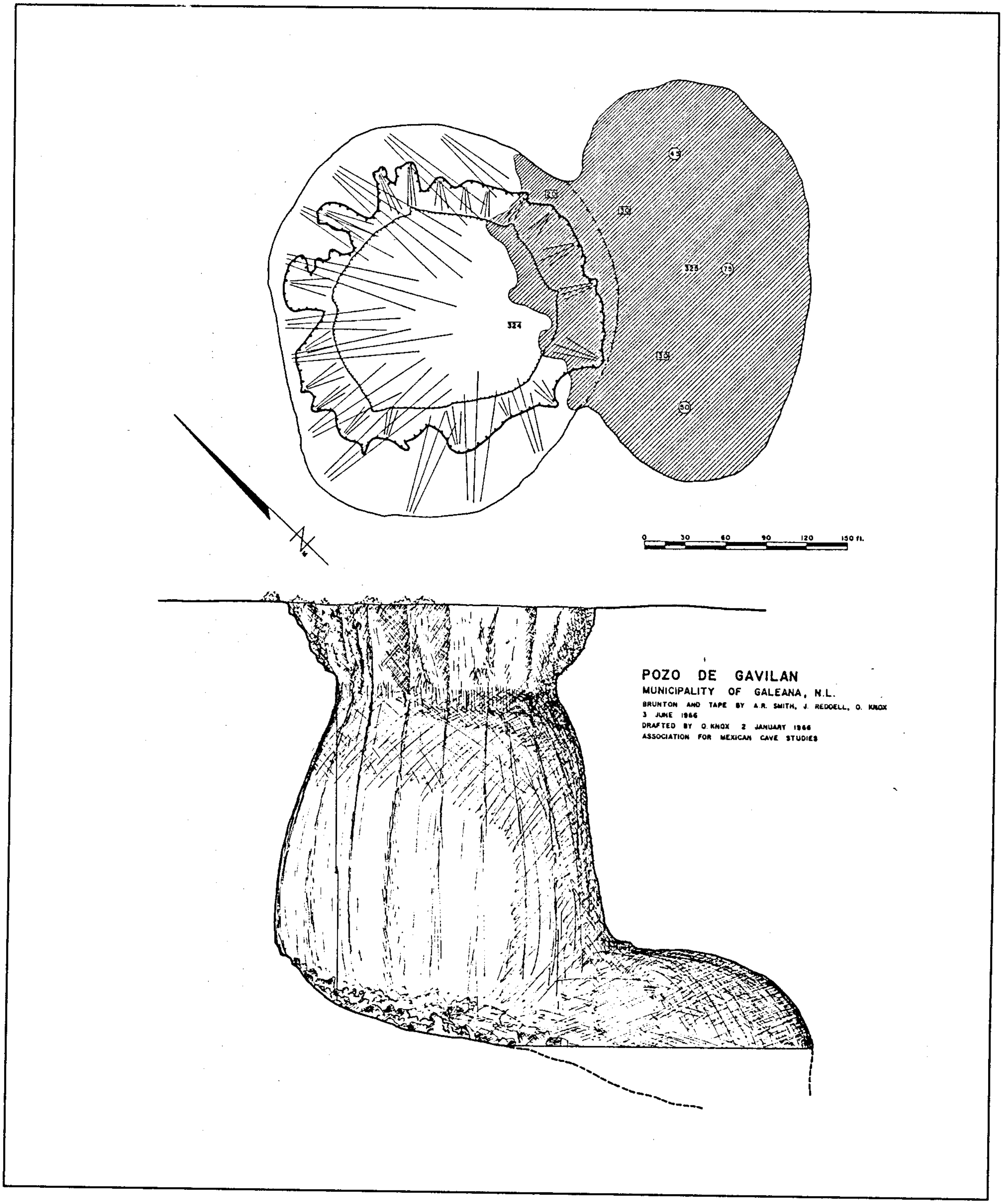

Figure 3: Pozo de Gavilan by Orion Knox. An early example of artistic rendering inspired by landscape architecture. From Russell & Raines (1967, p.40).

The 1980s: Art, Science and Democratization

The NSS Cartographic Salon continued into the 1980s, bringing national and international ideas to different regions of the country each year. Again, cavers came, saw, and went home with different ideas about what a 'good' cave map was.

By 1983 interest in approaches and techniques had grown to a point where the NSS Survey and Cartography Section was chartered to provide a forum aimed exclusively at this field. The Section's newsletter has contained discussions ranging from the mechanics of waterproofing survey instruments to the philosophical questions of maps as art and science. A detailed Bibliography of American Cave Mapping (Torode 1984) has been compiled and published.

The arrival of the personal microcomputer has resulted in a shift away from the large community-based data collection. Now the relatively isolated cave mapper can manage large collections of data, and this has encouraged small, dispersed group projects.

As the NSS moves into the next 50 years, cave mappers will increasingly be aided by technology which allows them to operate independently. Yet the uses of technology will continue to depend on a much wider sphere of ideas and influences as cave mapping evolves to meet the varied challenges of diverse caves. When cavers create novel maps for novel caves they can drive the field forward by bringing the larger community a new perspective on old caves and the representational problems that they present.

Authors Postscript

This article was invited as a section in the forthcoming NSS 50 Year History. Since it may be condensed considerably, I have decided to submit it to C&T as some cave mappers may find it to be an interesting and provocative perspective.

Each individual and group has biases; in caving these tend to be heavily regional. I do not have access to most of the early western US literature, so this is reflected in what I consider to be significant early history. A California caver would probably think of Halliday when I think of Davies and Douglas. Nevertheless, I feel that overall there was a predominance of eastern US influence in the 1940s and 1950s.

As for the AMCS in the 1960s and 1970s, the output of novel maps is undeniable, although their slick presentation and continued visibility even today (in back issues of the AMCS) tends to emphasize their importance. Something happened in Texas. Maps became art. Was this a unique revolution or one of many? Early 1960s Texas Speleological Survey maps were serviceable but not extraordinary. In the late 1960s, Bill Russell, Terry Raines, David McKenzie et al. were all drawing impressive maps of spectacular caves. Was it Orion Knox, with this background and the influence of mainstream landscape architecture, who drove the community forward into something new? By the mid-1970s disciples had arrived, notably Bill Stone and Peter Sprouse, who would carry the influence into the late 1970s, the first cartographic salons, and the rest of the country.

Why research and speculate on such history? Cavers as a group are obsessed with newness and gigantism. Everything is the newest, the best, the biggest. *Our cave is longest. Our formations are the best and they look like Elvis. We invented cave mapping.*

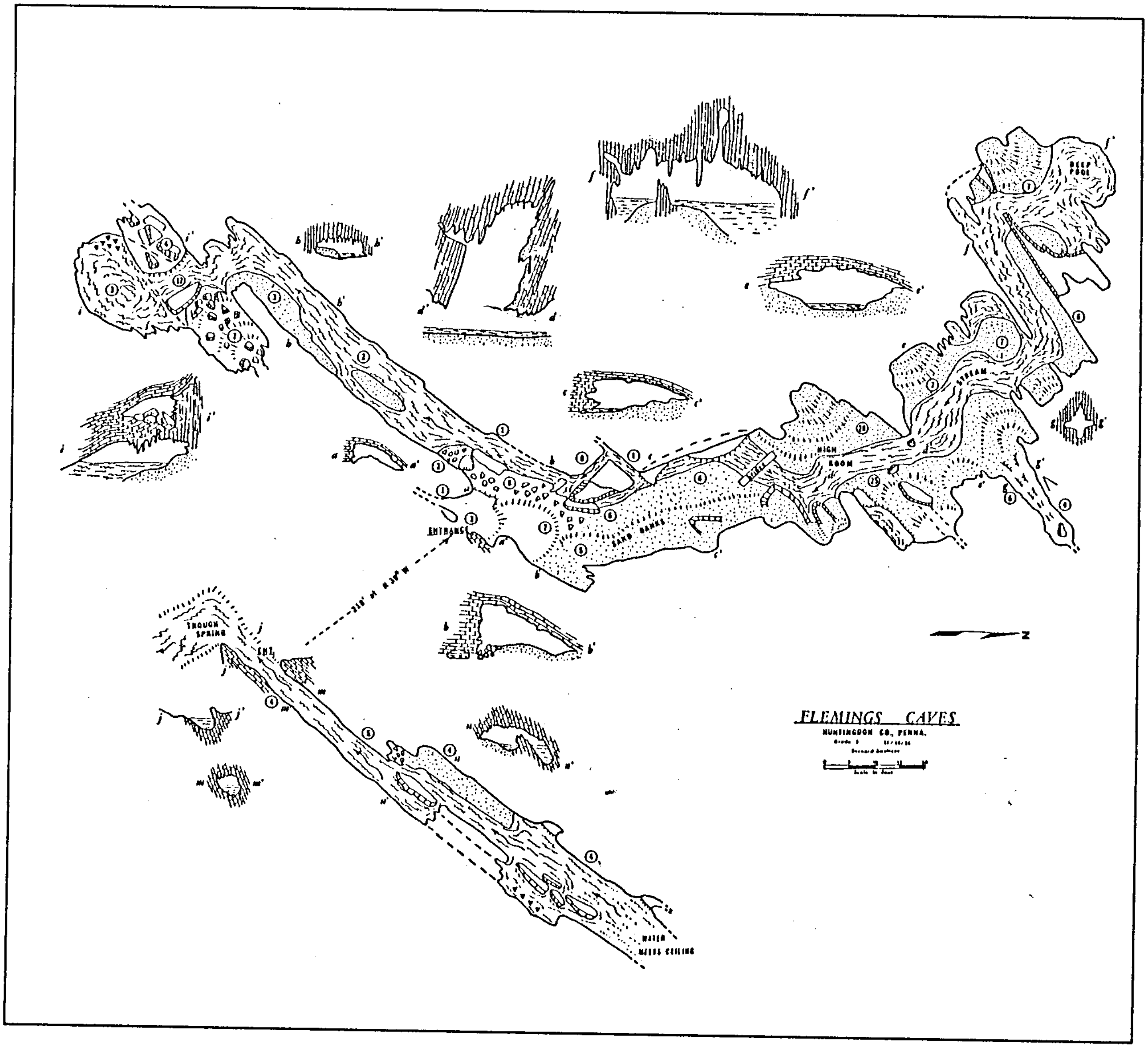

Figure 4: Flemings Caves, Pennsylvania, by Bernard L. Smeltzer, 1951. An early example of pictorial floor and cross section detail. From Cullinan and Speece (1975, p. 23)

We invented plotting software. We are the dawning of a new age. The truth is seldom so simple and aggrandizing. If we are to understand and promote innovation we must look underneath to see the plexus of influences, experiences, experiments and failures which litter and pave the passage of this evolving field.

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USE ONE EYE WITH THE SUUNTO

by
Roger V. Bartholomew NSS 9349

The Suunto should be sighted using only one eye. If two eyes are used to sight the Suunto as the manufacturer recommends, "so that the hairline [seen by one eye] is superimposed on the target" [seen by the other eye] there will always be what I shall call a rivalry error in the azimuth reading.

The human binocular vision system normally superimposes two identical images of an object the same distance from each eye. In the two eye method of sighting the Suunto, the vision system is forced to superimpose images of two different objects, hairline and target station, each located at different distances from the eye. This sets up a rivalry over which eye's image will control the convergence angle of the optic axes of the eyes. This misuse of the human vision system causes rivalry error. The manufacturer states a partial truth that an "eye condition called heterophoria" can impair the reading accuracy of some users. The whole truth is that heterophoria, a biological condition, can add another error which may increase or decrease rivalry error but heterophoria is not the cause of rivalry error.

Rivalry error can be demonstrated by the following test. Mount the Suunto on a tripod about 10 to 50 feet from a target. Using the two eye sighting method read the bearing first with the right eye on the instrument (RI) and second with the left eye on the instrument (LI). Then sight with the one eye method (OI). RI & LI will be different and OI will be about equal to the average of RI & LI! For a 360 degree compass scale the RI bearing will be the smaller and the LI bearing the larger. See DATA TABLE 1.

The explanation of this depends on two characteristics of the human binocular vision system: 1. When one eye focuses at a point, the other eye automatically tends to point to and focus on the same point. 2. Fusion of the signals from each eye to make one picture is controlled by the brain.

Suppose the Suunto is pointing directly at the target. (See Stage 1 in drawing.) When the right eye on the Suunto focuses on the hairline image which is near the right eye just beyond the target end of the Suunto case (See Stage 2, RI Sighting), the automatic coupling system between the two eyes tends to angle the left eye towards the nose. When the brain fuses both images together it appears that the hairline is now slightly to the right of the target. The only way to get the hairline on the target is to point the whole head and compass system more to the left. (See Stage 3, RI Sighting) This causes the RI bearing to be smaller than the correct bearing.

Experiments have shown that if I focus both eyes on the target and move my head up and down allowing one eye an occasional quick glimpse of the hairline so that it does not have a chance to focus on the hairline then no rivalry error will occur. For this case the Suunto must be mounted on a tripod so that it can be alligned first and then the scale read later.

The magnitude of the rivalry error can be estimated from the following experimental data:

DATA TABLE 1
(All units are in degrees unless otherwise marked.)

Suunto to target distance (feet)	Right eye on Suunto RI	RI error	One Eye Sighting Method OI	LI error	Left Eye on Suunto LI	RI+LI / 2	Average Error
5	246.1	-0.7	246.8	0.2	247.0	246.6	0.45
10	243.8	-0.7	244.5	1.3	245.8	244.8	1.0
50	244.0	-0.3	244.3	0.4	244.7	244.4	0.35
100	242,9	-0.5	243.4	0.5	243.9	243.4	0.5
150	243.3	-0.4	243.7	0.7	244.4	243.9	0.55
5208	65.8	-0.7	66.5	0.9	67.4	66.6	0.8

Average RI error = -0.55

Average 0.67 = LI error

This chart means that in practice if I survey 5 fifty-foot shots in one direction using the two eye method and with the right eye on the Suunto, the last station will be 2.4 feet off just due to this rivalry error. The greatest source of error in the Suunto is that it cannot be precisely sighted on targets with high vertical angles. For a large number of sightings this would tend to produce random errors, but the rivalry error is systematic error and sighting methods to avoid it should be used. If the surveyor alternates between RI and LI sightings this would cause the rivalry error to behave like a random error. However, the fact that the Average RI error is less than the Average LI error in DATA TABLE 1 indicates that dominance of one eye can still introduce a small systematic rivalry error.

A bit of thought will reveal that rivalry error can not be detected by checking loop closures because it tends to cancel out around a loop. Rivalry error can not be eliminated by taking backsights.

It is interesting to note that the RI and LI bearings can have a range of values depending on whether one eye focuses more strongly on the Suunto scale or whether the other focuses more strongly on the target. For example if the left eye is focused more strongly on the target, the right eye's image of the hairline becomes unfocused, the left eye does not angle as much toward the nose and a slightly larger RI bearing will be obtained. By consciously varying the strength of focus on the Suunto scale or target I can get RI or LI readings anywhere between the range limits. This is supported by the following data:

DATA TABLE 2

(All units are in degrees unless otherwise marked.)

Suunto to Target distance (feet)	Range of RI Readings (Right eye on Suunto)		OI	Range of LI Readings (Left eye on Suunto)	
	Right eye focused on Suunto Scale	Left eye focused on target		Right eye focused on target	Left eye focused on Suunto Scale
5	245.0	246.4	246.8	246.8	247.4
10	243.3	244.2	244.4	244.8	246.5
50	241.0	243.6	244.3	244.8	247.7
100	242,2	242.9	242.8	243.8	245.6
150	242.2	243.4	243.1	244.3	246.4

In his article "A Trigonometric Analysis of Suunto Sighting Error", <u>Compass and Tape</u> V.5. #3, Winter 1988, Brad Neff:

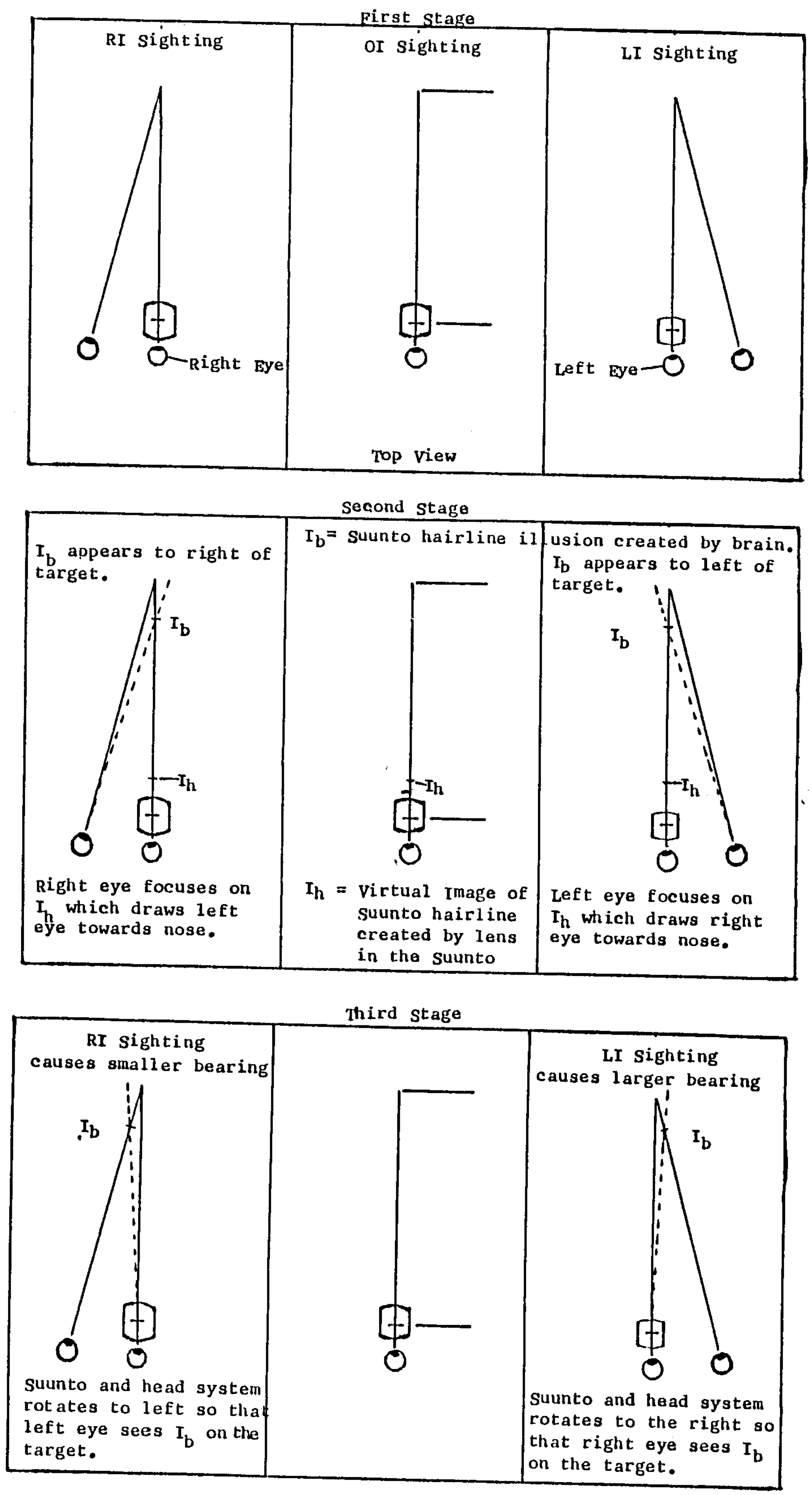
1. bases his analysis of two-eyed Suunto error on an approximation that the optic axes of the eyes are always parallel with "the compass eye tracking the sighting eye"
2. attributes the two-eye error to parallax
3. says that placing the sighting eye over the station rather than the compass should eliminate two-eye error
4. says that the two-eye error will decrease with increasing Suunto to target distance according to the formula:

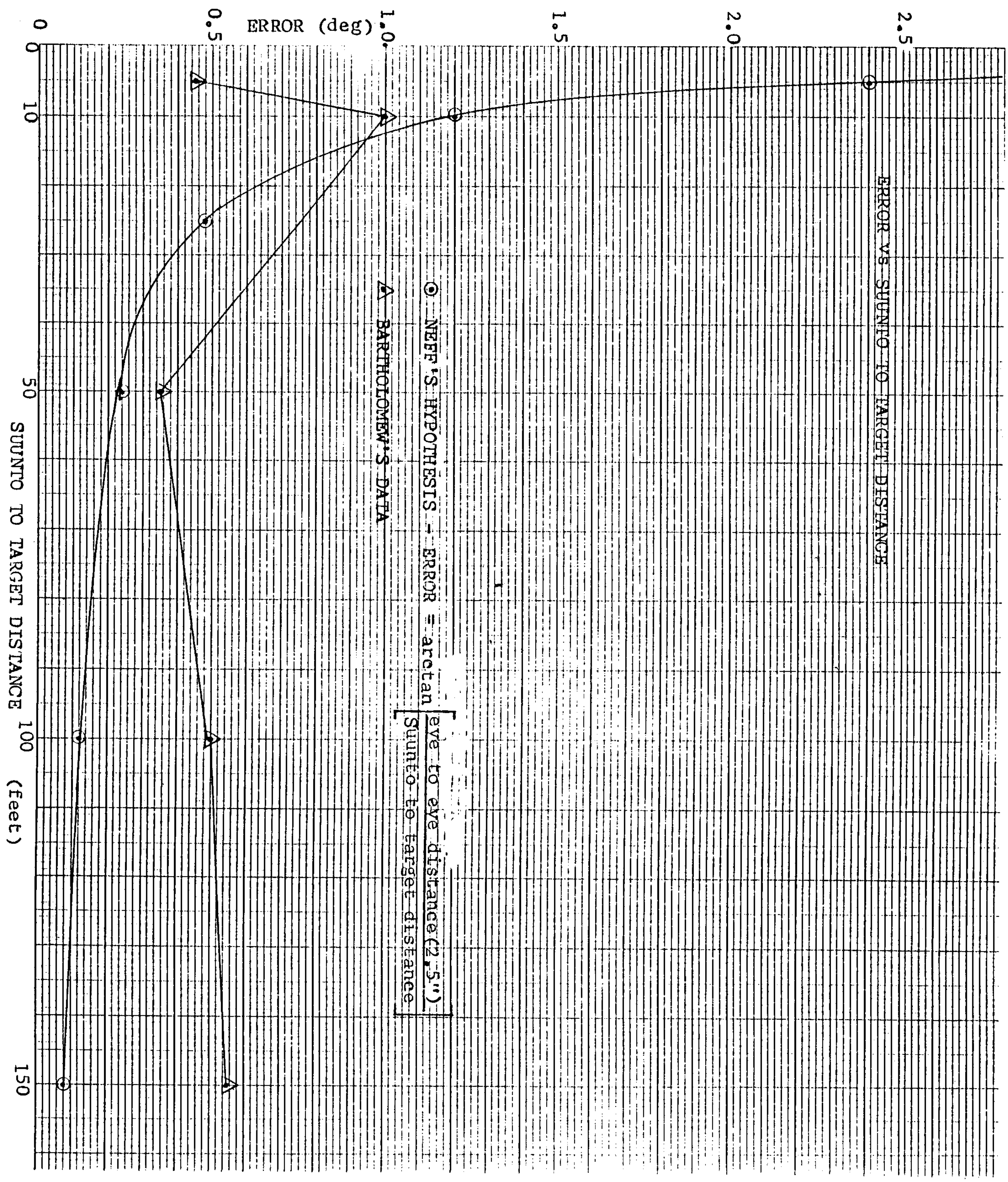
error = arctan [eye to eye distance/Suunto to target distance]

With respect to points 1 & 2 my above analysis and data shows that in two eye Suunto sightings the optic axes of the eyes do not remain parallel and that rivalry error is due not to parallax, but to erroneous convergence of the eyes' optic axes caused by rivalry of the two eyes each of which is attempting to focus at a different point.

Point 3 is wrong. Placing the target sighting eye over the station will not eliminate the two-eyed error, but will introduce another error which adds to the rivalry error. For example, on a RI sighting, if you place the left eye over the station you move the compass to the right of the station and decrease the compass bearing. Data Table 1 shows that the rivalry error in RI sighting also decreases the compass bearing. The two errors are in the same direction and more error is introduced!

Concerning point 4 it can be said that the rivalry error should increase with longer Suunto to target distances because there is an increasing distance between the objects each eye is forced to focus on, which are, the Suunto hairline image and the target. Also one would expect the rivalry error to be zero when the target is the same distance away from the eyes as is the Suunto hairline image. The graph shows that the plot of Neff's hypothesis does not fit the average error from DATA TABLE 1.


First Stage
RI Sighting
OI Sighting
LI Sighting
Right Eye
Left Eye
Top View
Second Stage
Ib appears to right of target.
Ib= Suunto hairline illusion created by brain.
Ib appears to left of target.
Ib
Ih
Right eye focuses on Ih which draws left eye towards nose.
Ih = Virtual Image of Suunto hairline created by lens in the Suunto
Left eye focuses on Ih which draws right eye towards nose.
Third Stage
RI Sighting causes smaller bearing
LI Sighting causes larger bearing
Suunto and head system rotates to left so that left eye sees Ib on the target.
Suunto and head system rotates to the right so that right eye sees Ib on the target.


ERROR vs SUUNTO TO TARGET DISTANCE
NEFF'S HYPOTHESIS - ERROR = arctan [eye to eye distance (2.5") / Suunto to target distance]
BARTHOLOMEW'S DATA
ERROR (deg)
0
0.5
1.0
1.5
2.0
2.5
0
10
50
100
150
SUUNTO TO TARGET DISTANCE (feet)

AN EVALUATION OF THE AUTOHELM PERSONAL COMPASS FOR CAVE SURVEYING

by

Roger V. Bartholomew, NSS 9349

The Autohelm Personal Compass is a battery operated electronic fluxgate compass with a digital liguid crystal display readout. It was developed by Nautech Ltd. in England for sailing navigation and is waterproof. Specifications: fluxgate compass ±1 deg., basic accuracy ±2 deg., repeatability over 3 bearings within 3 deg.. No compass needle means no settling time and no delay, just point and press a button. A ten minute memory stores up to nine bearings, as fast as you can aim and click the record button. It has a stopwatch: 0 to 10 hours count up or a 10 minute to zero countdown. It looks like a stretched Suunto (6" x 2 1/4") and has gunsight devices along both top edges. It costs about $100.

I do not recommend the Autohelm Personal Compass for cave surveying because it is too sensitive to being off level. When pointed on a bearing of 49 deg. it was 2.5 times more sensitive to tilting than to a bearing change. For example, at a bearing of 49 deg. if the compass is rotated 1 deg. to a new bearing the reading will change by 1 deg., but if tilted by 1 deg. the reading changes by 2.5 deg.. At 49 deg. the compass must be held level to better than 0.4 deg. in order to obtain a correct bearing to the nearest 1 deg.! The two graphs show the effects of pitch and roll on the readout when the compass is kept pointing at 49 deg.

Also the Suunto does much better in a loop closure. A 500.68 foot loop with 12 stations and negligible vertical relief was surveyed. The distances between the station pegs were measured to the nearest one hundreth of a foot. The results are recorded below:

Compass and Conditions	Closure Error distance & %
Autohelm: Hand held, no level, front sight only	11.74 ft.- 2.35%
Autohelm: Tripod , level, front sight only	8.39 ft.- 1.68%
Autohelm: Hand held, level* , front sight only	4.37 ft.- 0.87%
Autohelm: Hand held, level* , front & back sight	4.15 ft.- 0.83%
Autohelm: Hand held, level* ,3 front+back sights	3.41 ft.- 0.68%

(Note: Why the AUTOHELM on the tripod with level performed worse than when it was hand held with the level is an unanswered question.)

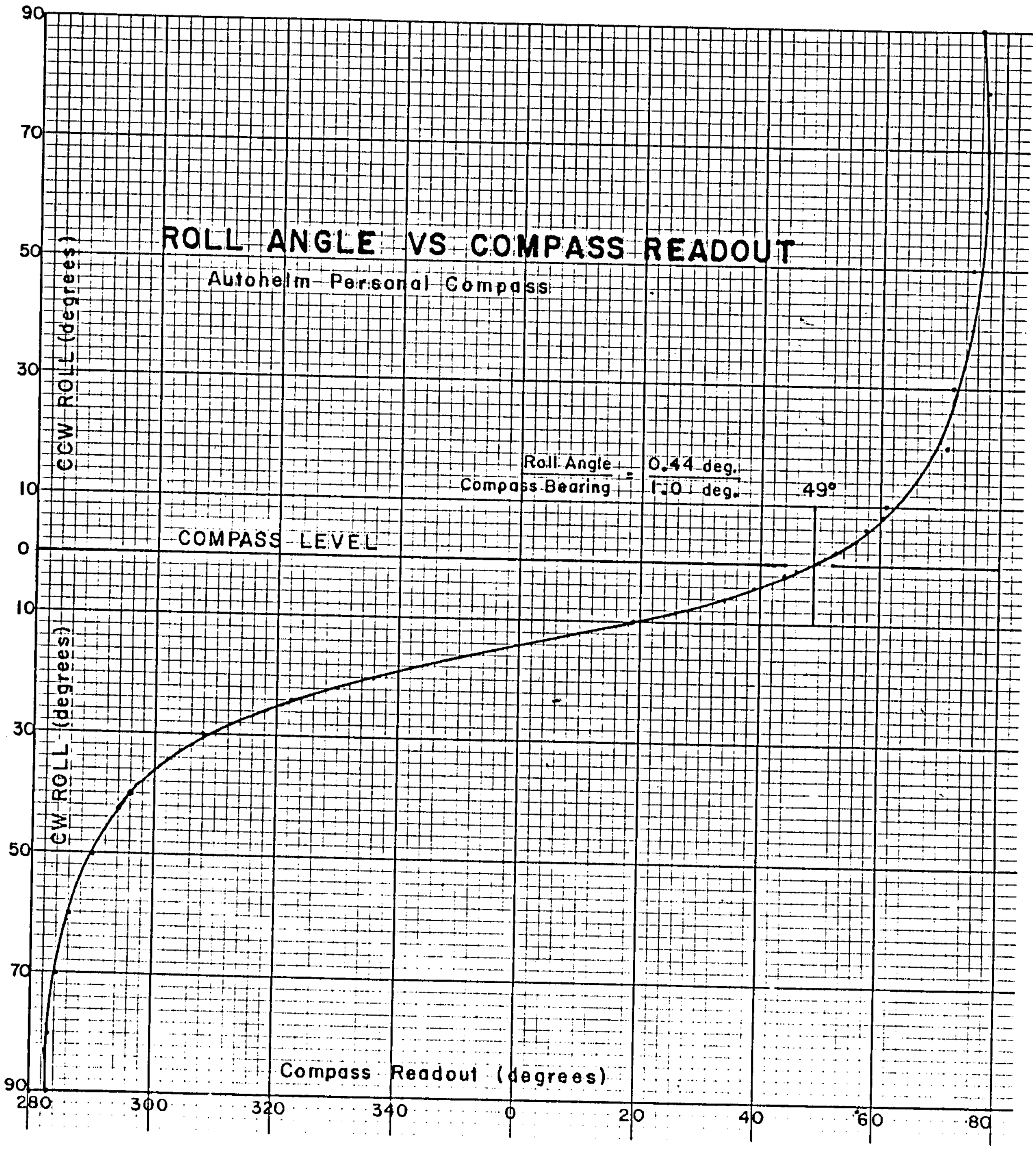
(* Level mounted such that sights, target and bubble can be seen simultaneously)

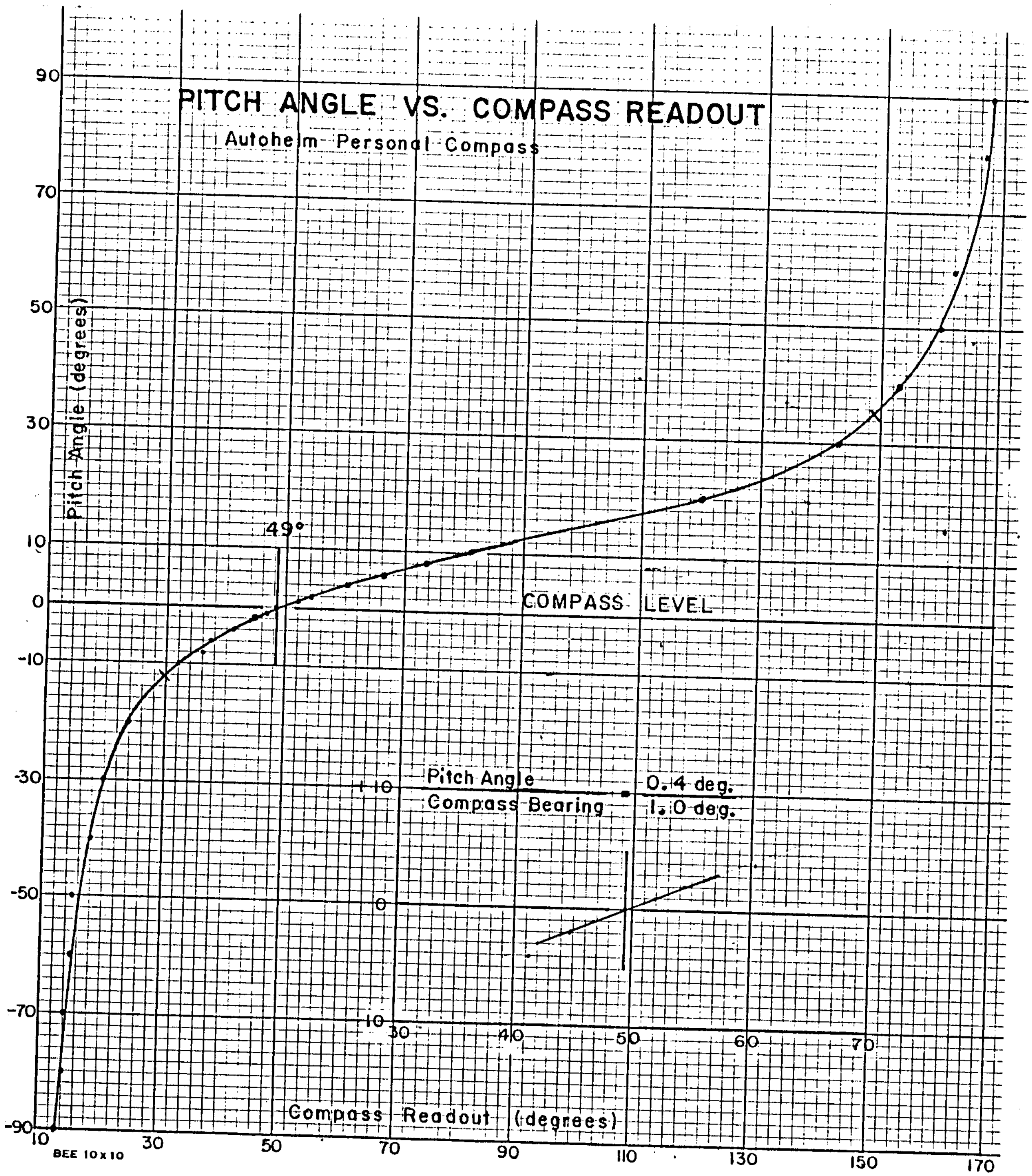
Suunto : Hand held, no level, front sight only	0.94 ft.- 0.19%

(Note: Suunto was sighted using the one-eye method.)

Surveyor Compass: tripod, level, front sight only	0.49 ft.- 0.098%

(Note: Welch Surveyor Compass has a 4 " needle.)


ROLL ANGLE VS COMPASS READOUT
Autohelm Personal Compass
Roll Angle / Compass Bearing = 0.44 deg. / 1.0 deg.
49°
COMPASS LEVEL
CCW ROLL (degrees)
CW ROLL (degrees)
Compass Readout (degrees)
90
70
50
30
10
0
10
30
50
70
90
280
300
320
340
0
20
40
60
80


PITCH ANGLE VS. COMPASS READOUT
Autohelm Personal Compass
Pitch Angle (degrees)
90
70
50
30
10
0
-10
-30
-50
-70
-90
49°
COMPASS LEVEL
Pitch Angle 0.4 deg.
Compass Bearing 1.0 deg.
+10
0
-10
30
40
50
60
70
Compass Readout (degrees)
10
30
50
70
90
110
130
150
170
BEE 10x10

Total Vertical Traverse

by Bill Mixon

For several years I have wondered just how much vertical caving was really involved in the exploration of Sistema Huautla, Oaxaca, Mexico. The total depth of the system, 1353 meters, is impressive enough, but the large number of entrances and independent deep routes that have been integrated into the system makes it the most complex of the world's great vertical caves. As Mark Minton pointed out in an article in Descent number 79, there are two routes over 1000 meters deep, two over 600 meters. It is theoretically possible to descend 1225 meters from one entrance and then ascent 1110 meters up to another without retracing a single step. I wrote "theoretically" because the trip would involve rigging over one hundred drops and diving two sumps.

The figure that seemed likely to illustrate the vertical nature of the system is the total amount of vertical survey in it, that is, the sum of the magnitudes of the vertical components of every survey shot. It turned out that Ellipse, David McKenzie's program that is used to close and plot most of the surveys done by members of the Association for Mexican Cave Studies, has always calculated that figure, which I will call the total vertical traverse. The total vertical traverse of the Huautla System is, if memory serves, 17,768 meters.

The total vertical traverse is similar conceptually to the not very interesting true horizontal cave that is sometimes computed. The true horizontal cave is the sum of the lengths of the shots projected onto a horizontal plane, whereas the total vertical traverse is the total length of the shots projected onto the vertical axis. (The horizontal figure analogous to the depth of the cave might be its "plane extent," the greatest straight-line distance between the horizontal projections of any two points. Is there a simple and efficient way to compute that -- one that does not require comparing n squared numbers, where n is the number of stations? Or perhaps one could compute the "plane diameter," the diameter of the smallest circle enclosing the entire cave in plan view. Note that this is not always the same as the plane extent.)

Like most figures that can be derived from cave surveys, the total vertical traverse can be misleading. For example, the total vertical traverse of Mammoth Cave is surely over one kilometer, despite the fact that practically all the cave can be visited without any ropework at all. Five hundred kilometers of nearly horizontal survey shots with average inclinations of only 0.1 degrees will give a TVT of one kilometer. The number needs to be considered in relation to the length of the cave. The Huautla System had a length of 52.7 kilometers when its TVT was 17.8.

It would be interesting to know the total vertical traverse of other large and deep systems. Does Huautla hold the record? Holloch might have a comparable figure.

Don't Use two Eyes with your Suunto

by Robert Thrun

Contrary to what is claimed by the instructions that come with a Suunto compass, it should not be used with two eyes; one eye sighting on the compass and the other eye sighting on the target. You should have only one eye open and look into the eyepiece. The target should be visible above or below the eyepiece.

Brad Neff's (C&T, Vol. 5, No. 3) analysis of the reading errors that occur when you read a Suunto claimed to consider a worst-case situation. Actually, it was a best-case situation. The analysis assumed that the eyes were pointing in parallel directions when reading the compass. The problem with using two eyes is that your eyes do not always point in the same direction. When you look at something close, your eyes cross or turn toward each other; the right eye turns a bit to the left and the left eye turns to the right. When you are focused at a point two feet in front of you, your eyes are pointed in directions that differ by six degrees. Although they are controlled by different muscles, focusing and crossing of the eyes normally occur together. You have to practice to do one without the other.

When you hold a Suunto in front of you and concentrate on it, you instinctively want to focus your eye on it. The eyepiece lens focuses the dial at approximately infinity, but the hairline appears considerably closer. The tendency to focus on the Suunto is increased if you hold it so that it completely blocks the view of the target and the target's surroundings for one eye. If you hold the Suunto so that you can see the target with both eyes, you are essentially reading the Suunto one-eyed with both eyes open. There is, in many people, a master eye effect that can lead to errors even if both eyes can see the target, but this is avoided because people normally put the Suunto up to their stronger eye.

The amount of error obviously varies with individuals and conditions. I tried a Suunto on a distant landmark to see just the error might be. I found that it is easy to make a two degree error. I could make that kind of error and not notice it. If I tried hard, I could get a 10 or 15 degree error.

I also read a Suunto clinometer with one eye. There is a condition, for which I do not know the name, where the eyes do not look at the same level. The condition is common enough so that routine eye examinations check for it.

Flashlight Tip

by Barbara am Ende

In Vol. 6 #1 of Compass & Tape, you solicited contributions. Here's a nifty tip that Jim Hardy suggested on a recent surveying trip. A mini-mag flashlight with its head screwed off makes an ideal light station. The bulb becomes a point source withe nonte of the convetional problems such as holding a carbide lamp above the station while taking the azimuth readings and moving it to the side for inclination. Naturally, extreme care must be taken because with the head screwed off, the bulb is vulnerable to being broken.

Letter to the Editor

by Lang Brod

Dear Tom,

I enjoyed reading your first issue of Compass & Tape, and I was especially interested in the article on sketching by George Dasher. A lot of what George says in the article on sketching makes sense, and his explanation of sketching to an approximate scale is well thought out. There are, however, some statements with which I take exception. I do not wish to imply that George is wrong, but simply that there can be two differing viewpoints. In his comments in Method One (sketching to scale), George states that (in his opinion) sketching to scale is "a bunch of bull". Well, I sketch to scale all the time, and I feel that the added effort is well spent. I am one sketcher who habitually uses a scale, a 360 degree protractor, and a pocket calculator (to correct for inclination) in the cave. I favor this method because I can record a large amount of wall width data in unambiguous fashion. I measure wall widths from the tape at 5- foot intervals, or even at closer intervals if the wall is complex. If the sketch does not match what I think I see, I can work on the problem in the cave until I get it right, and not have to wonder about the sketch when I start to draft the map.

After a survey trip, I lay out the station lines with a drafting machine (sorry, no computer) at the same scale as my sketch; then, using a light box, I simply trace the sketch details onto the draft map. For larger and more complex caves I can then reduce the draft map by a scale factor, such as 2:1 in a reducing photocopy machine and add it to the main map. For quick comparisons, it is not necessary to re-plot the station lines at the scale of the larger map; the beginning station of the last segment can be superimposed on the end station of the previous segment and the new segment rotated to bring its north arrow into alignment.

But, one might argue, is the ease of reduction worth the added effort of sketching to scale? Well, there are other advantages. I have on a number of occasions completed a number of small closures on my sketch, a somewhat difficult accomplishment if one is not sketching to scale. I personally find my visual estimates to be in error when compared to measurement, leading me to believe that appearances in a complex geometrical situation can be deceptive. Also, the natural tendency of a sketcher to draw approximate or "average" walls on the basis of incomplete measurements can conceal relevant data. As an example, some years ago I surveyed a cave which was principally a large room with two short side passages and a number of solution pockets around its periphery. I carefully sketched the cave to scale, and after completing the map, I was amazed to find that the side passages and solution pockets were all aligned in the same direction, indicating structural control of the solutional enlargement. This alignment was not apparent either in the cave or on a previous map done by someone else, and I am convinced that only my careful sketching revealed the true relationship.

The rigor imposed on the survey crew when sketching to scale can be beneficial. Measurements of wall widths can in some cases require that a surveying crew member crawl or climb into an apparently dead end cavity, only to find that it leads to more cave. Even if more cave is not found, other cave features can be discovered in such cases.

I will concede that sketching to scale (method one) is not preferable or even possible in all cases. I would be inclined to use method two when lying in cold, wet mud. When the constraints are severe and minutes count, surveying to scale could be detrimental. On maps of extremely large caves, such as Lechuguilla Cave, small discrepancies would never even be visible. There are, of course, caves with fairly comfortable conditions, not too large, where survey trips are not faced with time constraints. In such situations, the choice of methods is optional. I do believe that the novice sketcher should do his first sketching in an easier cave and sketch to scale in order to learn the technique. Later, when the sketcher faces a more difficult situation, it will be possible to utilize method two, because the sketcher understands what data is required to most adequately portray the passage configuration.

Letter to the Editor

by Sue Bozeman

Dear Tom,

In direct response to George Dasher's article, "One Judge's View," in the Summer, 1988, issue of Compass & Tape, there are a few points I wish to address.

First, though, I thank Mr. Dasher for his list of criteria. It is a first of the sort in my awareness. Although I drew the "No Elevations" Oklahoma maps and was disheartened to be disqualified for not including a necessary datum, I am at least glad to know what was lacking. I have sent in many maps over the years and it is like tossing them into File 13. I only hope that next year's judges will use the same criteria; no fair changing the rules as you go!

I do wish that a simple "Judges Comment Sheet" could be filled out by the judges on each map submitted and a copy of each judge's report sent to the contributor. The judge's names could even be "un-included" or coded so that responses could be addressed to Judge #, etc., but would not result in guano letters or recriminations -- it is a voluntary position and a subjective view, as Mr. Dasher notes. The best way to teach is through feedback -- exams, reports, etc., that occupy all teachers' off- hours. The submitted maps are our exams. We need detailed feedback.

As to usefulness: the Jester map was the second map that I have sent in using the A, B, C/1, 2, 3, etc. locator marks along the edges. As far as I know, I am the only one using these and I can only wonder why. If you are in the midst of an accident situation and transmitting the victim's location over the phone, how much easier to use a coordinate such as B12 than "See the big loop on the NW side of the little side passage by the ..., etc." The locator marks are also useful if an accompanying report is provided. It is much easier for a reader who is unfamiliar with the cave to be able to pinpoint the location of a formation, area or critter- site by coordinates than by place name.

Regarding "precise cave locations," I understand Mr. Dasher's argument and can only advise the Oklahoma argument, which is probably no different than many others': the caves are on private land. The gaining of landowner confidence and trust is a full- time affair around our area. Poor economic conditions have rustlers snitching cattle, some of the remote areas have marijuana patches surreptitiously planted with cave resurgence waters only later found by the landowner, and easily accessible entrances have evidence of beer and pot parties. If our landowner requests not to even be thanked by name in the article we write about the cave, why ever would we put a specific location on the map? We will accede only as to county and put the phrase "Cave Location Omitted Per Landowner's Request" on each map and hope that satisfies the judges as to that particular criterium.

Finally, is there a chance that a copy of the winning map could be printed in your publication? Hope so.

Letter to the Editor

by John P. Brooks

Dear Editor,

In Mr. Dasher's article concerning sketching: he implies that ceiling changes are secondary features added after the placement of walls and floors in a cave survey sketch. There is an inherent flaw to this logic. The sketcher is depicting a three dimensional environment using a two dimensional convention. In constructing a two dimensional depiction of a cave passage, frequently ceiling plane changes will generate wall placement and define the location and shape of the mythical 4 foot square breakdown block. That block of breakdown had to come from somewhere.

The challenge to sketching is to accurately depict the rhythm, symmetry, and flow of a cave passage. How could the ceiling ever be added later?

Reply to Ms. Bozeman

by George Dasher

I was <u>very, very</u> impressed with your map. It was as good a map as I have ever seen. In another day, another age, it would have probably won the Medal Award. Unfortunately (or perhaps fortunately), North American cavers are setting a <u>very</u> high standard for their present day cave maps.

There has always been lists of criteria available so that the cartographers could understand why they placed where they did in the Cartography Salon. Unfortunately, in the past, it was often necessary to chase down Person X and literally pull teeth to locate your individual criteria sheet. Because I too have come up short in the Cartography Salon, I wanted to make sure that each and every contestant knew what we liked and did not like about their map. This too was why I wrote the article for Compass & Tape. In many cases, this year's judging was a very, very difficult decision.

Unfortunately, as in your case, something important (i.e., the cave elevations) had been overlooked and as good as your map was, we did not feel it proper to award you a ribbon or a medal. Profiles and cave elevations are the primary mechanisms the cartographer has of showing that their cave is a three dimensional entity, not a two dimensional pancake. As I recall, your cave had several vertical drops, so it was not a perfectly horizontal cave.

As I understand the rules of the Cartography Salon, if a person can add sufficient passage to their cave map, they can re-enter the map. There is, however, no guarantee that the judges in that particular year will use the same criteria as we did this year. That is the problem with the Cartographic Salon, it is very subjective and the rules change with each year. (I used to show beef cattle in 4-H; that too was very subjective with an infinite number of rules changes. I never did well.)

Still, I hope that the vast majority of the NSS's cave cartographers will display their maps; it gives us a chance to improve our techniques and to see what everyone else has been up to. I hope that the NSS will remove the rule in the Salon that every entry has to be donated to the NSS. Some maps, because of organizational, governmental, or landowner criteria, can not be donated to the NSS and the cartographers of such maps should not forfeit their chances to display their work.

One other thing: The person in charge of the Cartographic Salon is Bill Nelson, currently of Memphis, Tennessee. You should approach him and judge for one year. That is a real eye-opening experience. Be forewarned; during Convention, I spend approximately 99% of Monday, 60% of Tuesday, and 75% of Wednesday judging those maps. Plus, I had to present the awards Thursday night and spend most of Friday morning defending my decisions. I hope, sometime in the future, to try judging the Salon again.

Regarding precise cave locations: I understand your concerns. We have marijuana growers, people who party in caves, and the Nation's worst economy here in West Virginia. Still, I think it is very important to give precise locations on the map; otherwise, down the road, the location of many of the caves will be lost. That, I feel would be a crime. This is an argument in which we both could be right and we both could be wrong. Obviously, if "my" caves are vandalized in the future, I was wrong; if "your" caves are lost to future generations of cavers, you too were wrong.

If the landowner requests it, the cartographer should not put the precise location on a cave map. Occasionally, he or she can not even indicate the political location on the map. In those cases (Life according to Dasher), the map should be labeled, "Cave Location Omitted Per Somebody's Request".

Once upon a time, in an earlier life, I attended a cave rescue where one of my maps was used by the rescuers (i.e., us). Because the map made the rescue one hell of a lot easier, it was a moment I remember with a great deal of pride and satisfaction. Please don't think I am wishing a cave rescue situation on you, but if you too have this experience, I think you will realize new meaning to your caving and cave cartography.

Reply to Mr. Brooks

by George Dasher

I was not implying that ceiling changes are subordinate to wall placement. Ceiling changes--as well as floor changes, slopes, pools of water, and just about everything--are very important. Ceiling changes often delineate ancient passage routes and they occasionally blend into a wall to form an unbroken line or fault.

It is just that, when sketching, you have to start somewhere. When in the cave, I often start directly at my feet (or head) and sketch the most immediate features; then I work out toward the walls. When drawing the map at home, I first mark off the left and right distances for each station, then I draw the walls, then the interior detail. I use this technique because it works for me, not because one feature in the cave is more important than another. Simply put, I have to start drawing somewhere and I start with the walls. The ceiling changes are added 'later' because of technique, not because of importance.

This said, I must note that many cave surveyors must consider the walls the dominant feature in the cave. This is because the walls are the only feature they display on their sketch, then on their maps. You obviously are not a part of this 'Hopefully Soon to be Extinct' species. For this I complement you, you "see" what is in the cave, not walk through it blindly.

Letter to the Editor

by George Dasher

The other day, for better or worse, I happened to be reading my own articles in the Summer 1988 Compass and Tape.

I discovered two things: I had contradicted myself and I had left one point unclear.

First, in my article entitled "One Judge's View", I stated that a zero datum and ceiling heights are important. This is true, but only if there is no profile view. If there is a profile view you do without all or some of the aforementioned items. If there is no profile, then you damn well better have a datum, ceiling heights, pit depths, cave elevations, and water depths. I wrote that article in a hurry at Convention; that may have been a mistake.

Second thing; in this article, I considered the type of survey and the cartographer's name to be of minor importance. Since then, I have read an article by Lang Brod in which he stated that these items are very important. His arguments were sound and I have changed my mind.

Keep in mind, these are my opinions and not a hard fast rule written in concrete somewhere.

Next thing: In the article entitled "Sketching" I stated that I always begin a sketch with the walls. In last issue's Letter to Da Editor, I said I always begin with the breakdown under my feet. Both were correct; i.e., two different caves, two different methods. One was a linear cave developed along the flank of an anticline; I used the walls. The other was a maze cave; I started at my feet. Each person sketching should be flexible and it was silly to think I always started with the same features for each sketch.

I am not trying to be redundant and I hope this is not overkill.

Editor's Remarks

by Tom Kaye

In this issue of C&T there are three letters to the editor. Two of them I sent to George Dasher, the author of the articles that raised the issues. I assume that a letter to the editor is partly written to elicit further information or clarifications from the previous author. At least that is the way I took two of the letters. The letter by Lang Brod was not sent to George Dasher since it seemed to bring up no questions to George. Incidentally, George went on a surveying trip in Paxtons with us and he used a clipboard (required by the project). We may hear more from him on that subject in the future. (He says he wants to sketch that way some more!)

The C&T is late in terms of the seasonal naming scheme and in terms of getting my act together initially. According what I understood from my predecessor, John Ganter, the fall issue is supposed to come out in December. It is now February 1. I intend to try to fix some of this by putting out another issue (Winter) soon.

I received only one comment about the problem I mentioned about our press not being able to print on heavy stock for a cover. That was to at least make it with colored paper. I like this idea.

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